# Performance and Injury Predictability during Firefighter Candidate Training

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Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

In

Curriculum and Instruction

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February 2006

Blacksburg, Virginia

Keywords: Functional Movement Screen, Kinetic Chain, Core Strength, Fundamental Movement Patterns

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ABSTRACT

The purpose of this study was to determine if a firefighter's fundamental movement patterns can act as predictors for occupational injury and performance during the firefighter academy training. The study consisted of 23 firefighter candidates entering the 16-week firefighter academy training. The firefighter candidates', VO2Max, 1.5 mile-run and Firefighter Physical Conditioning Course and movement patterns were assessed at the on-set of the 16-week training. The firefighter movement patterns were assessed utilizing the Functional Movement Screen, which was designed to identify flaws in fundamental movement patterns. The firefighter candidates were then observed and their injuries documented during the firefighter academy training. The injury results as well as the initial performance tests were then compared to the results obtained by the Functional Movement Screen. There were no significant findings when comparing the Functional Movement Screen to the performance tests. The only significant correlation was with the Functional Movement Screen asymmetry score and the Firefighter Physical Conditioning Course. The relationship between the injuries recorded and Functional Movement Screen scores were inconclusive. The results of this study were unable to determine if a movement-based assessment such as the Functional Movement Screen can be utilized as an injury or performance predictor tool. The findings determined that further research needs to be performed with efforts placed on larger population groups and more emphasis placed on the scoring and analysis criteria used by the movement-based assessment.

# ACKNOWLEDGEMENTS

I would like to first thank the members of my committee: Dr. Richard Stratton (chair), Dr. Kerry Redican, Dr. Mike Krackow, Dr. Del Bolin, their guidance and input were invaluable during this dissertation process. I would like to specifically thank Dr. Richard Stratton for his insight, direction and encouragement throughout my education at Virginia Tech.

I would like to express my gratitude to the members of the Chesterfield County Fire Service for their efforts in assisting and participating in this study. Specifically, I would like to thank Eric Meade, Donald Reekes and Ricky Earhart for allowing me the opportunity to work with them and members of the Chesterfield County Fire Service.

I would like to extend a tremendous amount of appreciation to the members of the Averett University Administration and Physical Education Departments, specifically, Dr. Tommy Foster, Dr. Richard Ferguson, Barbara Kushubar, Dr. Richard Pfau and Dr. Jeff Fager, their support and encouragement made this process much easier to complete. A special thanks goes to Dr. Richard Ferguson and Dr. Bobby Carlson for their efforts and assistance during this project and throughout my education.

Finally, a sincere appreciation must be extended to my colleague, mentor and friend, Gray Cook. His insight, creativity and drive, continue to motivate and inspire me to always listen, learn and question.

# DEDICATION

This dissertation manuscript is dedicated to my wife, Sally, and our son, Sam, their love, support and encouragement continue to inspire me to be a better husband, father, and friend. I would also like to extend a sincere thank you to my family and friends who have had such a great influence in my efforts to obtain this goal.

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# INTRODUCTION

## Introduction

The profession of fire fighting is arguably one of the most important and dangerous service professions in the world. These professionals have the responsibility of caring for an individual's most prized possessions while placing their own life on the line. The firefighter performs a variety of services for most communities, from educating community members on safety to extinguishing fires hundreds of feet above the ground. These brave men and women perform their duties, in most situations, with little or no recognition.

The past few years has seen this profession draw much more attention in the national media, mainly due to the events on September 11, 2001. These tragic events brought the dangers of fire fighting into everyone's home and placed a new perspective in many people's minds about the importance of being a firefighter. The profession suffered great losses and it became very clear to everyone the dangers firefighters face. In order to confront these dangers firefighters must be both mentally and physically prepared for the worst situations.

In every fire department firefighters are constantly training and honing their skills for fighting fires. However, the importance of proper physical fitness and overall wellness has only recently been addressed as an important component to their training. It is the belief of many that the fire service has paid more attention to their equipment than to the individual firefighter (Peltin & Alkonis, personal communication, January 10, 2004).

The physical demands thrust upon firefighters place them in a situation where they must maintain an adequate level of physical fitness. Firefighters are asked to respond to emergency incidents that often challenge their physical and mental capabilities. The firefighter's exposure to these dangerous situations have made their risk of a fatal accident three times greater than for other workers (Clark & Zak, 1999). Firefighters continue to have one of the highest fatality rates in the workforce according to the 2000 injury survey by the International Association of Fire Fighters (IAFF). Fire fighting also ranks third behind agriculture and mining for job related fatalities. This survey also reports that fire fighting has the highest rate of job related injuries (Schaitberger, 2000). These statistics show the importance in making sure that fire fighters are properly prepared for any type of situation.

The fire service must incorporate cardiovascular fitness and strength training as part of their daily training in order to be prepared to perform at high levels. One of the main goals when instituting this type of training is to decrease the number of musculoskeletal injuries. In a profession that has been deemed one of the most physically and hazardous civilian professions, injuries have to be a major concern. In the most recent report by the National Fire Protection Agency (NFPA), a total of 80,800 firefighter injuries occurred in the line of duty in 2002 (Karter & Molis, 2003). A statistic of this magnitude shows the difficulties faced by the firefighter.

It has been previously determined that firefighters typically score average or slightly above average on physical fitness tests when compared to other male adults (Pearson, Hayford, & Royer, 1995). This population group should be scoring well above average with the physical demands required by their occupation. These low levels of cardiovascular endurance, strength, and overall physical fitness can certainly contribute to the health problems within the fire service. This is why improving the wellness and fitness of the individual firefighter has become such an important aspect of the fire service.

In many instances, within the fire service, there are long periods of stress-free activity immediately followed by sudden intense energy demands. This certainly helps create many of the serious cardiovascular and physical problems associated with the fire service. This situation is further compounded by the low levels of cardiovascular and physical fitness, which exist among many fire fighters. These issues are what place heart attacks as the leading cause of fatalities according to the United States Fire Administration (Schaitberger, 2000). In order to address cardiovascular disease the American Heart Association for years has stressed that improving physical fitness will decrease the chances of cardiovascular disease (American Heart Association, 2004). This being true the firefighter must place an even greater emphasis on cardiovascular training than the normal population due to the physical demands required by the fire fighting profession.

Cardiovascular fitness as well as adequate strength is imperative in order to perform the duties of a firefighter(Rhea, Alvar, & Gray, 2004). This is extremely important because of the various, intense situations that are faced by the firefighter over extended periods of time. The unpredictable environment places even greater stress on the cardiovascular and musculoskeletal systems during fire fighting. Firefighters must adapt and overcome adverse thermal conditions and physical obstacles on the fire ground, this requires a tremendous amount of strength and cardiovascular endurance. The protective equipment generally weighs around 50 pounds, which will increase the energy expenditure needed to perform certain tasks. It has been determined it is not uncommon, that while wearing protective gear heart rate rises to near maximal levels for periods averaging 12-14 minutes (Pearson et al., 1995).

The excessive heat also plays a role in the demand for cardiovascular endurance. The body is less efficient at the higher temperatures firefighters are subjected to, making it more difficult to dissipate the heat that the body is producing. These elevated temperatures place an extreme amount of stress on the cardiovascular system especially when performing tasks such as dragging hoses, climbing stairs, and carrying heavy equipment. These duties and environment place an extreme amount of stress on the individual firefighter, further demonstrating the importance of a holistic strength and conditioning plan.

In order to create a fitness plan that will address all of the needs of the firefighter, strength training cannot be overlooked. The firefighter performs a variety of tasks that require strength and cardiovascular endurance. These tasks may include climbing stairs, holding high-pressure hoses and pulling ceilings. Proper strength training will supplement the cardiovascular training by allowing more efficient movement patterns. By improving strength levels and efficiency, the individual's performance will be enhanced. The individual will require less energy expenditure in order to complete both difficult and simple tasks during the day-to-day operations.

The equipment and environment make it very difficult for firefighters to perform their duties adequately if they do not have the requisite strength levels. The heavy lifting and maneuvering over uneven terrain requires tremendous amounts of both upper and lower body strength. The body must be able to react and perform appropriately to sudden unexpected problems as well as sustain high levels of energy output for long periods of time. By improving the strength and cardiovascular efficiency the firefighter will be better prepared to handle all types of both physical and mental situations. This will lead to a more productive and efficient firefighter.

The fire service has certainly recognized the serious problems faced by the firefighter. Strategies are underway to reduce the number of injuries and the fatalities within the fire service. In 2000, the National Fire Protection Association (NFPA) released a standard which established minimum requirements for a health-related fitness program for fire departments.(National Fire

Protection Association, 2000) The idea was to enable firefighters to develop and maintain a level of health and fitness in order to safely perform their duties. The International Association of Fire Fighters (IAFF) in cooperation with the International Association of Fire Chiefs (IAFC) created a wellness-fitness initiative in 1997 to address the fitness needs of the firefighter (International Association of Fire Fighters, 2004). A task force created by the IAFF and IAFC has been working to implement a holistic and non-punitive approach to wellness in the fire service.

These efforts are certainly positive steps toward instituting a physical fitness protocol. However, the difficulty arises when trying to determine which type of program will be the most productive. A good wellness program is designed to not only to decrease work loss time and worker compensation claims but also improve the overall quality of life for the firefighters (Pearson et al., 1995). In order for this initiative to be successful there must be a cultural shift within the administration, fire departments and the individual firefighter toward enhancing the overall wellness of the profession. If this is accomplished, it will enhance the performance and lengthen the careers of many firefighters. This improvement will hopefully correlate to a decrease in musculoskeletal injuries and an overall reduction in workers' compensation claims and time loss.

In most fire departments nationwide, sprains and strains are the leading cause of on-duty injuries (Karter & Molis, 2003). These types of injuries need to be avoided, not only because of the physiological problems but also the workers' compensation and workers' time loss associated with these issues. These musculoskeletal injuries cost the individual firefighter and the fire departments hundreds of thousands of dollars each year in time loss and workers' compensation (Green & Crouse, 1991; Reekes, 2004a)**.**

The sprains and strains suffered by the firefighter are most often overuse or non-contact occupational injuries. These types of injuries, which include rotator cuff strains/tendinitis, patellar tendonitis, and low-back pain, have the potential to be avoided if a proper physical assessment and physical fitness program are instituted.  The unavoidable injuries such as falls, and direct blows are more difficult to prevent, however, with proper physical fitness levels, the recovery from these injuries may be quicker.

The implementation of strength and conditioning programs in departments across the nation is an attempt to eliminate these musculoskeletal injuries. There have been studies that show improving the fitness levels of firefighters improve their performance (Cady, Bishoff, O'connell, Thomas, & Allan, 1979; Hilyer, Brown, Sirles, & Peoples, 1990). However, even with the recent changes and efforts toward physical fitness, overuse and non-contact musculoskeletal injuries continue to occur at very high rates. It is very important that a more aggressive, functional and individualized wellness and fitness program be instituted in an attempt to have a greater impact on the injuries occurring. If this happens everyone associated with the fire service will benefit. The firefighter will have improved health, the public will benefit due to more productive firefighters assisting them with their needs, and the department will have a reduction in worker time loss and worker compensation claims.

The fire service has identified the need for such a wellness and fitness program and has taken steps to begin incorporating some type of program to improve the health and wellness of the firefighter. The problem arises when attempting to determine which type of cardiovascular and fitness program will best fit the needs of the fire service. Traditionally, strength, flexibility and cardiovascular training has been recommended as a deterrent to cardiovascular risk factors as well as a way to improve performance (American Heart Association, 2004; Cady et al., 1979; Hilyer et al., 1990; Williford & Scharff-Olson, 1998). However, with the changes constantly occurring in regards to individual physiology, equipment, strength and conditioning protocols and working environment, the physical fitness regime that is instituted must evolve along as well. The trend in most occupational fitness settings continues to move toward functional training (Cook, 2004). Knowing this, a more individualized approach incorporating functional training, designed to focus on movement and kinetic chain weaknesses should be incorporated into the physical fitness protocol.

The profession of fire fighting should incorporate functional training in order to develop a more comprehensive and aggressive physical fitness regime. A fitness program like this must begin with a proper assessment in order to gain knowledge of an individual's risks of injury. In the traditional model, prior to beginning training or incorporating a physical fitness protocol, a medical professional must perform a pre-participation or pre-placement physical. The pre-performance medical evaluation is the preliminary assessment tool utilized to identify potential medical problems.

Once this is completed and the individual has been cleared to participate in activities, more rigorous testing can be performed. In most fire departments this type of physical testing is accomplished by performing a series of fitness tests such as a 1.5-mile run, sit-ups, push-ups, sit and reach, $VO_{2max}$, and bench press (International Association of Fire Fighters, 2004). There are also functional tests performed: the Candidate Physical Aptitude Test (CPAT), pulling hoses, and climbing stairs with a weighted vest. These types of functional performance tests are designed to mimic real life scenarios. There are many departments which develop their own functional test assessments that incorporate tests that are specific to their environment, such as the Firefighter Physical Conditioning Course in Chesterfield County, Virginia (Reekes, 2004b).

Most pre-performance examinations are performed primarily to help detect life-threatening conditions, abnormalities and musculoskeletal conditions, which may lead to injury. The common evaluations that are performed include height, weight, blood pressure, pulse, vision and certain musculoskeletal tests. These tests along with a detailed medical history provide useful information. However, there is much concern as to whether this examination has any relationship to performance and injury, especially in active populations (Fields & Delaney, 1989; Meeuwisse & Fowler, 1988).

This type of examination will provide useful information concerning the fitness status of the firefighter. The fitness tests are utilized to gather quantitative data concerning strength, agility and cardiovascular fitness. The information gathered is used to establish baseline information in order to create starting points and goals for the individual's physical fitness protocol. The functional tests give the incoming firefighter an idea of what is expected and provides the incumbent firefighter an idea of what they may need to work on.

In the traditional model, performance or functional tests are performed after the firefighter successfully completes the pre-placement physical. The problem with this traditional, systematic form of assessment is the tremendous gap between the medical evaluation and fitness/functional testing. The physical examination only provides a baseline level of a person's health, it doesn't indicate who is prepared to perform certain tasks. In order to bridge the gap between the pre-performance physical and fitness testing, the firefighter's movement mechanics should be assessed. The firefighter should possess efficient fundamental movement mechanics to be successful during fitness and functional testing. If basic movement patterns cannot be performed effectively, then higher-level functional activities will be executed inefficiently.

The Functional Movement Screen (FMS) is an assessment tool which was designed to evaluate basic movement mechanics (Cook, Burton, Fields, & Kiesel, 1998). This evaluation technique will isolate deficiencies and imbalances in the movement patterns. If these types of problems go unnoticed, compensatory movement patterns will develop. These compensatory movement patterns will lead to inefficiencies during physical fitness activities and daily work duties. It is these inefficiencies that will lead to decreased performance and a possible susceptibility to musculoskeletal injuries.

The FMS assesses mobility and stability weaknesses and imbalances during seven specific movement patterns. These tests attempt to place specific joints and muscle groups in a position where they must achieve a balance between mobility and stability in order to produce the required movement. If the test is not performed properly, then a compensatory movement pattern exists. These compensatory patterns could be the underlying cause of non-contact and overuse musculoskeletal injuries. If the firefighters are identified with fundamental movement flaws, then they can be addressed through proper mobility and stability exercise techniques. This philosophy will allow the fire departments to create more individualized strength and conditioning programs while becoming more pro-active in their approach in injury prevention.

**Statement of Problem**

The purpose of this study was to determine if an assessment of an individual's movement mechanics and functional mobility and stability can act as a predictor and risk factor for musculoskeletal injury. This study was designed to determine whether individual fundamental movement patterns act as predictors to firefighter functional performance efficiency.

**Research Questions**

The study will specifically attempt to answer these questions:

1. Does the FMS total scores of a firefighter have a relationship with the results of the performance test scores in firefighters during their fire academy training?
2. Does the FMS asymmetry scores of a firefighter have a relationship with the results of the performance test scores in firefighters during their fire academy training?
3. Does a firefighter's performance test scores, their FMS total score and FMS asymmetry score results have an inverse relationship with the number of individual occupational injuries during their fire academy training?
4. Is there an inverse relationship with a firefighter's FMS score results and the number of individual occupational injuries during fire academy training?
5. Is there an inverse relationship with a firefighter's asymmetrical FMS score results and the number of individual occupational injuries during fire academy training?

**Research Null Hypotheses**

1. The FMS score results do not show a significant relationship with performance testing in firefighters during fire academy training.
2. The FMS asymmetry score results do not show a significant relationship with performance testing in firefighters during fire academy training.
3. The interaction between performance testing, FMS total score and the FMS asymmetry score results do not show a significant inverse relationship with individual occupational injuries in firefighters during their fire academy training
4. The FMS score results do not show a significant relationship with individual occupational injuries in firefighters during their fire academy training.
5. The FMS asymmetry score results do not show a significant positive relationship with individual occupational injuries in firefighters during their fire academy training.

**Significance to Field**

Fire fighting is a profession that is plagued with orthopedic injuries and cardiovascular problems. These issues cause tremendous financial and performance troubles within the fire service. It is also a profession that requires a tremendous amount of physical and mental strength to perform at the levels necessary to succeed. It is because of these issues that strength and conditioning training must be part of the daily routine of every firefighter. There has been a positive effort in the last few years to incorporate a strength and conditioning program within the fire service to fight these issues. However, there continues to be a significant number of fatalities and injuries occurring even with these changes.

Strength and conditioning programs have shown positive effects in decreasing certain injuries, improving cardiovascular problems while improving performance (American Heart Association, 2004; Cady et al., 1979; Hilyer et al., 1990; Pearson et al., 1995). This is why the implementation of a physical fitness program is so important. In most situations, the strength and conditioning programs in the fire service begin with medical evaluations and performance testing. These evaluations are designed to get a baseline of physical fitness, anthropometric information as well as determine any obvious life threatening conditions. Once this information is gathered a strength and condition program can be designed around these initial measurements.

The information provided by medical evaluations and performance tests has shown to have some predictability of athletic and occupational injury (Frone, 1998; Iverson & Erwin, 1997). There are several factors that may limit any assessments' ability to predict who is predisposed to injury. One is the difficulty of isolating individual risk factors. Second, is the variety of tests being performed during most evaluations, there is no set standard technique. Finally, if risk factors are identified, they may not easily be addressed through conventional training. For example, Frone (1998) found that gender and job tenure were two predictors of work injuries. However, these predictors cannot easily be altered. There have been other researchers who have questioned the intent and purpose of these pre-participation medical evaluations because of these limitations and difficulties (Fields & Delaney, 1989; Meeuwisse & Fowler, 1988).

A more practical approach, which may identify individuals who are likely to sustain occupational injuries, could be to perform a more functional, dynamic assessment of an individual's basic movement mechanics. Typical medical evaluations and performance tests are not designed to evaluate these types of movement patterns. Therefore, providing a more applicable tool to utilize in the prevention of injuries is warranted. A problem is that there is limited research in the predictability of injury by assessing an individual's movement mechanics.

When evaluating the efficiency in fundamental movements you can determine who is utilizing compensatory movement patterns. The individual's right and left side muscle and joint imbalances along with mobility and stability weaknesses can be identified. These imbalances and problems have been shown to predispose individuals to injuries (Knapik, Bauman, Jones, Harris, & Vaughn, 1991). The FMS is an assessment tool that will identify these types of problems by quickly assessing the efficiency in the fundamental movement patterns. It accomplishes this by placing the body in a position where the body must overcome imbalances and weaknesses in order to successfully complete the movement pattern. These weaknesses and inefficiencies in movement cause increases in total body energy expenditure and micro-trauma during activity (Cook, Burton, & Kiesel, 1999).

If it is determined that the FMS can identify inefficiencies and certain predisposing injury risk factors, then the micro-traumatic occupational injuries should decrease and performance should increase. The improved efficiency and productivity of the firefighter will enhance their quality of life and lengthen the careers of many individuals.

There are tremendous costs associated with injuries in every profession, especially a highly active profession such as the fire service. The Chesterfield County, Virginia's annual report on injuries stated that there was $234,774 spent on 61 injuries in 2003 (Reekes, 2004a). In fire departments nationwide hundreds of thousands of dollars are spent annually on injuries. The study performed by Hilyer et al. (1990) was unable to show a significant difference between the control group and flexibility group, however there was a substantial difference in the amount of money spent on injuries between the groups. The total injury cost by the experimental group was only $85,372 compared to the control group, which was $235,131. The reduction in financial costs demonstrated by this study clearly shows the benefits of implementing a fitness program.

A decrease in injuries may or may not lead to a decrease in dollars spent on worker's compensation due to the unpredictability in the healthcare system. However, it should lead to improvements in work loss time and worker compensation claims. These improvements should show improvements in the efficiency of the fire department. The advantages of a holistic, individualized fitness program should provide both physical and financial benefits that will positively affect the entire fire department.

**Basic Assumptions**

1. The subjects performed the same daily training routines and individuals did not alter their strength and conditioning programs.
2. A supervising firefighter will evaluate and record all injury data.
3. The subjects will report all injuries that occur during the 16-week training.
4. The subjects entering the fire academy have no pre-existing musculoskeletal conditions, which will alter their performance on the FMS and performance tests.
5. The performance measures and FMS will be conducted and recorded by an experience tester.
6. The performance measures utilized (VO2Max, 1.5 mile run) are recognized as adequate measurement of performance by the American College of Sports Medicine(2000).
7. The Fire Fighter Physical Conditioning Course was developed by members of the Chesterfield, County Fire Service and is considered a valuable baseline measurement and training tool for the firefighter candidates.(Mead, 2004)
8. The FMS inter/intra-rater reliability has been previously established in unpublished materials.(Cook, 2001c)

**Limitations**

1. The test subjects will be obtained during the training, which will limit the number of subjects available for testing. The limited number of subjects may decrease the power in the study.
2. Subjects may not report all occupational injuries or problems due to the effect it may have in performance ratings given during training.
3. The subjects may not perform the tests to the best of their ability.
4. The length of time of the fire academy training is 16 weeks, this may not allow for movement efficiency problems to cause noticeable micro-traumatic breakdown.

**Operational Definitions**

1. Documented/Reportable Injury: an event that results in pain or damage to the body and for which the individual communicated the issue to their superiors.
2. Injury Duration: the amount of time a documented injury will alter an individual's normal training.
3. Exposures: individuals have similar training, which will allow for equal opportunities for potential injuries or problems.
4. Core Strength: ability of the trunk, spine and abdominal musculature to provide mobility, stability and transfer energy to and from the lower and upper extremities.
5. Kinetic Linking/Chain: large base segment of the body passing momentum to smaller adjacent segments. A system of segments moving at a certain velocity has momentum, once a base segment decelerates it passes the momentum on to the next segment, increasing its velocity (Welch, Banks, Cook, & Draovitch, 1995).
6. Fundamental Movement Pattern: observable performance of basic locomotor, manipulative and stabilizing movements (Gallahue & Ozmun, 1995).
7. Compensatory Movement Patterns: Disruptions in the body's fundamental movements, causing the body to sacrifice quality of movement for quantity.
8. Performance Measures: VO2 Max, 1.5 mile run and Fire Fighter Physical Conditioning Course

# Chapter 2

# REVIEW OF LITERATURE

## **Introduction**

There are numerous duties performed in the fire service that place the firefighter in very dangerous situations. These situations make it extremely important that each firefighter is prepared for any type of situation whether it is physical or mental. The complexity of this profession has consistently ranked it as one of the most demanding professions in the world (Clark & Zak, 1999). Fire fighting ranks third in job related fatalities and first among job related injuries. Heart attacks rank first among the job related fatalities and sprains and strains rank first among injuries, when comparing them to the various occupations (Schaitberger, 2000). These statistics seem very alarming, however most of these problems have the potential to be reduced or even eliminated.

A wellness and physical fitness program, which will elicit positive lifestyle changes, can be designed in an effort to prevent many of the musculoskeletal injuries and cardiovascular diseases. According to the American Heart Association, cardiovascular disease is the leading cause of heart attacks. In order to decrease the chances of a heart attack, improved eating habits, eliminating smoking, and daily exercise have long been recommended by the American Heart Association (American Heart Association, 2004). A strength and conditioning program which focuses on improving the body’s movement mechanics and inefficiencies should serve to improve the cardiovascular performance in individuals.

The prevention of musculoskeletal injuries however is a much more complex issue, which is why it has been such a highly researched and discussed topic. Considering the importance and complexity of the fire service, prevention of injuries becomes even more difficult to accomplish. In order to develop strategies in preventing musculoskeletal injuries, the initial goal should be to identify who is at risk for these injuries.

This literature review will present information pertaining to the various risk factors that have been identified as predictors of injuries in active and occupational settings. The current literature studying the effectiveness of the evaluation techniques that are utilized to identify these risk factors will be reviewed as well. The focus will then shift toward more contemporary views and foundations for movement-based assessment techniques. Their influence in potential injury predictability and individualized functional training will also be discussed.

**Prevention of Musculoskeletal Injuries**

The prevention of musculoskeletal injuries is a goal for every medical professional working with active population groups. Musculoskeletal injuries continue to be a problem within most professions, even with numerous technological advances in the medical field. Police and fire departments, as well as the military, provide services that require high levels of physical fitness. Injuries in these professions not only lead to physical disability and decreased performance but also enormous financial costs which are associated with workers' compensation benefits.

The profession of the fire service has continued to make strides in attempting to prevent musculoskeletal injuries by instituting the Wellness and Fitness initiative. The IAFF and IAFC have made positive strides. However, even with their efforts, injuries still remain a very big problem. According to the National Fire Protection Agency the fire service injuries have decreased over the past three years, going from 84,550 in 2000 to 80,800 in 2002 (Karter & Molis, 2003).These numbers still remain very high and efforts must continue in order to eliminate many of the non-contact and overuse injuries.

**Epidemiology of Musculoskeletal Injuries**

In order to tackle the issue of injury prevention, the risk factors associated with similar professional organizations and active population groups must be observed. It is very important to first identify the individuals who are at risk for musculoskeletal injuries. Once identified these areas can then be addressed through training and technology. There have been numerous studies that have attempted to identify these risk factors. In much of this related research, the risk factors associated with injuries seem to be multi-factorial, making it extremely difficult to develop prevention strategies (Knapik et al., 1991; Knapik, Sharp et al., 2001; Macera, 1992; Macera et al., 1989; Neely, 1998b). The risk factors associated with injuries are typically divided into two categories: intrinsic and extrinsic. The intrinsic risk factors include age, gender, physical build, physical fitness, psychological factors, previous injury and biomechanical abnormalties. The extrinsic risk factors include activity, intensity of activity, exposure, environmental factors (surface, weather, etc.), and equipment.(Neely, 1998b)

Intrinsic Risk Factors

The age of individuals has been shown to be a risk factor, though studies differ in determining whether older or younger individuals are more prone to suffer more injuries. A study, which utilized a military population, demonstrated that individuals over the age of 24 had a higher relative risk for lower extremity injury than individuals less than 19 years of age. Contrary to this study, Macera, Jackson, and Hagenmaier (1989) found that injury rates in runners did not increase with age.

Studies performed in occupational settings tended to find differing results as well. Frone (1998) found that age did not have any statistical significance in reported work injuries in adolescents. This study did find however, that job tenure was related to work injuries; individuals who had worked longer sustained a less number of injuries. Laio, Arvey, and Butler (2001), whose study utilized the fire service, also found injury duration was negatively related to job tenure. This would indicate that longer tenured fire fighters suffered injuries that were less severe, typically requiring a shorter healing period. These results are thought to be due to less tenured employees having less experience and having more stressful and physically demanding jobs. In this study, Laio et al. were able to find that age was positively related to injury duration, indicating older firefighters took more time to recover from injuries. This would seem obvious due to the physiological changes that occur as people age. However, Iverson and Erwin (1997) were unable to show a relationship with job tenure and injuries. The information presented in this study would make it difficult to conclude whether job tenure has a significant relationship to injuries.

These studies all have very diverse population groups including military, adolescents, and active individuals. But, they all demonstrate differing results in determining if age is a risk factor for injuries. Literature reviews conducted by Macera and Neely (1992; 1998b) also failed to reveal significant evidence showing age as a determining factor for injury risk. It seems that most of the studies relating age to injuries differed in their results, indicating no clear direction on whether age can be considered a risk factor for injuries. This would signify that more specific, individual factors, such as job description and tasks would have a greater impact on injuries.

There also seems to be a debate on whether gender is a risk factor for injuries. Studies utilizing active occupational settings such as the military, police force and fire service were consistent in concluding that gender does have a significant relationship to injury rates. A study performed by Knapik et al. (2001) showed that during basic combat training females had over twice the injury rate as men. In a study by Hauret, Shippey, and Knapik (2001) women were 3.7 times more likely than men to sustain injuries requiring they enter the Physical Training and Rehabilitation Program. Liao et al.(2001) reported similar results when they observed workers' compensation results from 1987-1998. Their results showed that female firefighters experienced more injuries, thereby having higher worker compensation claims. This study also revealed that single females had higher costs associated with these claims than single males. A study performed by Boyce, Hiatt, and Jones (1992), who investigated the relationship between physical fitness and workers compensation claims in the police force, also showed that females had higher claims for workers' compensation.

Studies in civilian population groups differ in their results. A study performed by Macera (1989), based on elite recreational runners, failed to show significant differences in injuries between male and females. A study performed in the occupational setting revealed that in adolescents, males had more injuries than females. However, in this study exposures to injuries were not accounted for, which could affect the overall results (Frone, 1998). The review of literature performed by Frymoyer and Cats-Baril (1987) failed to determine if gender was a significant risk factor for injury in the civilian population.

Overall, it seems that more vigorous training settings lead to greater incidence of injury to females. This is thought to mainly be due to the physiological differences (body weight, biomechanics, cardiac volume) between males and females (Neely, 1998b). If the training is modified for these physiological differences, then significant findings between genders may decrease in professions such as the military and fire service. Depending on the population setting and difficulty of training it may be hard to determine if gender is indeed a risk factor for injury.

Psychological characteristics seem to be less debated in their influence as risk factors for injuries. There are numerous studies in active and occupational populations, which show that psychological characteristics have significant influences on injuries. Many of these studies utilize different design and evaluation methods in their research to determine personality and psychological characteristics. However, it does seem that most studies agree that there is a significant relationship.

A prospective study of Type A personality behaviors and runners by Fields, Delaney, and Hinkle (1990) revealed that runners who scored 120 or greater on the Type-A Self-Rating Inventory had higher incidence with injuries. Lysens et al. (1989) utilized six personality tests which revealed a clear relationship with acute injuries in young athletes. In occupational studies performed by Frone (1998) and Iverson and Erwin (1997) it was again concluded that injuries were significantly related to personality and psychological characteristics. Another study by Laio et al. (2001), which involved firefighters, utilized the Minnesota Multiphasic Personality Inventory (MMPI) to test the relationship with injury duration and various MMPI scales. The results of this study showed that two MMPI scales were significant predictors of injury duration. These studies utilized varying population groups from active individuals to blue-collar employees.

The psychological and personality characteristics seem to have significant influences in injury predictability. However, an issue arises when reviewing the literature; most of the studies utilized different personality and psychological evaluation techniques. These varying techniques make it more difficult to isolate which factor or factors is most influential in predicting injuries. The research does clearly suggest that individuals who possess certain psychological characteristics do have a tendency to suffer more injuries.

Studies performed by Jones et al.(1993), Baumhauer, Alosa, Renstrom, Trevino, and Beynnon (1995) and Macera et al.(1989) were unable to find any significant relationships between height, weight, body mass index, and injuries. Contrary to these findings Lysens et al.(1989) reported that there was a relationship between injury proneness and height and weight in young athletes. The reviews of literature by Macera (1992) and Neely (1998b) were unable to establish whether a relationship indeed exists between anthropometric measures and injury frequency. There does not seem to be a consensus in the literature examining whether these types of measures are predictors of injury.

The review of literature again reveals different findings concerning biomechanical factors and their relationship to injury. A study performed by Baumhauer et al.(1995) found no significant differences between ankle injuries and foot anatomic alignment. Contrary to Baumhauer et al., Donatelli (1987) did find a relationship between individuals who have been diagnosed with pes cavus feet and ankle sprains. His study indicated that individuals with these types of foot structures had a higher incidence of ankle sprains.

In a study utilizing motion analysis to obtain a dynamic assessment of the arch, it was determined that a relationship exists between pes planus feet and injuries(Kaufman, Brodine, Shaffer, Johnson, & Cullison, 1999). This dynamic measurement indicated that individuals with pes planus feet had a higher incidence of injury. Static measures in this study also found that individuals with abnormal arches, pes planus or pes cavus feet had an increased incidence of stress fractures. However, the dynamic assessment, when performed in shoes, found a significant relationship between pes planus and injuries, but the static assessment was unable to find a relationship when performed in shoes. Most individuals perform their daily tasks and train in shoes so it could be assumed that this measurement may be more appropriate. Kaufman et al. found very different results when utilizing the dynamic assessment. It was their conclusion that dynamic assessments are more indicative of true structural characteristics of the foot and ankle. This finding may lead us to believe that dynamic assessments may be a better tool when evaluating the body in order to gain a more thorough understanding of functional movement mechanics.

There does seem to be some relationships between injury and lower extremity alignment according to several studies. Cowan, Jones, and Frykman (1996) found that excessive Q-angles of the knee were associated with higher risk of lower extremity stress fractures and other injuries in military trainees. Lysens et al. (1989) found similar results when studying adolescents. They determined that larger Q-angles resulted in a significant positive relationship with individuals who had higher injury rates. There are other studies that contradict these findings. A study utilizing basketball players was unable to determine a significant relationship between structural measures and injuries (Grubbs, Nelson, & Bandy, 1997). The literature reviews performed by Jones, Cowan, and Knapik (1994) and Neely (1998a) determined that it remains controversial as to whether varus or valgus knees predispose individuals to injuries. It seems that much of the research is inconclusive in determining whether biomechanical factors influence the occurrence of musculoskeletal injury.

There is a need for further research concerning biomechanical factors, perhaps utilizing more functional approaches and motion analysis. However, it is very difficult to alter or improve many of these biomechanical risk factors. For example, risk factors such as an excessive Q-angle, pes cavus and pes planus may not easily be addressed through conventional or conservative treatment. This issue could also be raised when considering other risk factors such as gender, age, height and even weight in some situations.

There is more controversy in determining which intrinsic risk factors are predictors when reviewing studies concerning physiological factors such as strength and flexibility. It has long been thought that increases in flexibility and strength would translate into decreases in injury rates. However this is not the case according to several studies. Two independent studies utilizing Army infantry trainees found that individuals who were at both extremes of flexibility (limited flexibility and very flexible) had a higher incidence of injury (Jones et al., 1993; Knapik, Sharp et al., 2001).

A study performed by Battie et al. (1990), who studied subjects with back pain, did not find a significant relationship between pain in the back and flexibility. However, Mellin (1988) found that hip mobility deficiencies would lead to increases in forces placed on the lumbar spine. This, theoretically, would lead to increases in low back pain over time. A study by Hilyer et al. (1990) tends to agree with Mellin's findings. Hilyer et al. found that by implementing a flexibility program within the fire service, medical costs and severity of musculoskeletal injuries decreased. This finding would lead us to believe that limited flexibility may be a precursor to injury.

A different view was found in a study within the fire service. The results revealed that individuals who had higher sit and reach scores also had more workers' compensation claims than individuals who scored lower on the sit and reach (Boyce et al., 1992). This would agree with the findings of Knapik, Sharp et al. (2001) and Jones et al. (1993). They determined that individuals who have increased flexibility have a higher incidence of injury. There does seem to be some controversy in the conventional thinking that improving flexibility will decrease injury, according to these studies.

The studies that researched the relationship between strength and injuries have displayed varying results. Studies by Knapik, Canham-Chervak et al. (2001) and Jones et al. (1993) showed higher strength levels revealed increases in injuries during military training. This trend was also found in the civilian occupational setting by Boyce et al. (1992), who stated that individuals who recorded higher strength values in the fire service also had higher workers' compensation claims. However, in related research by Battie et al. (1989) there was no significant relationship between back pain and isometric strength in an occupational setting. It is the belief of these researchers that individuals who possess greater strength are typically exposed to more difficult tasks or activities thereby increasing their risk for injury.

It does seem, according to the previous studies, that higher strength and flexibility levels show significant relationships to injuries. However, there have been numerous literature reviews performed on this topic that found no significant results to implicate strength and flexibility as injury predictors (Bracko, 2002; Gleim & McHugh, 1997; Macera, 1992; Meeuwisse & Fowler, 1988; Neely, 1998b; Young & Behm, 2002). It would seem that individuals who have greater strength and flexibility would have more exposures during activities, possibly due to their performance levels. This would certainly account for a higher incidence of injury for stronger and more flexible individuals. In order to determine if this is the case, more research should be performed, placing more emphasis on controlling for exposures across subject groups.

There appears to be very little clear evidence to suggest that flexibility and muscle strength predispose individuals to injury. However, there seems to be significant findings that suggest that muscle strength and flexibility imbalances lead to musculoskeletal injuries. Knapik et al. (1991) determined that females who had a 15% or more knee flexion strength imbalance were 2.6 times more likely to suffer an injury. They also found that the athletes were 2.6 times more likely to have an injury if they had a hip extension flexibility imbalance of 15% or more. Nadler et al. (2001) had similar findings when studying low back in females. They found that females who were suffering from low back pain had 15% stronger left hip extension when compared bilaterally. Baumhauer et al. (1995) supported this finding in their study of ankle injury risk factors in athletes. In this study they measured joint laxity, anatomic foot alignment, isokinetic strength and ankle joint laxity of 145 college-aged athletes. The finding was that athletes who had significantly greater inversion-to-eversion and plantarflexion-dorsiflexion strength ratios had higher rates of inversion ankle sprains. Knapik, Jones, Bauman, and Harris (1992) also determined, in their review of literature, that there was a consistent positive relationship between muscle and flexibility imbalances and musculoskeletal injuries. This would indicate that individuals who exhibited greater muscle flexibility imbalances would be more likely to sustain injuries.

The literature is also consistent in implicating previous injuries as an intrinsic risk factor for injury. This factor was found to be a determining factor in training related injuries in studies performed by Jones, Cowan, and Knapik (1999), Cowan et al. (1996), and Knapik et al. (1991) using military population groups. Macera et al. (1989) had similar findings during her study of habitual runners. In Lysens' et al. (1989) study of adolescents it again was determined that previous injuries was a predictor of injury prone athletes. A review performed by Troup (1984) had similar findings when investigating low back pain. Previous musculoskeletal injuries were consistently found to be predictors of low back pain at work. A prior history of injury was also considered a predictor when Frymoyer and Cats-Baril (1987) established their model to predict low back pain disability.

The literature certainly suggests that both strength and flexibility imbalances along with previous injuries both lead to injuries. It could be argued that the muscle and flexibility imbalances will cause the initial injury or that the previous injury will lead to these imbalances. These two thoughts would certainly warrant further study in order to determine the implications for each problem. However, in either scenario both previous injury and muscle and flexibility imbalances are consistently considered predictors of musculoskeletal injuries and should be identified early in pre-placement screening. Once identified, they can be addressed through proper therapeutic activities in order to prevent future injuries.

There seems to be limited and inconsistent research stating clear evidence on whether several intrinsic risk factors can be considered predictors of musculoskeletal injury. There is controversy over anthropometric measures, demographics, and biomechanical factors in their ability to determine who is predisposed to injury. It was also found that strength and flexibility were not clear in their ability to be considered risk factors. This would certainly be contrary to conventional beliefs that greater strength and flexibility would lead to a reduced number of injuries.

The research did reveal consistent, significant indications that the area of psychological characteristics, previous injury, and muscle and flexibility imbalances can all be considered risk factors for injury. It does seem that most studies suggest a need to have more research performed in predicting intrinsic factors utilizing different population groups and sample sizes, while controlling for exposures and training techniques. These controls would allow for a deeper appreciation and understanding for many these risk factors. The previous studies provided very useful information in what may or may not be predictors. However, in order to develop strategies to decrease injuries further research must continue in order to pinpoint the factors that predispose individuals to certain injuries.

<u>Extrinsic Risk Factors</u>

In many situations the extrinsic risk factors are not nearly as influential on injury prediction as intrinsic risk factors. The extrinsic risk factors are very different across population groups, depending largely on equipment, environment and exposures. An occupation such as the fire service is influenced greatly by these extrinsic factors. The job responsibilities, exposures, working environment and equipment place unusual stress on the firefighter and must be addressed. It does seem that research on extrinsic risk factors is somewhat limited when compared to intrinsic risk factors. This maybe due to the limited interventions that may be accomplished in the case of firefighters. It will be difficult to alter the working environment, equipment and job related tasks that predispose them to injuries. The focus is most often geared toward improving the technology as it relates to these factors.

Occupational settings do reveal relationships between working environment and injuries. It has long been recognized that heavy manual work correlates to degenerative changes in the lumbar spine (Troup, 1984). When discussing these extrinsic risk factors for injury in both the athletic setting and working environments the exposures to each individual will differ tremendously, thus making it difficult to extrapolate relevant data across population groups.

There have been studies within the fire service that show that certain extrinsic risk factors do predispose firefighters to certain injuries. A biomechanical analysis performed by Lavender, Conrad, Reichelt, Johnson, and Meyer (2000) simulated the work tasks performed by paramedics and emergency medical technicians. They found that in many of the simulated tasks strength levels would not be sufficient in most of the population to perform the necessary movements. They went on to find that some of the tasks exceeded the compressive values in the low back recommended by the National Institute for Occupation Safety Hazards. Their findings indicated that many of the responsibilities in this profession placed a tremendous amount of force on the joints in the extremities, and specifically the low back. This study provides insight into how the working environment in certain occupations, particularly the fire service, can lead to a higher incidence of injuries than other less demanding professions.

An area that should not be overlooked when studying the risk factors of firefighters is the treacherous environment where their tasks are performed. The setting is very dangerous and unpredictable, thus increasing their injury risks. The most obvious environmental concern for firefighters would be the intense thermal conditions.

The equipment designed to prevent burns adds additional weight and insulating properties that places significant stress on the cardiovascular and musculoskeletal system (Duncan, Gardner, & Barnard, 1979). These thermal conditions were also found to decrease plasma volume in the early stages of fighting a fire. This can lead to dehydration, and heat related illnesses (Davis & Dotson, 1987). The breathing hazards associated with fire fighting are avoided by utilizing breathing masks or self-contained breathing apparatus (SCBA). These masks, while necessary to perform more dangerous and taxing duties, have been shown to significantly decrease work capacity (Matticks, Westwater, Himel, Morgan, & Edlich, 1992).

The turnout coat and pants, SCBA, boots and helmet are necessary pieces of equipment needed when fighting fires, however they significantly increase the needed strength and stamina to perform certain duties. This equipment and the hazardous environment will place a tremendous amount of stress on the cardiovascular and musculoskeletal systems (Pearson et al., 1995). These issues will, in many cases, predispose the firefighter to injuries.

Another issue that should be included when discussing risk factors for occupational injuries is workers' compensation. The research in this area is limited, but due to the enormous financial impact workers' compensation has on the profession, it should be reviewed. In a previous study by Butler and Worrall (1985), it was determined that greater workers' compensation benefits led to longer duration of injury. In a study specific to the fire service, Laio et al. (2001) revealed on duty injury claims had longer duration, which is consistent with Butler and Worrall's earlier findings. According to these two studies it would seem that workers' compensation claims could be considered an extrinsic risk factor for injury duration. The information provided by these studies' was limited in their ability to correlate injury risk to worker's compensation. However, their findings concerning the increased length of time it took individuals to return to duty does provide valuable information and would certainly increase the cost associated with injuries.

The extrinsic risk factors may generally be more difficult to address than the intrinsic risk factors. The extrinsic risk factors specific to the fire service in many cases cannot be avoided. The environment the fire fighter is placed in will always be unpredictable and treacherous, however education and training will continue to be updated and addressed to avoid as many fire ground injuries as possible. The equipment, which is designed to protect against injury, can also be considered a risk during fire fighting. This equipment is constantly being updated as new technology is created. Worker compensation claims, which may be considered a risk factor by some, can be addressed through administrative and legislative changes as they continue to be studied.

There are many intrinsic risk factors that were previously discussed that may not be easily addressed. The biomechanical factors, and demographics are examples of risk factors that are difficult to alter when attempting to prevent musculoskeletal injuries. However, many of these factors were not deemed to be consistent predictors for injuries according to numerous studies. The intrinsic factors that were consistently found to predict injury, which were muscle and flexibility imbalance, previous injury and psychological characteristics, can be addressed through proper training and intervention.

**Pre-Participation Evaluations' influence in injury prevention and physical fitness protocols**

In order to address many of these intrinsic risk factors through physical training a physical assessment must first be performed. It is during this assessment that many of these risk factors should be detected and then addressed. However, Meeuwisse and Fowler (1988), who performed a study on the effectiveness of the pre-participation physical, were unable to find a relationship between the results from the preseason examination and injury occurrence. Fields and Delaney (1989) had similar findings when reviewing the effectiveness of the pre-participation physical. They determined that a very small percentage of the athletes being tested were disqualified from participation. The research involving the relationship between pre-season physicals and injury rates is limited. This is most likely due to the necessity to intervene if problems are observed during the pre-participation medical evaluation.

The perception by several researchers in this area is that there are no standards for pre-participation examinations, there should be more uniformity in what is included, and adequate time for intervention should be allowed (Fields & Delaney, 1989; Kibler, Chandler, Uhl, & Maddux, 1989; Meeuwisse & Fowler, 1988; Metzl, 2000). By not having a consistent assessment, it is difficult to find a relationship between the pre-participation examination results and injuries. Recently, the Physician and Sportsmedicine published recommendations for what should be included in pre-participation physicals, hopefully allowing for more consistent evaluations. (The Physician and Sportsmedicine, 2005) However, even with a more consistent evaluation, it will only provide general baseline medical information. This general information does not seem to provide what is necessary to predict and prevent injury as well as determine who will perform at higher levels. Currently, with the increasing number of active individuals and advances in sports medicine, a more sport or activity specific evaluation should be added to this pre-participation examination.

In the traditional, systematic model of pre-placement screenings, the initial medical evaluation is performed, and then performance assessments are conducted. The recommended performance tests include; sit-ups, push-ups, endurance runs, sprints and agility activities (American College of Sports Medicine, 2000). In many athletic and occupational settings these performance activities become more specific to the tasks needed to perform in that particular area. In the fire service the activities may include hose drag, stair climbing, and fireman carry (International Association of Fire Fighters, 2004). These performance tests are not typically utilized as injury predictors; they are utilized in an attempt to establish baseline levels of assessment for performance enhancement programming.

There was a recent study performed to determine the correlations between many of these traditional fitness tests and firefighter performance measures(Rhea et al., 2004). The study found that some of the traditional tests (abdominal curl-up, 12-minute run) didn't show a significant relationship to performance measures while some non-traditional, dynamic fitness tests(400 m. run, bench press, shoulder press) showed a significant relationship. It was determined that a wider range of fitness tests should be performed on firefighters due to the wide range of demands placed on their bodies. It was concluded that in order to address the musculoskeletal problems in the fire service a more individualized testing and programming should be instituted.

It is very important according to Battie et al. (1989) that job-related testing be performed in order not to discriminate unfairly, particularly against women and older workers. The information gathered during these tests is most often used to develop strength and conditioning protocols, establishing goals for training activities, and placement for certain occupational duties.

In numerous studies physical fitness levels have been able to predict who is likely to sustain injuries. In these studies physical fitness levels were determined using many of the performance tests previously discussed. In studies utilizing military trainees, Knapik, Canham-Chervak et al. (2001), Jones et al. (1993) and Hauret et al. (2001) found that soldiers who performed more push-ups, sit-ups and had lower 3-mile run times were less likely to be injured during training. This relationship was also found in civilian populations by Macera et al.(1989) and Troup (1984). These types of performance tests are certainly more functional than the information gathered during the medical screenings. These functional and activity specific performance measurements would seem to provide a better technique in predicting injury susceptibility, and creating a physical fitness protocol.

It has been the traditional thinking that implementing strength and conditioning protocols will decrease the amount of injuries in active population groups. This was supported in the studies previously discussed. Knapik, Sharp et al. (2001) and Jones et al. (1993) indicated that more physically fit soldiers entering basic training were less likely to get injured. One of the earliest studies performed on firefighters indicated that the most physically fit individuals had fewer subsequent back injuries. This study, conducted by Cady et al. (1979), indicated that firefighters' fitness scores were based on isometric strength, heart rate recovery and spine flexibility. The basis for implementing a strength and conditioning protocol was further supported by Hilyer et al. (1990). In this study they examined the effects of flexibility on severity and cost of injuries in firefighters. During this study both the experimental group and the control group had similar injury rates, however the cost and time loss was significantly less in the group performing a flexibility program. These studies would indicate that implementing a fitness program would decrease the number of injuries and costs associated with them.

These findings do differ from other studies previously discussed in this literature review. There were findings by numerous researchers, which were unable to indicate whether improvements in strength and flexibility actually decreases injuries (Gleim & McHugh, 1997; Jones et al., 1993; Knapik et al., 1992; Macera, 1992). Research has been inconsistent in determining whether there is a relationship between strength and flexibility and injury predictability. The inconsistencies can be attributed to differences in research design, including physical fitness measures and evaluation as well as population group. It could also be argued that individuals who are stronger and more flexible have more exposures than weaker, less flexible individuals.

The standardized fitness measures currently being utilized are not providing qualitative information that is able to establish a foundation to create a productive strength and conditioning protocol. The main goal in creating a physical fitness plan is to decrease injuries, enhance job performance and ultimately improve quality of life. Currently, the research is inconsistent on whether the pre-participation physical and standardized fitness measures have the ability to do this. A reason for this is their inability to provide individualized, fundamental analysis of their movements. The pre-participation physical and performance assessments, which seem to be most often performed in active occupational and athletic populations, offer very different analysis of the individual.

These evaluations gather baseline quantitative information and then attempt to make recommendations, and establish goals. The recommendations are based on standardized information, which may not be relative to the individual's specific needs. These evaluations, in many cases, provide objective information that fails to evaluate the efficiency in how individuals perform. An example of this would be: A person who has an above average score on the sit-up test but is performing very inefficiently, compared to a person who scores above average and is performing very efficiently. These two individuals would be deemed above average without assessing their individual movement inefficiencies. In this scenario both individuals would be evaluated as equals; recommendations for training would then be based solely on their performance. There doesn't seem to be a consistent dynamic evaluation that bridges the gap between the two traditional pre-participation assessments.

In order to gain a better knowledge of an individual's ability to perform certain performance tests, and eventually how they perform during participation, a more individualized movement-based assessment could be introduced. The Functional Movement Screen is an assessment, which provides a better blueprint of the individual's movement weaknesses. This will lead to a more applicable way of evaluating who may be predisposed to musculoskeletal breakdown. It will also serve to create an individualized approach in establishing a more functional strength and conditioning protocol. By improving individual goals it may provide a more precise way to evaluate its results on the influence of injury and performance.

**The Basis of the Functional Movement Screen and its influence on injury prevention**

The Functional Movement Screen (FMS) is an evaluation tool designed by Cook et al. (1998) in an attempt to assess an individual's fundamental movement patterns. This assessment tool fills the void between the pre-participation/pre-placement screenings and performance tests by evaluating the individual's in a more dynamic and functional capacity. A screening tool such as this offers a different approach to injury prevention and predictability. It will lead to individualized and functional recommendations for physical fitness protocols in active population groups.

The test is made of 7 fundamental movement patterns that require a balance of mobility and stability. These fundamental movement patterns are designed to be observable performance of basic locomotor, manipulative and stabilizing movements. The tests place the individual in extreme positions where weaknesses and imbalances become noticeable if appropriate stability and mobility is not utilized. It has been observed that many individuals who perform at very high levels during activities are unable to perform these simple movements (Cook et al., 1999). These individuals are considered to be utilizing compensatory movement patterns during their activities, sacrificing efficient movements for inefficient ones in order to perform at high levels. If these compensations continue then poor movement patterns will be reinforced leading to poor biomechanics.

The FMS tests were created on fundamental proprioceptive, kinesthetic awareness. Each test is a specific movement, which requires appropriate functioning of the body’s kinetic linking system. The kinetic link model is used to analyze movement. It depicts the body as a linked system of interdependent segments, often working in a proximal-to-distal sequence, to impart a desired action at the distal segment (McMullen & Uhl, 2000). A very integral aspect of this system is the body’s proprioceptive awareness. Proprioception can be defined as a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement and joint position sense (Lephart, Pincivero, Giraldo, & Fu, 1997). Proprioceptors in each segment of the kinetic chain must be functioning properly in order for efficient movement patterns to occur.

During the earlier stages of growth and development an individual’s proprioceptors are developed through reflexive movements in order to perform basic motor tasks. This development occurs proximal-to-distal, the infant learning to first stabilize the hypermobile joints in the spine and torso and eventually the extremities. This progression, according to Gallahue and Ozmun (1995), occurs due to maturation and learning. The infant learns the fundamental movements by responding to a variety of stimuli through motor control. As the growth and development progresses the proximodistal process becomes operational and has a tendency to reverse itself. The process of movement regression slowly evolves in a tail to head direction (Gallahue & Ozmun, 1995). This occurs as individuals gravitate toward specific skills and movements through habit, lifestyles and/or training.

This can be illustrated within the fire service by the firefighter constantly training certain duties for improved performance. They initially train through voluntary movements, and then as they are repeated, the movement is stored as central commands leading to subconscious performance of the task. This involves the highest levels of central nervous system function, which refers to cognitive programming (Lephart et al., 1997). However, problems arise when the movements and training being “learned” are performed inefficiently or asymmetrically.

An example of this would be a firefighter entering training who does not have the requisite balance of mobility or stability to perform tasks such as the hose drag, stair climb or the fireman carry. The individual will perform these tasks utilizing compensatory movement patterns in order to overcome the stability or mobility inefficiencies. The compensatory movement pattern will then be developed throughout the training. If this happens the individual will have created a poor movement pattern that will be utilized subconsciously whenever the task is performed. This has the potential to lead to mobility and stability imbalances, which has been previously identified as an injury risk factor.

An alternative view of what may lead to these poor movement patterns could be previous injuries. Individuals who have suffered from an injury will have a decrease in proprioceptive input, if left untreated or treated inappropriately (Lephart et al., 1997). A disruption in proprioceptive performance will have a negative effect on the kinetic linking system. The result will be altered mobility, stability, and asymmetric influences, eventually leading to compensatory movement patterns. This may be a reason why prior injuries have been determined to be one of the more significant risk factors in predisposing individuals to injuries (Neely, 1998b).

It is difficult to determine which of these risk factors has a larger influence on injury, previous injuries or strength/flexibility imbalances. In either case, both lead to deficiencies in functional mobility and stability. It has been determined that these functional deficits lead to pain, injury and decreased performance. Cholewicki, Panjabi, and Khachatryn (1997) found that limitations in stability in the spine led to muscular compensations, fatigue and pain. It has been previously determined by Gardner-Morse, Stokes, and Laible (1995) that spinal instabilities result in degenerative changes due to the muscle activation strategies, which may be disrupted due to previous injury, stiffness or fatigue. Nadler et al. (2002) further found that individuals with previous low-back pain performed timed shuttle runs at a significantly lower pace than individuals who did not have previous low-back pain.

It would seem that the important factor in preventing injuries is to quickly identify deficits in mobility and stability because of their influences on creating poor motor programs in the kinetic chain. The complexity of the kinetic linking system will make it difficult to evaluate weaknesses using conventional, static methods. Therefore, it has been recommended that functional tests that incorporate the entire kinetic chain need to be utilized to isolate deficiencies in the system. (Cook, 2001a; Nadler et al., 2002)

The FMS is designed to identify individuals who have developed compensatory movement patterns in the kinetic chain. This is accomplished by observing right and left side imbalances and mobility and stability weaknesses. The seven movements in the FMS attempt to challenge the body's ability to facilitate movement through the proximal-to-distal sequence. This course of movement in the kinetic chain allows the body to produce movement patterns more efficiently. The correct movement patterns were formed initially during growth and development. However, due to a weakness in the kinetic linking system, a poor movement pattern may have been produced. Once this inefficient movement pattern has been isolated by the results of the FMS, functional prevention strategies can be instituted to avoid micro-traumatic breakdown and injury.

**The Functional Movement Screen and Functional Training**

The deficiencies in the kinetic chain are identified utilizing the FMS. Once this occurs core and functional training protocols can be created based upon these findings. These types of training techniques have gained a tremendous amount of popularity over the past few years. Core training includes abdominal techniques involving isometrics with imposed loads through limb movements (Hodges, 2003). Functional training is designed to improve stability and mobility through specific movement patterns. It is believed this type of training will provide a better foundation of neuromuscular input to improve the efficiency of the kinetic linking system (Gambetta & Clark, 1998; Hedrick, 2000; Voight & Cook, 2001).

There are many techniques that institute core and functional training. However, in order to prevent injury, an individual's weakest link in the kinetic chain must be identified prior to instituting training techniques. Once this occurs, the correct movement pattern must then be enhanced utilizing core and functional training. This neuromuscular training should be designed to focus on the weak link in the kinetic chain, re-enforcing the appropriate movement pattern.

Strength and conditioning professionals must continue to evolve and study the different techniques in order to create more contemporary ways to prevent injury and improve performance. The idea of the FMS is to identify where the weakest link is located and then utilize techniques in functional and core training to improve it. Once the weakness has been addressed more advanced and aggressive techniques should be instituted to re-enforce the correct motor program.

**Conclusion**

The prevention of musculoskeletal injuries is one of the most important responsibilities faced by medical professionals who work with active population groups. There are efforts constantly being made to eliminate and reduce injuries through advances in technology, equipment and training. However, even with the best efforts some injuries cannot be avoided. The best attempt to reduce these injuries is to identify the risk factors associated with them.

There have been numerous studies that have identified a variety of risk factors in diverse settings that predispose active individuals to injuries. In some of these studies, the results are inconsistent in their ability show a significant relationship between certain intrinsic risk factor and injuries. Biomechanical abnormalities, anthropometric measures, strength and flexibility show inconsistent relationships with injuries. Studies have been able to show a significant relationship between gender and age, and injuries. However, the direction of the relationship between younger and older or male and female individuals will depend on the population group and setting being studied.

The literature does seem to be consistent with other intrinsic risk factors. There does seem to be certain psychological factors that show a significant relationship with injury. However, the data collection methods in these studies differed, making it difficult to determine which factors had a greater influence on injuries. There are other studies that suggest muscle and flexibility imbalances have a significant influence on injury predictability. Another consistent finding in the research is that previous injuries appear to be a significant risk factor. These two findings would seem obvious due to their negative influence on proprioceptive input during activities. These two risk factors, if the weakness is identified, could be eliminated through proper training and treatment.

There were extrinsic risk factors that showed relationships with injury predictability. The significance of these factors varied depending on the occupational or athletic setting being studied. The job responsibilities, environment and equipment were the main factors that have been researched within the fire service. Workers' compensation is an area that seems to be getting increased attention, mainly due to the increasing costs associated with the benefits given to employees during work time loss. However, there seems to be limited research available in this area.

There are some significant relationships between the working environment, equipment, musculoskeletal injuries and cardiovascular problems in the fire service. The significant findings between the environment and injuries would seem plausible considering the unpredictable and dangerous situations that occur while performing the duties of a firefighter. There have been findings that show a relationship between injuries and the equipment utilized even though it is designed to decrease the risk while fighting fires. Studies have shown that there is a decrease in work capacity due to the size and awkwardness of the equipment. It is very difficult to perform certain tasks in this environment, which increases the stress placed on the musculoskeletal and cardiovascular system. While it is virtually impossible to change the environment, the studies provide information that is utilized to enhance the technology in constructing the various pieces of equipment. This should serve to make the firefighter more efficient while performing their duties.

Generally, it seems that there are certain intrinsic and extrinsic risk factors associated with injuries that show a level of predictability. However, most researchers agree that the evidence showing injury predictability will have a large level of unpredictability. It has been suggested that even with the most extensive battery of predictor variables, injuries to certain individuals will always occur (Lysens, de Weerdt, & Nieuwboer, 1991). The past research in this area is inconsistent with its findings. This would seem to suggest that the causes of injuries are multifactorial, making it difficult to isolate certain risk factors as predictors.

Meeuwisse (1991) states that there is very little epidemiological evidence to date for predicting individual injury. The prediction is possible through single or multiple factor analysis, but one problem in finding significant results appears to be due to the wide individual variability in predisposing risk factors. Knowing this, it seems to be the consensus of most medical professionals that more research must be performed. The overall exposures in the active and occupational populations will continue to increase, which can be attributed to the public's overall awareness of the benefits of exercise. This certainly has the potential to increase the number of overall injuries.

According to Knapik et al. (1992) more investigations in injury prevention and predictability must be performed with more consideration for adequate sample size and appropriate data analysis. The research varies in the methodologies, population groups and data analysis, more consistency in these areas may lead to improved results and predictability. Currently, the research that is performed is, in many cases, limited to the population group being studied. In order for the results to be carried over across different settings and populations greater emphasis must be placed on sample size and distribution.

The difficulty in preventing injury seems to be directly related to the inability to determine who is predisposed to injuries. In many situations there is no way of knowing if an individual will fall into the injury or non-injury category no matter what the individual's risk factors are. Meeuwisse (1991) suggested that unless specific markers are identified for each individual it would be very difficult to determine who is predisposed to injuries. The FMS was created to identify individuals with these types of biomarkers and weaknesses.

It has been very difficult to determine who is predisposed to injury with the current evaluation techniques being utilized. The inconsistencies surrounding the pre-participation physical and performance tests offer very little significance in identifying individuals who are predisposed to injuries. These two evaluation methods do not offer a dynamic testing method that is individualized in identifying specific kinetic chain weaknesses. Numerous sports medicine professionals have suggested this type of assessment technique as a more functional approach to identify movement deficits (Battie et al., 1989; Cook et al., 1998; Kiesel, Burton, & Cook, 2004; Nadler et al., 2002).

The FMS is an assessment technique, which attempts to identify imbalances in mobility and stability during fundamental movement patterns. This assessment tool is thought to exacerbate the individual's compensatory movement problems allowing for easy identification. It is these movement flaws that may lead to breakdown in the kinetic linking system causing inefficiency and micro-trauma during activity (Cook et al., 1998).

The FMS should be introduced as part of the pre-placement/pre-participation physical examination to determine deficits that may be overlooked during the traditional medical and performance evaluations. In many cases muscle flexibility and strength imbalances along with previous injuries may not be identified. These problems, which were previously acknowledged as significant risk factors, will be identified using the FMS. This movement-based assessment will pinpoint functional deficits related to proprioceptive, mobility and stability weaknesses. If these risk factors can be identified and addressed utilizing the FMS then decreases in injuries and improved performance should follow.

The research relating to movement-based assessments is extremely limited, mainly because there are only a few movement-based quantitative assessment tests being utilized. The purpose of this study is to determine if a firefighter trainees' performance on the FMS can act as a risk factor for occupational injuries during the fire academy training.

This study will also attempt to determine if a firefighter's FMS score can serve as a predictor for performance efficiency during testing. It has been previously determined that certain performance testing does show a positive relationship with injury. If an individual's FMS score can predict who performs more efficiently during occupational related tasks then more individualized injury prevention strategies can be established based on the individual's movement weakness.

According to Battie et al. (1989), the ultimate test of any pre-employment or pre-placement screening technique is its effectiveness in identifying individuals at the highest risk of injury. If this screening tool can identify these individuals at risk then prevention strategies can be instituted based on their scores. This has the potential to positively influence a profession such as the fire service dramatically. These types of improvements should relate to decreases in claims for worker compensation and worker time loss creating a much more productive service profession. A proactive, functional training approach that decreases injury through performance efficiency will enhance overall wellness and productivity in most any active population group.

# Chapter 3

# METHODOLOGY

## **Introduction**

The profession of fire fighting has one of the highest injury rates of any profession (Schaitberger, 2000). The significance of their job makes it essential that injuries are avoided and performance enhanced. In order to eliminate or decrease injuries and improve performance, individual risk factors should be identified and baseline performance measures obtained. These individual markers should provide information needed to design a strength and conditioning protocol based on the individual's specific deficiencies.

It was difficult to determine in the literature review what predisposes individuals to injuries. The most consistent variables that showed a relationship to injury were previous injuries, and strength and flexibility imbalances (Baumhauer et al., 1995; Knapik et al., 1991; Nadler et al., 2001). These risk factors, if identified, have the potential to be addressed through proper strength and conditioning. There are risk factors in the fire service that cannot be avoided due to the nature of the profession. These factors include the working environment, and the equipment utilized by each fire fighter.

This study was designed to determine if a weakness or disruption in a firefighter's fundamental movement patterns could be deemed a risk factor for injuries. To date, the research incorporating movement-based assessments has been very limited. In order to determine if an individual has poor movement mechanics, the FMS was performed. It has been previously determined that certain performance measurements can act as predictors for injury(Hauret et al., 2001; Jones et al., 1993; Knapik, Sharp et al., 2001). Knowing this, performance measures were also be compared to the FMS scores. This was performed in order to determine if the FMS can be a useful tool in predicting individual performance levels. This comparison will supply useful information when establishing baseline information to create individualized strength and conditioning protocols. This will further serve to decrease injury and improve performance, while enhancing the firefighter's quality of life. In order to determine if there are relationships between the previously discussed variables, this chapter will identify the subjects, methods and procedures utilized to answer the specific research questions.

**Subjects**

The subjects were individuals who were beginning their 16-week fire academy training. The testing was performed as part of the initial baseline performance measures obtained during the first few days of the 16-week training. The subjects all performed very similar duties throughout the 16-week training, which should allow for comparable exposures to injury and performance improvements. There were 23 firefighter candidates who participated in the study. The ages ranged from 20 to 42 with an average age of 29.6. The weight of the subjects ranged from 153lbs. to 285lbs. with an average of 195.5lbs. Each subject was informed of the details and requirements of the study prior to their participation and subsequently signed an informed consent form outlining the research study. (Appendix A)

**Study Design and Rationale**

This prospective study was designed to determine if an individual's poor movement mechanics can be considered a risk factor for injury and a predictor for performance. This is accomplished by assessing the subjects' fundamental movements utilizing the FMS at the onset of the fire academy training. The subjects' $VO_{2max}$, run times, and functional performance efficiency were all measured in order to get baseline physical fitness levels at the onset of the 16-week training. The functional performance efficiency was measured using the Firefighter Physical Conditioning Course (FPCC). This is an obstacle course designed and utilized specifically by the Chesterfield County Fire Service to provide training and baseline assessments in real-life fire fighting situations. The FMS scores, $VO_{2max}$, run time, and FPCC results were recorded and documented at the on-set of 16-week training.

During the training the injuries for each individual were reported and documented by the supervising firefighter. Once the training was completed and the amount of injuries were finalized for each individual, the number of injuries were then compared to the overall FMS score results, and asymmetric FMS score results. The FMS total score and asymmetric score were also compared to the $VO_{2max}$, run times and FPCC results to determine if the FMS score results have any relationship with performance test results.

Injury Documentation

In this study, an injury is considered an event that results in pain or damage to the body and for which the individual communicated the issue to his or her superiors. The reportable injuries can be due to overuse or acute trauma. Reportable injuries that are included in this study do not have to lead to modification in their training routine. Due to the limited number of test subjects, the injury location and type of injury was not analyzed.

**Functional Movement Screen:**

An experienced tester performed the FMS and the scores were recorded. The FMS was performed as described by Cook, et al.(1998). The FMS is made up of seven tests which includes: Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-up and Rotary Stability.

Test 1: Deep Squat

The squat is a movement needed in most athletic events. It is the ready position and is required for most power and lifting movements involving the lower extremities. This proper squatting is especially important within the fire service due to the heavy lifting and maneuvering that is required to perform many of their tasks. The deep squat is a test that challenges total body mechanics when performed properly. It is used to assess bilateral, symmetrical, functional mobility of the hips, knees, and ankles. The dowel held overhead assesses bilateral, symmetrical mobility of the shoulders as well as the thoracic spine. The ability to perform the Deep Squat requires appropriate pelvic rhythm, closed-kinetic chain dorsiflexion of the ankles, flexion of the knees and hips, and extension of the thoracic spine, as well as flexion and abduction of the shoulders.

Test 2: Hurdle Step

The hurdle step is designed to challenge the body's proper stride mechanics during a stepping motion. The movement requires proper coordination and stability between the hips and torso during the stepping motion as well as single leg stance stability. The firefighter needs to have efficiency in this pattern in order to navigate through the uneven terrain and move heavy objects up and down stairs. The hurdle step assesses bilateral functional mobility and stability of the hips, knees and ankles. Performing the hurdle step test requires stance-leg stability of the ankle, knee, and hip as well as maximal closed-kinetic chain extension of the hip. The hurdle step also requires step-leg open-kinetic chain dorsiflexion of the ankle and flexion of the knee and hip. In addition, the subject must also display adequate balance because the test imposes a need for dynamic stability.

Test 3: In-Line Lunge

This test attempts to place the body in a position that will focus on the stresses as simulated during rotational, decelerating and lateral type movements. The in-line lunge is a test that places the lower extremity in a scissored position challenging the body's trunk and extremities to resist rotation and maintain proper alignment. This test assesses torso, shoulder, hip and ankle mobility and stability, quadriceps flexibility and knee stability. The ability to perform the in-line lunge test requires stance leg stability of the ankle, knee, and hip as well as apparent closed kinetic-chain hip abduction. The in-line lunge also requires step-leg mobility of the hip, ankle dorsiflexion, and rectus femoris flexibility. The subject must also display adequate stability due to the rotational stress imposed.

Test 4: Shoulder Mobility

The shoulder mobility screen assesses bilateral shoulder range of motion, combining internal rotation with adduction and external rotation with abduction. It also requires normal scapular mobility and thoracic spine extension. The ability to perform the shoulder mobility test requires shoulder mobility in a combination of motions including abduction/external rotation, flexion/extension and adduction/internal rotation. It also requires scapular and thoracic spine mobility.

Test 5: Active Straight Leg Raise

The active straight leg raise tests the ability to disassociate the lower extremity while maintaining stability in the torso. The active straight leg raise test assesses active hamstring and gastroc-soleus flexibility while maintaining a stable pelvis and active extension of the opposite leg. The ability to perform the active straight leg raise test requires functional hamstring flexibility, which is the flexibility that is available during training and competition. This is different from passive flexibility, which is more commonly assessed. The subject is also required to demonstrate adequate hip mobility of the opposite leg as well as lower abdominal stability.

Test 6: Trunk Stability Push-up

The trunk stability push-up tests the ability to stabilize the spine in an anterior and posterior plane during a closed-chain upper body movement. It assesses trunk stability in the sagittal plane while a symmetrical upper-extremity motion is performed. The ability to perform the trunk stability push-up requires symmetric trunk stability in the sagittal plane during a symmetric upper extremity movement. Many functional activities require the trunk stabilizers to transfer force symmetrically from the upper extremities to the lower extremities and vice versa. Movements such as blocking in football, and pulling ceilings or hoses in the fire service, are common examples of this type of energy transfer. If the trunk does not have adequate stability during these activities, kinetic energy will be dispersed, leading to poor functional performance as well as increased potential for micro traumatic injury.

Test 7: Rotary Stability

This test is a complex movement requiring proper neuromuscular coordination and energy transfer from one segment of the body to another through the torso. The rotary stability test assesses multi-plane trunk stability during a combined upper and lower extremity motion. The ability to perform the rotary stability test requires asymmetric trunk stability in both sagittal and transverse planes during asymmetric upper and lower extremity movement. Many functional activities require the trunk stabilizers to transfer force asymmetrically from the lower extremities to the upper extremities and vice versa. Running and exploding out of a down stance in football and moving and carrying heavy equipment or objects are examples of this type of energy transfer. If the trunk does not have adequate stability during these activities, kinetic energy will be dispersed, leading to poor performance as well as increased potential for injury.

Scoring the FMS

The individual tests have certain criteria that must be accomplished in order to obtain a high score. The scoring is broken down into four basic criteria; a three (3) is given if the individual can perform the movement without any compensations according to the established criteria, a two (2) is given if the individual can perform the movement but must utilize poor mechanics and compensatory patterns to accomplish the movement, a one (1) is given if the individual cannot perform the movement pattern even with compensations, and finally a zero (0) is given if the individual has pain during any part of the movement or test. There are five tests which require bilateral testing this will result in two scores for those tests. The lowest test score is recorded for the overall score, however for assessment and data collection purposes both scores are needed. Three tests have clearing test associated with them that are scored as pass/fail. If a person fails this part of the test then a zero (0) is given as the overall score.

The asymmetric score is obtained by first determining if an asymmetry exists in the five tests that evaluate both right and left sides. If an asymmetry is observed it is weighted depending on the amount of difference between the two scores. For example, if an individual gets a score of three on the right side and a score of one on the left then an asymmetry score of two will be given.  The asymmetry score for the five tests will then be added and a total asymmetry score will be determined. This asymmetry score will be compared to the performance measures and to the injury totals.

**Performance Measures:**

The firefighter candidates perform a series of performance tasks at the onset and again at the end of the 16-week training. A 1.5 mile, timed run is performed and the $VO_{2Max}$ is measured. The FPCC is also utilized as a performance measure and training tool during the training. These measures are utilized to gather baseline fitness levels of the individuals in order to establish goals and assess the individual's progress through the training.

The subjects performed a 1.5-mile run on a road course surrounding the training facility. The time to complete the 1.5-mile run was recorded by a supervising firefighter. The $VO_{2max}$ was calculated utilizing the field test equation recommended by the American College of Sports Medicine(2000). The subjects' 1.5-mile run time was inserted into the field test equation in order to calculate the subject's $VO_{2Max}$.

The FPCC is an obstacle course designed as a performance training and assessment tool. The goal of this course is to improve the overall physical conditioning of a firefighter while performing a series of firefighter specific skills, and wearing the necessary protective gear. This gear includes the structural firefighting protective equipment (PPE) and self-contained breathing apparatus (SCBA) which together weighs approximately 50 pounds. The course is designed to have the firefighter work at various levels of physical exertion for approximately 20-30 minutes. (Mead, 2004)

The FPCC is a series of fire fighter related tasks which includes:

1. Carrying a hose bundle from starting line to tower
2. Climb stairs to top of tower, and return to ground
3. Raise hose bundle to pulley and lower to ground hand over hand
4. Carry hose bundle to pipes and crawl through pipe with hose bundle
5. Carry hose bundle to flat roof of burn building, lower bundle and raise hand over hand with rope
6. Carry hose bundle to Kaiser area, drop hose bundle, and strike block until it moves past the appropriate mark with sledgehammer.
7. Return hose bundle back to starting point

The firefighter worked through as many cycles of the FPCC as possible until exhaustion. The supervising firefighter then documented the distance or cycles covered by each firefighter candidate. The relationship between the initial FPCC results, VO2Max, 1.5-mile run and FMS scores was then be determined.

**Data Analysis**

Hypothesis Analysis:

In the most recent sport injury prediction studies the statistical analyses have generally fallen into one of three categories; chi-square, analysis of variance and correlation/regression (Petrie & Falkstein, 1998). The data gathered and the hypotheses established in this study will require correlation and regression analysis be utilized to garner the appropriate outcomes. The FMS scores, performance measures and injury data were analyzed using Statistical Package for the Social Sciences (SPSS, Version 10.1).

Null Hypothesis One: The FMS total score does not demonstrate a significant relationship with the performance test results in firefighters during the fire academy training.

There were three separate Pearson Product-Moment Correlation Coefficient($p \leq 0.05$) analysis performed measuring the relationship between the FMS scores and the initial performance test results. Specifically, the initial $VO_{2max}$ score, 1.5-mile run time, and FPCC results were correlated with the FMS scores in order to determine if there was a significant relationship.

Null Hypothesis Two: The FMS asymmetry score does not demonstrate a significant relationship with performance test results in firefighters during fire academy training.

There were three separate Pearson Product-Moment Correlation Coefficient($p \leq 0.05$) analysis performed measuring the relationship between the FMS asymmetry scores and initial performance test results. Specifically, the initial $VO_{2max}$ score, 1.5-mile run time, and FPCC results were correlated with the FMS scores in order to determine if there is a significant relationship.

Null Hypothesis Three: The interaction between the performance tests, the FMS total score, and the FMS asymmetry score results do not exhibit a significant inverse relationship with the occupational injuries sustained in firefighters during the fire academy training.

A stepwise linear regression analysis was utilized to determine the variability the performance measures, and FMS scores have in their ability to predict occupational injury during the fire academy training.

Null Hypothesis Four: The FMS score and firefighter occupational injuries do not show a significant inverse relationship during fire academy training.

The Pearson Product-Moment Correlation Coefficient($p \leq 0.05$) was utilized to measure the relationship between the FMS overall score and the injury rates. The total FMS score was correlated to the occupational injuries sustained during the fire academy training.

Null Hypothesis Five: The FMS asymmetry score does not exhibit a significant positive relationship with occupational injuries in firefighters during their firefighter academy training.

The Pearson Product-Moment Correlation Coefficient($p \leq 0.05$) was utilized to measure the relationship between the total FMS asymmetry score and the injury rates. The total FMS asymmetry score was correlated to the occupational injuries during the fire academy training.

## Conclusion

The purpose of this study was to determine if the FMS score has a relationship to performance measures and injury frequency. The performance test scores of these firefighters were compared to the FMS test results to determine if there is a relationship. In order to perform these analyses, individuals from a firefighter training academy were examined. The fire academy places the individual firefighters in very similar training and performance situations. This produces an environment where the firefighters have the same opportunities for injury.

The supervising firefighter in the training academy documented the injuries and performance results, throughout the 16-week training. An experienced tester performed the FMS test on each firefighter trainee at the on-set of the 16-week training. Once the firefighter training was completed the FMS test results were compared to the frequency of injuries and performance test results.

## Chapter 4

## RESULTS

There were 23 subjects who completed the 16-week fire academy and were subsequently included in this research project. The standard firefighter pre-employment/physical screenings did not reveal any medical or physical issues, which would limit or exclude any of the subjects from participating in this study. The subjects were tested on their performance, which was obtained at the onset of their training and measured by their $VO_{2Max}$, 1.5 mile run and FPCC (Appendix B). The subject's fundamental movement patterns were also measured at on-set of their training utilizing the FMS (Appendix B). The descriptive statistics were calculated on the data obtained and can be viewed in Table 1. There were a total 8 injuries reported to the supervising firefighter during the 16-week training (Appendix B).

A Pearson Product-Moment Correlation Coefficient was performed to determine if the first null hypothesis should be rejected. Null hypothesis one indicates that there is not a significant relationship between the FMS total score and $VO_{2Max}$, 1.5 mile run and FPCC. The results from the analysis of the correlation indicates that there were no significant relationships($p \leq 0.05$) between the performance measures and the FMS total score.(Table 2) This would lead us to accept null hypothesis one, indicating a relationship does not exist between performance tests and FMS total score.

The second null hypothesis was tested using a Pearson Product Moment Correlation. This null hypothesis states that there is not a significant relationship between the FMS asymmetry score and the $VO_{2Max}$, FPCC, and 1.5 mile run. The results indicated that there was not a significant relationship between the 1.5 mile run and $V0_{2Max}$, however it was indicated that a significant inverse relationship($p \leq 0.05$) exists between the FPCC and FMS asymmetry score. (Table2) These results would lead us to reject the null hypothesis, due to the significant relationship between the FPCC and FMS asymmetry score. However, a significant relationship($p \leq 0.05$) did not exist between the $VO_{2Max}$ and 1.5 mile run and the FMS asymmetry score indicating that this part of the null hypothesis could not be rejected.

Null hypothesis three was tested using a stepwise linear regression in order to analyze the interaction between the FMS score, FMS asymmetry score results and performance scores ($V0_{2Max}$, FPCC, and 1.5 mile run) in their ability to predict occupational injuries. When performing the analysis for null hypothesis three the results revealed r=0.445 and R-squared = 0.198, indicating that 19.8% of the variance in the occupational injuries can be explained by the variance in the performance results, FMS total score and FMS asymmetry score. The results specifically indicated that the performance scores on the FPCC was the only variable that significantly acted as a predictor in this regression equation. The variance in occupational injuries could not be significantly explained by the variance in the FMS total score, FMS asymmetry score, $VO_{2Max}$ and 1.5 mile-run.(Table 3)

The analysis for null hypotheses four and five utilized a Pearson-Product Moment Correlation in order to determine if a significant relationship exists between occupational injuries, the FMS total score and FMS asymmetry score. The correlation results indicate that a significant relationship ($p \leq 0.05$) does not exist between the variables(Table 2). This would lead us to accept both null hypotheses four and five, signifying that the FMS total score and FMS asymmetry score do not exhibit relationships with occupational injuries.

Summary of Results

The results indicated a significant inverse relationship with the FPCC and FMS asymmetry score. There were no other significant relationships noted between the FMS total score and FMS asymmetry score when compared to the performance tests. The results also showed no significant relationships between occupational injuries and the FMS total score and FMS asymmetry score. It was also determined that the interaction between the FMS total score, FMS asymmetry score and performance tests showed a 19.8% ability in predicting occupation injury. However, when analyzed separately the only variable with a significant ability to predict injury were the results on the FPCC. The other variables in the regression equation, performance (VO  and 1.5 mile-run), FMS total score and FMS asymmetry score were unable to show a significant ability to predict injury.

Table 1

Descriptive Statistics

| | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| AGE | 20 | 42 | 29.61 | 6.351 |
| 1.5 mile run | 11:10:00 | 16:09:00 | 13:44:05 | 1:33:05 |
| VO2Pre | 33.11 | 46.73 | 39.5343 | 4.24046 |
| Grinder Start | .7 | 1.4 | .978 | .1622 |
| DS | 1 | 3 | 1.87 | .548 |
| HSL | 1 | 3 | 2.00 | .302 |
| HSLR | 1 | 3 | 2.00 | .522 |
| ILLL | 1 | 3 | 2.43 | .662 |
| ILLR | 1 | 3 | 2.26 | .689 |
| SML | 1 | 3 | 2.22 | .671 |
| SMR | 1 | 3 | 2.39 | .656 |
| ASLRL | 1 | 3 | 2.00 | .522 |
| ASLRR | 1 | 3 | 2.13 | .458 |
| TSPU | 1 | 3 | 1.83 | .834 |
| RSL | 1 | 3 | 1.96 | .367 |
| RSR | 2 | 3 | 2.04 | .209 |
| TOTAL1 | 9 | 17 | 13.61 | 1.948 |
| Asym | 0 | 3 | 1.61 | .783 |
| | | | | |

Table 2

Pearson Correlations

| | | VO2Pre | TOTAL1 | 1.5 mile run | Injury | FPCC | Asym |
|---|---|---|---|---|---|---|---|
| VO2Pre | Pearson Correlation | 1 | -.003 | -.791 | -.379 | .135 | -.322 |
| | Sig. (2-tailed) | . | .990 | .000 | .074 | .541 | .134 |
| | | | | | | | |
| TOTAL1 | Pearson Correlation | -.003 | 1 | -.285 | -.112 | .375 | .014 |
| | Sig. (2-tailed) | .990 | . | .187 | .610 | .078 | .949 |
| | | | | | | | |
| 1.5 mile run | Pearson Correlation | -.791 | -.285 | 1 | .276 | -.380 | .203 |
| | Sig. (2-tailed) | .000 | .187 | . | .202 | .074 | .354 |
| | | | | | | | |
| Injury | Pearson Correlation | -.379 | -.112 | .276 | 1 | -.445 | .338 |
| | Sig. (2-tailed) | .074 | .610 | .202 | . | .033 | .115 |
| | | | | | | | |
| FPCC | Pearson Correlation | .135 | .375 | -.380 | -.445 | 1 | -.464 |
| | Sig. (2-tailed) | .541 | .078 | .074 | .033 | . | .026 |
| | | | | | | | |
| Asym | Pearson Correlation | -.322 | .014 | .203 | .338 | -.464 | 1 |
| | Sig. (2-tailed) | .134 | .949 | .354 | .115 | .026 | . |
| | | | | | | | |

N= 23

Table 3

Regression Results

Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| | .445 | .198 | .160 | .431 |

a Predictors: (Constant), FPCC

ANOVA

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | .966 | 1 | .966 | 5.195 | .033 |
| | Residual | 3.904 | 21 | .186 | | |
| | Total | 4.870 | 22 | | | |

a Predictors: (Constant), FPCC
b Dependent Variable: Injury

Coefficients

| | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Correlations | | |
|---|---|---|---|---|---|---|---|---|---|
| Model | | B | Std. Error | Beta | | | Zero-order | Partial | Part |
| 1 | (Constant) | 1.568 | .561 | | 2.792 | .011 | | | |
| | FPCC | -1.291 | .567 | -.445 | -2.279 | .033 | -.445 | -.445 | -.445 |

a Dependent Variable: Injury

Excluded Variables

| | | Beta In | t | Sig. | Partial Correlation | Collinearity Statistics |
|---|---|---|---|---|---|---|
| Model | | | | | | Tolerance |
| 1 | VO2Pre | -.325 | -1.726 | .100 | -.360 | .982 |
| | 1.5 mile run | .125 | .584 | .566 | .130 | .856 |
| | TOTAL1 | .064 | .295 | .771 | .066 | .860 |
| | Asym | .168 | .752 | .461 | .166 | .785 |

a Predictors in the Model: (Constant), FPCC
b Dependent Variable: Injury

# Chapter 5

# DISCUSSION, CONCLUSIONS, RECOMMENDATIONS

## Introduction

This study was performed to determine the effectiveness of the FMS to predict occupational injury and performance within the fire service. The FMS is a testing procedure that has shown clinical effectiveness in its ability to assess individual movement patterns (Cook, 2001c, 2004; Cook et al., 1998). These fundamental movement patterns require appropriate, symmetrical mobility and stability in order to perform the movement properly. It has been hypothesized that the movement patterns assessed by the FMS would have the potential to establish biomarkers which may act as predictors for injury and performance (Cook et al., 1998; Cook et al., 1999). There have been many previous research studies that have attempted to pinpoint potential injury predictors, however there remains much debate on what these predictors may be (Knapik et al., 1992; Lysens et al., 1991; Meeuwisse, 1991).

The fire service is an occupation that is plagued with injuries (Karter & Molis, 2003; Schaitberger, 2000). An ability to show a relationship between pre-employment testing and occupational injuries as well as performance has the potential to have an immediate, positive impact within that profession. Recently, the IAFF has begun to institute a wellness and fitness plan to improve health, wellness and performance (International Association of Fire Fighters, 2004). However, injuries still remain a major concern and any technique or information that can assist in injury prevention could be a very valuable asset.

## Interpretation of Results

The results in this study were unable to find a significant relationship with the total FMS score and performance measures (VO2Max, 1.5 mile run and FPCC). It was hypothesized that the individuals who had higher FMS scores would have lower performance scores during the testing, indicative of an inverse relationship. The results showed an inverse relationship, however, the results were not significant. The correlations between the FMS asymmetry score and performance measures were higher, however, the only significant relationship was with the FMS asymmetry score and FPCC.

The FPCC is the performance measure which best represents the firefighter's occupational environment. The FMS asymmetry score is calculated using the components of the total FMS score. A higher asymmetry score indicates the individual has more asymmetrical movement patterns than an individual with a lower asymmetry score. This score provides a better indication of an individual's movement patterns than simply looking at the FMS total score. It is logical for this performance measure to have a significant relationship to the asymmetry score because both of these variables better represent the firefighters performance and movement patterns. This significant relationship between the FPCC and asymmetry score is an encouraging finding.

Currently, there are no standard movement assessments being utilized in the pre-employment or pre-season medical screenings (Cook, 2004; The Physician and Sportsmedicine, 2005). The fire service utilizes medical evaluations and performance measures to first, ensure that individuals have the physical capability to perform certain tasks and secondly to establish baseline measures to create protocols and improve skills. There has been little evidence to this point to determine whether the pre-employment/participation evaluations have any correlation to injury or performance (Fields & Delaney, 1989; Meeuwisse & Fowler, 1988; Metzl, 2000). In the past there has been inconsistent findings on whether higher performance measures relates to injuries (Gleim & McHugh, 1997; Hauret et al., 2001; Jones et al., 1993; Knapik et al., 1991; Knapik, Sharp et al., 2001; Rhea et al., 2004).

The significant relationship between the FMS asymmetry score and FPCC indicates that the FMS could be included or offered as an alternative to the current performance and pre-employment evaluations within the fire service. The inverse relationships to the FPCC and VO2Max, along with the positive relationship to the 1.5-mile run indicate that as the asymmetry score increases performance scores decrease.  This relationship would be expected due to the disruptions in the functioning of the kinetic chain caused by asymmetries. The identification of these functional asymmetries will allow the individual to address these potential problems during their strength and conditioning routine.

The results of this study were unable to support the hypothesis that movement asymmetries lead to occupational injury. It has been previously determined that certain musculo-skeletal asymmetries can serve as potential predictors for injury (Baumhauer et al., 1995; Knapik et al., 1991; Nadler et al., 2001). However, the fundamental movement pattern asymmetries observed in this study were unable to support these previous findings.

It was determined that there was a significant finding when the performance test results, FMS total score and FMS asymmetry score were analyzed to determine their predictability to occupational injury. However, further analysis revealed that the variance accounted for in occupational injuries by the V02Max, 1.5 mile-run, FMS total scores and FMS asymmetry scores results could be related to chance and were therefore not significant. The only predictor was determined to be the FPCC. This finding would indicate that the FMS scores do not account for enough of the variance in occupational injuries to be considered a predictor.

The results do support the use of the FPCC not only as a performance measure but also as a potential injury predictor. This is not the purpose of the FPCC but it could be a consideration when observing the results during the academy training. The FPCC is the variable that best represents the duties and tasks the firefighter must perform on a daily basis. The other performance tests(VO2Max, 1.5 mile-run), and the FMS scores do not represent functional tasks of the firefighter. This determination indicates that more emphasis should be placed on utilizing tests that represent the occupational or functional environment of the population being observed.

The correlations performed between the FMS scores and occupational injuries were insignificant. The relationship the FMS total score and occupational injuries revealed a very small relationship. The FMS asymmetry scores did reveal a larger relationship to injury, however it was determined to be insignificant. This would indicate that utilizing the FMS assessment total and asymmetry scores solely as an injury predictor for occupational injuries in the fire service may not be applicable. These findings would support previous research indicating a difficulty in the ability to predict who is predisposed to injury (Lysens et al., 1991; Macera, 1992; Meeuwisse, 1991).

**Conclusions**

The difficulty in preventing injuries lies in determining who is predisposed to injuries. There have been numerous research studies performed attempting to pinpoint factors, which will indicate what is considered an injury predictor. However, most of the information regarding injury risk factors has been inconclusive, and in most situations requiring further research (Lysens et al., 1991; Macera et al., 1989; Neely, 1998b). The findings of this study would support this determination as well.

There was evidence in this study that suggest the FMS scores when analyzed with the performance measures do have an ability to predict who may be predisposed to injuries. It cannot be suggested that the FMS score and FMS asymmetry score has the same ability when studied separately. The relationships of the FMS total score and FMS asymmetry score to occupational injuries were also inconclusive. However, it should be noted that even though the results in this study have difficulty determining the influence of the FMS on injury prediction, there still may be a clinical significance. This screening tool offers the clinician an alternative view of human movement, which allows for earlier implementation of exercise techniques to correct the movement problems.

It is logical to believe that any tool that identifies individuals who have certain characteristics, which predispose them to injuries, is useful in injury prevention. The fire service is working towards instituting wellness and fitness protocols in an attempt to improve performance and lifestyle as well as decrease injuries. The results of this study suggest that the FMS could be utilized, along with current performance measures, as an effective orthopedic screening tool to identify individuals with poor movement patterns which predispose individuals to injury. This procedure provides a foundation for more individualized fitness protocols within the fire service, moving away from the standard strength and flexibility routines currently being employed.

The FMS is designed to assess individual fundamental movement patterns. It has been suggested that the tests that make up the FMS are the foundation that basic movements and skills are built upon. It was originally designed to be utilized as an orthopedic screening tool for athletics, ideally used in conjunction with the pre-season medical evaluation (Cook, 2001b; Cook et al., 1999). The difficulty in finding a significant relationship between the FMS score results and injuries could be the scoring system utilized in the FMS. The four scores allowed in the FMS permits a very broad range of movements to be categorized within each score. If there were more scores allowed for each movement, it would increase disparity between individuals. This would allow for a more individualized score. However, this was not the original purpose of the FMS, which was designed as a quick screening tool utilized to easily identify individuals with movement pattern problems. A more detailed scoring system would move the process into more of a clinical evaluation, making it more difficult to perform and teach to individuals.

The determination that the FPCC had the best ability to determine who was more likely have an injury suggest that more research needs to be performed in the area of injury prediction. This finding should lead future studies to focus more on functional testing and tasks representative of the occupational environment individuals are subjected to. The significant relationship the FMS asymmetry score has to the FPCC further suggests that the FMS process needs further research when attempting to determine a relationship to injuries. If the FMS remains a significant clinical tool future tests should focus less on the total or asymmetry scoring system and more on individual test results.

The inability of this study to determine whether the FMS can act as an injury predictor does not suggest the process of assessing human movement cannot be utilized in the prediction of injury and performance. The FMS offers an alternative for the clinician, exercise specialist or even employer to begin observing human movement as a basis for pre-performance and pre-occupational screenings. The results of this study show that efforts should continue in determining if a movement-based screening tool can have positive results in injury and performance prediction.

**Recommendations**

The results of this study show the difficulty in injury prediction. It is recommended that future studies should continue utilizing movement-based assessments due to their increased popularity in the field of sports medicine (Cook, 2001a). The difficulty in using the FMS as a predictor may lie in its scoring system and how it was analyzed in this research study. The total score was utilized as the predictor variable. This score may not be sensitive to the individual movement pathologies to account for injuries. It should not be recommended, due to the results of this study, to alter the scoring system. A change in the scoring system of the FMS may alter the integrity of the FMS. However, future studies utilizing the FMS should analyze each individual test score along with placing more emphasis on the asymmetry score.

It is also recommended that due to the broad scoring range of the FMS, a larger sample of the population being studied should be obtained. The limited number of subjects may not have allowed for an appropriate representation of firefighters. A larger sample size, utilizing more than one in-coming firefighter candidate class, may allow for an improved representation of the firefighter candidates. The number of injuries reported, the performance scores and FMS scores may be altered and be more representative of the overall population of firefighter candidates when a larger sample is used.

Future studies utilizing the FMS within an occupational setting such as the fire service, should be conducted on a sample population that better represents the overall population of the profession. This study only analyzed firefighter candidates entering the training academy; this does not represent the overall population of professional firefighters. It is recommended that studies be performed on a broad sample of firefighters in order to gain a better appreciation of how the FMS relates to the overall population base. This type of study design will account for real-life situations that firefighters encounter, not just training situations. The findings of this study showed separate significant relationships with the FPCC, injuries and FMS asymmetry score. These findings support the need for research comparing the FMS process to daily activities and functions of the firefighter, which would be more representative of the occupational environment.

A final recommendation, which may be the most important, is that when considering the FMS or any movement-based assessment, an epidemiological or longitudinal approach should be utilized. The FMS pinpoints movement weakness, which will lead individuals to develop compensatory patterns in order to circumvent their movement pathologies. It has been hypothesized that these types of inefficient patterns will lead to micro-trauma (Cook et al., 1998). This type of micro-trauma has the potential to lead to injury or physiological breakdown over a period of time. This study design analyzed individuals over 16-weeks, this may not be enough time for inefficiencies in movement to present themselves as injury. A future study utilizing the FMS should follow individuals over a period of time and monitor their injury and performance rates in order to determine if a relationship exist between the variables. One problem, however, with this type of design are the numerous extraneous variables that will arise. Another problem that exists is the need to intervene with exercise corrections once movement pathology is observed.

**Implications to the Fire Service**

The fire service is in need for any tool or assessment technique, which assists in improving performance and decreasing injuries. The results of this study were unable to determine if the FMS can be utilized as a technique for injury prevention within the fire service. It did, however, provide an alternative approach during the pre-employment testing during the fire academy training. A tool such as the FMS provides the firefighter an overview of their movement pattern weaknesses and will allow for a more individualized strength and conditioning protocol. The fire service is continuing to incorporate strategies to improve wellness, and strength and conditioning while attempting to decrease injuries. This study served to lay a foundation, on which to build future research relating to improved individual assessments. The results of future studies should allow for the creation of individualized strength and conditioning protocols designed to address specific weaknesses, which will lead to decreases in injuries.

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APPENDIX A

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

# Informed Consent for Participants in Research Projects Involving Human Subjects

Title of Project __"Performance and Injury Predictability during Fire Fighter Candidate Training"

Investigator(s) Richard Stratton, PhD and Lee Burton

## I. Purpose of this Research/Project

The purpose of this study is to determine if a fire fighter candidate's performance on a series fundamental movement patterns can be considered a risk factor for injury. It will also be determined if the subject's performance on these patterns will show a relationship to performance measures during fire fighter candidate training. The researcher will be utilizing approximately 20 male and/or female subjects from a fire fighter training academy. The subjects will be entering the fire fighter training academy and will have undergone a series of medical evaluations to ensure their health status is sufficient for the training. The ages will range from 18-55 years of age for both men and women.

## II. Procedures

Each subject who is a member of the Chesterfield Fire Training Academy and agrees to participate in the study will have the Functional Movement Screen(FMS) performed on them. The FMS is made of 7 fundamental movement patterns that require a balance of mobility and stability. These fundamental movement patterns are designed to be observable performance of basic-loco motor, manipulative and stabilizing movements. Each test is a specific movement, which requires appropriate functioning of the body's kinetic linking system. The movements in the FMS will be much less stressful on each test subjects than their day-to-day training at the academy.

The FMS will be performed by an experienced examiner, at the on-set of the initial 16-week training for fire fighters. The fire fighters will also be tested on performance; these tests will include a timed 1.5-mile run, $VO_{2Max}$, and an obstacle course. These tests are already part of the initial 16-week training and are performed by the supervising fire fighters at the academy.

The results of the FMS and performance tests will be collected and analyzed after the initial testing. The supervising fire fighter will document the injuries that occur throughout the 16-week training. The injuries will then be compared to the results from the FMS and performance tests.

## III. Risks

The FMS is a series of movements that all of which do not place extreme stress on the body. The daily duties and tasks being performed during the fire fighter training academy will place much more stress on the subjects than the FMS. The performance tests that will be utilized as part of the research are already a part of the training academy's testing and training routine.

**IV. Benefits**

There will be no promise of benefit to the subjects by performing in this research project. However, if it is determined that the FMS results can be considered a risk factor for injury then it can be utilized as a tool for injury prevention. A benefit will also exist if it is determined that there is a relationship with the FMS and performance testing. The FMS can be utilized to enhance the overall strength and conditioning protocols within the fire service to prevent injuries and become more efficient.

**V. Extent of Anonymity and Confidentiality**

The subjects being tested will be assigned a random number by the supervising fire fighter. This number will be the subjects' only form of identification in this study. The supervising fire fighter will match the number of the subject to his/her injuries, performance scores, and FMS score. This information will only be utilized for research purposes in this study.

**VI. Compensation**

There will be no compensation given to the individuals participating in this study.

**VII. Freedom to Withdraw**

I understand that I am free to withdraw my consent and terminate my participation in the study at any time. My status in the academy will not be affected by my participation, non-participation, or withdrawal from this study.

**VIII. Subject's Responsibilities**

I voluntarily agree to participate in this study. I have the following responsibilities:

1) Allow the researchers to perform all the necessary evaluation techniques described above
2) Report any injuries to the supervising fire fighter that occurs during the 16-week fire fighter candidate training.

**X. Subject's Permission**

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

_______________________________________________Date__________
Subject signature
_______________________________________________ Date __________
Witness (Optional except for certain classes of subjects)

Should I have any pertinent questions about this research or its conduct, and research subjects' rights, and whom to contact in the event of a research-related injury to the subject, I may contact:

_______Lee Burton__________ 434-791-5821/ lburton@averett.edu
Investigator(s) Telephone/e-mail

____Richard K Stratton_____ 504-231-5617 rstratto@vt.edu _
Faculty Advisor Telephone/e-mail

___ Jan Nespor___________________ 540-231-8372 nespor@vt.edu
Departmental Reviewer/Department Head Telephone/e-mail

David M. Moore 540-231-4991/moored@vt.edu
Chair, Virginia Tech Institutional Telephone/e-mail
Review Board for the Protection
of Human Subjects
Office of Research Compliance – CVM Phase II (0442)
Research Division

This Informed Consent is valid from ___5/05_____ to ___12/05____.

# APPENDIX B

| assigned | sex | age | begwt | runpre | vo2pre | injloc | injury | fpcc | ds | hsl | hslr | asym | illl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 927 | 1 | 20 | 170 | 14:12:00 | 37.57 | | 0 | .8 | 3 | 2 | 3 | 1 | 3 |
| 507 | 1 | 23 | 167 | 12:22:00 | 42.64 | | 0 | 1.4 | 2 | 2 | 2 | 0 | 3 |
| 926 | 1 | 34 | 196 | 14:14:00 | 37.37 | Knee | 1 | .9 | 2 | 2 | 3 | 1 | 3 |
| 937 | 1 | 30 | 166 | 11:10:00 | 46.73 | | 0 | 1.1 | 3 | 2 | 2 | 0 | 3 |
| 742 | 1 | 35 | 231 | 13:49:00 | 38.39 | shoulder | 1 | 1.1 | 1 | 2 | 2 | 0 | 2 |
| 614 | 1 | 22 | 163 | 11:35:00 | 45.17 | | 0 | 1.0 | 2 | 2 | 2 | 0 | 2 |
| 923 | 1 | 22 | 155 | 11:27:00 | 45.78 | | 0 | 1.0 | 2 | 2 | 2 | 0 | 3 |
| 929 | 1 | 35 | 172 | 12:35:00 | 41.86 | | 0 | 1.0 | 2 | 3 | 2 | 1 | 2 |
| 928 | 2 | 34 | 153 | 14:12:00 | 37.57 | Knee | 1 | .8 | 1 | 1 | 2 | 1 | 2 |
| 931 | 1 | 20 | 176 | 12:55:00 | 40.87 | | 0 | .9 | 1 | 2 | 2 | 0 | 1 |
| 939 | 1 | 42 | 285 | 13:51:00 | 38.39 | | 0 | 1.2 | 2 | 2 | 2 | 0 | 3 |
| 942 | 1 | 26 | 233 | 15:54:00 | 33.83 | Low Back | 1 | .8 | 2 | 2 | 1 | 1 | 3 |
| 941 | 1 | 36 | 199 | 14:00:00 | 37.98 | Shin Splints | 1 | .9 | 2 | 2 | 2 | 0 | 2 |
| 924 | 1 | 26 | 204 | 13:40:00 | 38.82 | | 0 | 1.1 | 2 | 2 | 1 | 1 | 3 |
| 930 | 1 | 23 | 179 | 11:10:00 | 46.73 | RT. Shoulder | 0 | 1.0 | 2 | 2 | 2 | 0 | 3 |
| 946 | 1 | 27 | 246 | 16:09:00 | 33.11 | | 0 | 1.0 | 2 | 2 | 2 | 0 | 2 |
| 936 | 1 | 38 | 230 | 15:55:00 | 45.78 | | 0 | .7 | 1 | 2 | 2 | 0 | 1 |
| 940 | 1 | 34 | 174 | 14:06:00 | 37.77 | Rt. Elbow | 1 | .9 | 2 | 2 | 2 | 0 | 3 |
| 456 | 1 | 34 | 234 | 14:20:00 | 37.18 | Low Back | 1 | .7 | 2 | 2 | 1 | 1 | 3 |
| 938 | 1 | 23 | 171 | 13:14:00 | 38.23 | | 0 | 1.1 | 1 | 2 | 2 | 0 | 3 |
| 475 | 1 | 32 | 192 | 15:50:00 | 33.99 | | 0 | 1.1 | 2 | 2 | 2 | 0 | 2 |
| 932 | 1 | 32 | 189 | 13:20:00 | 39.70 | | 0 | 1.0 | 2 | 2 | 3 | 1 | 2 |
| 933 | 1 | 33 | 211 | 15:54:00 | 33.83 | | 0 | 1.0 | 2 | 2 | 2 | 0 | 2 |

| assigned | illr | asym | sml | smr | asymsm | ail | air | aslrl | aslr | asyma | tspu | ppu | rsl | rsr | asumr | flx | total1 | asymt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 927 | 2 | 1 | 2 | 3 | 1 | n | n | 2 | 2 | 0 | 2 | NE | 2 | 2 | 0 | NE | 15 | 3 |
| 507 | 3 | 0 | 3 | 2 | 1 | n | n | 2 | 2 | 0 | 1 | NE | 2 | 2 | 0 | NE | 14 | 1 |
| 926 | 2 | 1 | 3 | 3 | 0 | n | n | 2 | 2 | 0 | 3 | NE | 3 | 2 | 1 | NE | 16 | 3 |
| 937 | 2 | 1 | 2 | 2 | 0 | n | n | 2 | 2 | 0 | 2 | NE | 2 | 2 | 0 | NE | 15 | 1 |
| 742 | 2 | 0 | 3 | 2 | 1 | n | n | 2 | 2 | 0 | 3 | NE | 2 | 2 | 0 | NE | 14 | 1 |
| 614 | 2 | 0 | 2 | 2 | 0 | n | n | 2 | 2 | 0 | 1 | NE | 2 | 2 | 0 | NE | 13 | 0 |
| 923 | 3 | 0 | 2 | 3 | 1 | n | n | 3 | 3 | 0 | 3 | NE | 2 | 2 | 0 | NE | 17 | 1 |
| 929 | 2 | 0 | 2 | 3 | 1 | n | n | 2 | 2 | 0 | 2 | NE | 2 | 2 | 1 | NE | 14 | 2 |
| 928 | 1 | 1 | 2 | 2 | 0 | n | n | 2 | 2 | 0 | 2 | NE | 2 | 2 | 0 | NE | 11 | 2 |
| 931 | 2 | 1 | 1 | 1 | 0 | n | n | 2 | 2 | 0 | 2 | NE | 2 | 2 | 0 | NE | 11 | 2 |
| 939 | 3 | 0 | 3 | 2 | 1 | n | n | 2 | 2 | 0 | 1 | NE | 2 | 2 | 0 | NE | 14 | 1 |
| 942 | 3 | 0 | 2 | 3 | 1 | n | n | 2 | 2 | 0 | 1 | NE | 1 | 2 | 1 | NE | 12 | 2 |
| 941 | 1 | 1 | 2 | 3 | 1 | n | n | 2 | 2 | 0 | 1 | NE | 2 | 2 | 0 | NE | 12 | 2 |
| 924 | 3 | 0 | 3 | 3 | 0 | n | n | 1 | 2 | 1 | 1 | NE | 2 | 2 | 0 | NE | 13 | 2 |
| 930 | 2 | 1 | 1 | 2 | 1 | n | n | 3 | 3 | 0 | 2 | NE | 2 | 2 | 0 | NE | 14 | 2 |
| 946 | 3 | 1 | 2 | 1 | 1 | n | n | 2 | 2 | 0 | 1 | NE | 2 | 2 | 0 | NE | 12 | 2 |
| 936 | 1 | 0 | 1 | 2 | 1 | n | n | 1 | 1 | 0 | 1 | NE | 2 | 2 | 0 | NE | 9 | 1 |
| 940 | 3 | 0 | 3 | 3 | 0 | n | n | 2 | 2 | 0 | 2 | NE | 1 | 2 | 1 | NE | 15 | 2 |
| 456 | 3 | 0 | 3 | 3 | 0 | n | n | 1 | 2 | 1 | 1 | NE | 2 | 2 | 0 | NE | 13 | 2 |
| 938 | 2 | 1 | 2 | 2 | 0 | n | n | 2 | 2 | 0 | 1 | NE | 2 | 2 | 0 | NE | 12 | 1 |
| 475 | 2 | 0 | 2 | 2 | 0 | n | n | 3 | 3 | 0 | 3 | NE | 2 | 2 | 0 | NE | 16 | 0 |
| 932 | 3 | 1 | 3 | 3 | 0 | n | n | 2 | 2 | 0 | 3 | NE | 2 | 2 | 0 | NE | 16 | 2 |
| 933 | 2 | 0 | 2 | 3 | 1 | n | n | 2 | 3 | 1 | 3 | NE | 2 | 3 | 1 | NE | 15 | 2 |

CURRICULUM VITAE

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## PROFESSIONAL STATUS

*Certified Athletic Trainer- #079402423*
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*Certified Strength and Conditioning Specialist- #977518*
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## OCCUPATIONAL STATUS

*Director Athletic Training Program,* Averett University, Physical Education, Wellness and Sport Science Department, Danville, Va.

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## PROFESSIONAL EXPERIENCE

*Head Certified Athletic Trainer*, George Washington High School,
Danville, Va. 1996- Present

*Director of Sports Medicine*, Orthopedic and Sports Physical Therapy,
Danville, Va. 1996-2000

*Certified Athletic Trainer*, Norfolk Academy,
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## EDUCATION

*Doctorate of Philosophy* in Curriculum and Instruction, Virginia Polytechnic and State University, Blacksburg, Va. May 2006.

*Master of Science* in Education, emphasis in Athletic Training, Old Dominion University, Norfolk, Va. May 1996.

*Bachelor of Science* in Athletic Training, Minor in Business Management, Appalachian State University, Boone N.C., May 1994