ESTABLISHING A LEGALLY DEFENSIBLE PHYSICAL EMPLOYMENT STANDARD FOR CANADIAN WILDLAND FIRE FIGHTERS

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ABSTRACT

Wildland fire fighting is a physically demanding public safety occupation in which unsafe, ineffective or inefficient job execution could result in loss of life or property. To meet the demands associated with front-line duty, wildland fire fighters (WFF) are expected to demonstrate a fitness level which results in safe, effective and efficient work performance under emergency circumstances. Duties often include tasks such as hiking, hand tool work, carrying heavy equipment and fire suppression implements over large distances and possibly arduous terrain. To identify candidates who are able to perform the critical physically demanding tasks encountered in a public safety occupation, a valid and reliable physical ability test for the exchange of IA WFF across Canada is required.

For WFF to be eligible for exchange to fight wildland fires in all Canadian Interagency Forest Fire Centre (CIFFC) member fire jurisdictions, they must demonstrate annually that they are able to achieve the Canadian Wildland Fire Fighter Exchange Fitness Test for IA WFF (WFX-FIT). The protocol was designed so that it would be legally defensible from a Human Rights perspective and conform to the Supreme Court of Canada's Meiron Decision. The results of this project indicated that back-carrying and hand-carrying a 28.5 kg pump, back-carrying a 25 kg hose pack and advancing charged hose, were the most demanding emergency WFF tasks. As well, performing the same emergency WFF tasks was significantly more demanding in British Columbia than in New Brunswick and Saskatchewan ($p \leq 0.05$). Owing to these regional terrain differences and the resultant differences in physical demands, a range of cut-scores was derived to account for these jurisdictional differences.

Content and construct validation measurements indicated that the physical demands involved in performing the WFX-FIT are the same as the physical demands involved in wildland fire fighting thereby providing convincing evidence for the validity of the WFX-FIT protocol. Test-retest reliability measurements demonstrated that repeat performances on the WFX-FIT are highly reliable. Lastly, with familiarization and training, non-WFF general population females were able to overcome the possible adverse impact of the WFX-FIT standard.

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Each of the 4 manuscripts includes a list of co-authors. In each case, individuals were included as a co-author if they provided significant input towards study design, participant recruitment and data collection, data reduction and analyses and/or preparation and revision of the manuscript. In each of the four manuscripts, R. Gumieniak was the primary author and contributor to each of the above mentioned aspects of the thesis.

Contributor	**Statement of Contribution**
Robert J. Gumieniak	Prepared all manuscript drafts, including journal submissions. Significant contributor to experimental design and ethics proposal submission. Coordination of participant recruitment and data collection. Completed statistical analysis.
Veronica K. Jamnik	Supervisor. Critical revision of manuscript and approval of final version for publication. Aided in experimental design. Co-contributor to interpretation of data and manuscript direction. Aided in securing project funding.
Norman Gledhill	Critical revision of manuscript and approval of final version for publication. Aided in experimental design. Co-contributor to interpretation of data and manuscript direction. Aided in securing project funding.
Jim A. Shaw	Aided in experimental design, data collection and analysis in Manuscript II.

TABLE OF CONTENTS

MANUSCRIPT II

MANUSCRIPT III

CHAPTER 4

LIST OF TABLES

REVIEW OF LITERATURE:

MANUSCRIPT I:

MANUSCRIPT II:

MANUSCRIPT III:

MANUSCRIPT IV:

LIST OF FIGURES

MANUSCRIPT III:

MANUSCRIPT IV:

LIST OF ILLUSTRATIONS

MANUSCRIPT I:

LIST OF ACRONYMS *(listed alphabetically)*

AB - Alberta

ANOVA - Analysis of Variance

BFOR - Bona Fide Occupational Requirement

BC - British Columbia

CEP - Certified Exercise Physiologist

CO - Correctional Officer

CON - Control Group

CIFFC - Canadian Interagency Forest Fire Fighter Centre

CPT - Certified Personal Trainer

ESPA - Emergency Service Physical Abilities Test

FIT*CO* - Fitness Screening Test for Correctional Officer Applicants

HR - Heart rate

HRR - Heart rate reserve

HR_{max} - Maximum Heart Rate

IA - Initial Attack

MB - Manitoba

NB - New Brunswick

NFL - Newfoundland

NWT - Northwest Territories

NS - Nova Scotia

ON - Ontario

PC - Parks Canada

PAR-Q+ - Physical Activity Readiness Questionnaire for Everyone

PEI - Prince Edward Island

PFT - Physical Fitness Training

PMT - Project Management Team

PPE - Personal Protective Equipment

PS - Performance Standard

QC - Quebec

RM - Repetition Maximum (reps)

RPE - Rating of Perceived Exertion (scored 6 to 20)

SE - Standard Error

SD - Standard Deviation

SK - Saskatchewan

VO_2 - Volume of Oxygen Consumed

VO_2max - Maximum Volume of Oxygen Consumed

WFF - Wildland Fire Fighter(s)

WFX - Circuit Only Group/weekly circuit trials

WFX-FIT - Wildland Fire Fighter Exchange Fitness Standard

YK - Yukon Territory

LIST OF MEASUREMENT AND SYMBOL ABBREVIATIONS

lb - pound(s)
kg - kilogram(s)
in - inch/inches
ft - foot/feet
mm - millimeter
cm - centimeter
m - meter(s)
km - kilometer(s)
wk - week(s)
sec - second(s)
min - minute(s)
min:sec - minutes:seconds
bpm - beats per minute
mph - miles per hour
yr - year(s)
$mL \cdot kg^{-1} \cdot min^{-1}$ - milliliters per kilogram per minute
$L \cdot min^{-1}$ - litres per minute

Symbol abbreviations

~ - approximately (roughly equal to)
n - number
Δ - Delta (change)
χ^2 - chi squared

CHAPTER 1: INTRODUCTION and LITERATURE REVIEW

FOREWARD TO THE THESIS

This thesis is organized as four separate manuscripts as described below, preceded by an introductory set of chapters including; an introduction and overall summary, a review of literature, list of objectives and hypotheses from each study, and descriptions of common methodologies across each of the studies. The manuscripts are followed by a general discussion and overview of the four manuscripts as well as a summary of conclusions, implications of the work and comments regarding future research in the field. The thesis concludes with a detailed list of references and appendices relevant to the project.

The thesis consists of the following four manuscripts, each principally authored by R. Gumieniak.

1. Physical Employment Standard for Canadian Wildland Fire Fighters*; Physical Fitness Bona Fide Occupational Requirements for Safety-Related Physically Demanding Occupations – Test Development Considerations*. RJ Gumieniak, N Gledhill and VK Jamnik. *Health & Fitness Journal of Canada*. 2011; 4(2):47-52.

2. Physical Employment Standard for Canadian Wildland Fire Fighters*; Identifying and Characterizing the Important, Physically Demanding and Frequently Occurring IA Response Tasks in Wildland Fire Fighting*. RJ Gumieniak, N Gledhill, JA Shaw, VK Jamnik.

3. Physical Employment Standard for Canadian Wildland Fire Fighters*; Constructing and Validating the Test Protocol.* RJ Gumieniak, N Gledhill and VK Jamnik.

4. Physical Employment Standard for Canadian Wildland Fire Fighters*: Examining Test Reliability plus Familiarization and Physical Fitness Training to Overcome Adverse Impact.* RJ Gumieniak, N Gledhill and VK Jamnik.

1.1. INTRODUCTION and OVERALL SUMMARY OF THE RESEARCH PROJECT

The Wildland Fire Fighter Exchange Fitness Test (WFX-FIT) project is a national scope research initiative to establish a physical fitness test and standard for the exchange of IA wildland fire fighters (WFF) across Canada. Prior to 2012, wildland fire jurisdictions (provinces) across Canada did not employ a standardized job-related physical employment standard for the jurisdictional employment and exchange processes associated with wildland fire fighting. Traditionally, each jurisdiction has implemented varying fitness-related screening protocols including the 1-mile timed pack hike test[1], the 'pack-test' battery incorporating selected job-related tasks[2] and/or physician medical screening for employment selection purposes. However, the application of scientific methodology and best practice obligated by arbitration and court decisions have become essential to the development of applicant and incumbent physical fitness screening protocols for physically demanding safety-related occupations.

Prior to 1999, physical fitness screening protocols for such occupations lacked a standardized framework for their development and validation. More recently, criteria to guide the establishment of bona fide occupational requirements (BFORs), and in particular the 1999 ruling of the Supreme Court of Canada (hereafter referred to as the Meiorin Decision), have necessitated the development of assessment protocols using a systematic methodological process as established at the 2000 BFOR Consensus Forum[3] (Toronto, Ontario). This Forum convened all stakeholders to clarify the Meiorin Decision requirements and provide direction for meeting the challenges that the requirements posed with respect to developing legally defensible physiological employment standards. A pivotal outcome of the Forum was the consolidation of best practices into a systematic research process template (reproduced in Manuscript I; *BFOR Development Considerations*) which provided detailed guiding principles for establishing a physical employment standard to *qualify* as a BFOR.

The first phase of this research project involved a comprehensive Physical Demands Analysis (PDA) which provided the basis for developing the WFX-FIT. This included a job inventory and ensuing job task analysis using subject matter experts to identify the critical, physically demanding and frequently occurring on-the-job tasks experienced by IA WFF[4,5] and the associated terrains that are encountered. Following the PDA, the next phase of the project involved a physiological characterization of the weights, force applications, heart rate responses (HR), oxygen utilization (VO_2) and ratings of perceived exertion (RPE) while incumbent WFF performed these tasks. The characterization measurements were conducted at wildland locations that are representative of the arduous terrains encountered in fire jurisdictions across Canada including rolling terrain and blow-downs in New Brunswick, muskeg/bogland in Saskatchewan and steep mountains in British Columbia.

Following the characterization, task simulations were developed embodying the same weights and applied forces measured in the characterization and these task simulations were combined into a continuous circuit to simulate IA on-the-job performances. These individual job simulation tasks and the overall circuit performance were then evaluated to establish the construct validity of the WFX-FIT protocol which involved confirming that the physiological responses (VO_2, HR and RPE) of "safe, effective and efficient" WFF while performing the job simulation test protocol were the same as those measured on the job during the characterization phase. To establish content validity, experienced "safe, effective and efficient" WFF from across Canada provided their evaluation of the "likeness" of the physical demands involved in completing the WFX-FIT circuit compared to the physical demands required to complete the on-the-job tasks upon which the job simulation tasks and circuit were based. Once the detailed instructions for performing the WFX-FIT protocol had been standardized, the next objective was to derive the associated performance standards. When attempting the test protocol for the derivation of performance standards, all participants, who were experienced WFF were instructed to complete the WFX-FIT circuit using a self-selected safe, effective and efficient emergency pace[6,7] which was confirmed to be an appropriate emergency pace by subject matter experts. Owing to regional differences in terrain difficulty, Fire Management Policy on population threat/forest value and emergency pace (completion time), there are associated differences in physical demands, and therefore a range of cut-scores were developed taking into account these jurisdictional differences.

The last phase of the WFX-FIT project was to evaluate whether the protocol and associated performance standard could have an adverse impact on a sub-group of potential applicants/incumbents. Job-specific physical employment standards are based on critical, physically demanding and frequently occurring emergency tasks in which personal safety, the safety of a co-worker and the general public may be compromised by inefficient performance or failure to complete the required task(s). Lowering such a standard to provide accommodation for a worker who is unable to meet the standard could result in front-line workers being unable to perform critical tasks during an emergency with a possible catastrophic consequence. Under the 2004 Criminal Code of Canada[8], employers could be deemed negligent and held liable if they fail to take reasonable measures to ensure the safe and efficient performance of workers.

Adverse impact describes the situation in which group differences in performance relative to a common standard result in a disproportionate failure rate in a sub-group[9–16]. It has been argued previously that participants have the capacity to markedly improve performance on a fitness screening protocol by engaging in familiarization and physical fitness training to thereby overcome adverse impact[12–14]. Because adverse impact was present when normally active, non-WFF general population volunteers attempted the WFX-FIT, familiarization opportunities and physical fitness training were investigated as strategies to overcome the adverse impact, thereby providing accommodation. The results confirmed the positive impact of familiarization opportunities and exercise training on WFX-FIT completion time and pass rates to overcome adverse impact.

The WFX-FIT project addressed the need for a valid, reliable and standardized physical employment standard for the exchange of WFF across Canada. This is the first project of such scope in Canada and will ensure that incumbent IA WFF, who are exchanged across Canada, can safely perform the job in all arduous terrains. It is expected that the implementation of standardized annual physical fitness testing may also contribute to enhanced performance, fewer injuries and the promotion of healthy behaviour.

1.2. REVIEW OF LITERATURE

1.2.1. Bona Fide Occupational Requirements

The field of job-specific physical employment standards for physically demanding public safety occupations is a complex milieu involving disciplinary interests such as human rights, law, medicine, occupational health and safety, and exercise physiology. The intent of a job-specific physical employment standard is to determine whether an applicant or incumbent possesses the necessary physical capabilities to safely and efficiently perform the critical on-the-job tasks encountered in a physically demanding occupation. Generally, a physical employment standard can only be implemented in those public safety occupations in which “ineffective job performance can result in loss of life or property” (ex. policing, fire fighting, military service). Since the safety of the worker, co-workers and the general public depends on successful and efficient job performance in such occupations, it is essential that workers have the physical capabilities required to meet the demands of the job. This distinction is based on the 1988 Government of Canada definition that a bona fide occupational requirement (BFOR) is a condition of employment imposed in the belief that it is necessary for the safe, efficient and reliable performance for the job and which is objectively, reasonably necessary for such performance[3,4,10–12,14,17,18].

It is common practice in physically demanding public safety occupations to establish a physical employment standard that conforms to specified legal requirements in Canada, including; government law[8], human rights legislation[19], court decisions[10], case law[20] expert consensus on the subject matter and ‘best practises’ research[4,7,9,11,14,18,21–28] to *qualify* as a BFOR. Although a physical employment standard is developed with the purpose of meeting the requirements to *qualify* as a BFOR, the designation that the physical employment standard *is* a BFOR only occurs when a human rights tribunal or court has judged that the specific physical employment standard *qualifies* as a BFOR. Generally this designation does not occur until an unsuccessful candidate pursues a legal challenge against a physical employment standard. The process followed to develop the Wildland Fire Fighter (WFF) Exchange Fitness Test (WFX-FIT) was *designed* to *qualify* this protocol as a BFOR.

In Canada, the 1999 Supreme Court Decision, referred to as the Meiorin Decision, obliges employers to follow a three step process to prove that a BFOR standard is not discriminatory. Relating the Meiorin requirements to the development and validation of a physical employment standard requires a brief review of these important precedents. In 1999 The Meiorin Decision of the Supreme Court of Canada provided a three-part test for determining whether a prima facie discriminatory standard is a BFOR[4,10–12,14,17,18,29]. An employer must provide justification for a discriminatory standard by demonstrating:

1) That the employer adopted the standard for a purpose rationally connected to the performance of the job;

2) That the employer adopted the particular standard in an honest and good faith belief that it was necessary to the fulfilment of that legitimate work-related purpose; and
3) That the standard is reasonably necessary to the accomplishment of that legitimate work-related purpose. To show that the standard is reasonably necessary, it must be demonstrated that it is impossible to accommodate individual employees sharing the characteristic of the claimant without imposing undue hardship on the employer.

Issues regarding the practical interpretation of the Meiorin Decision were deliberated by the major stakeholders in public safety occupations including subject matter experts (front-line employees and supervisors), human resource managers, union representatives, legal counsel and researchers. In September of 2000, The Bona Fide Occupational Requirement Consensus Forum (Toronto, Ontario) convened these stakeholders to clarify the Meiorin Decision requirements and provide direction for meeting the challenges that the requirements posed with respect to developing legally defensible physiological employment standards for physically demanding public safety occupations[3]. After scrutinizing the Meiorin Decision, it was the consensus of the Forum participants that to *qualify* as a BFOR, a physical employment standard must be based on both "safe" (properly executing the critical life threatening physically demanding emergency tasks) and "efficient" (completing these tasks in a time frame that is suited to the emergency circumstance) job performance. The assignment of "safe and efficient" job performance is the responsibility of the occupation-specific subject matter experts. Additionally, the critically important, physically demanding and frequently occurring emergency job tasks must *(i)* not be based on the physical fitness characteristics of current front-line workers (characteristics based) and *(ii)* must be based on the "safe and efficient" work performance of the current front-line work force, taking into account the diverse individualities of the workers with respect to age, sex, minority status, disability status, and work experience[5]. Further, the physiological employment standard must be based on the current ability to perform the job and not on future likelihood of failure to perform the job.

Meeting the first two Meiorin tests is relatively straightforward. The process followed in developing the WFX-FIT satisfies the rationale for establishing physical employment standards and the methodology involved in the physical demands analysis (PDA), job characterization, test development and validation convincingly illustrate that the employer/management adopted the physical employment standard “for a purpose rationally connected to the performance of the job” and that management “did so in an honest and good faith belief that it was necessary” to meet the physical demands encountered by incumbents on the job. Therefore, the WFX-FIT protocol should pass the first two Meiorin tests. Passing the third Meiorin test necessitates further attention.

At the 2000 BFOR Consensus Forum, it was concluded that undue hardship could be demonstrated if providing accommodation for adverse impact would undermine the due diligence responsibility of the employer[3,4,12,14]. Because the performance standard and cut-scores of the WFX-FIT are based on critical, physically demanding emergency tasks in which personal safety, the safety of a co-worker or the safety of the general public may be compromised by inefficient performance or failure to complete, it is not possible to accommodate an individual incumbent or applicant by lowering the cut-scores. Such an accommodation could result in an employee being unable to complete critical emergency tasks during an emergency scenario. That is, lowering the requirements would constitute undue hardship because supervisors and management have a due diligence responsibility to ensure that all incumbents are capable of meeting the emergency demands encountered on the job[3,29]. Failure to maintain these standards could result in a circumstance for which management is deemed liable for the foreseeable ineffective performance which led to a catastrophic consequence.

The due diligence provision was empowered by the 2004 revision to the Criminal Code of Canada (Bill C-45)[8] which indicated that management could be deemed criminally negligent if they failed to take reasonable measures to ensure the safe and efficient work performance of employees[8]. If an incumbent/applicant demonstrates that he/she meets a physical employment standard, then he/she is capable of safely and effectively working in that occupation. Further, if an incumbent/applicant does not initially pass the test standard, there is convincing evidence that, by taking advantage of test familiarization opportunities[12–14,30–32] and by engaging in a customized physical fitness training program[12–14,33–38], it is possible for most female and male incumbents/applicants to meet the performance standard and cut-score.

A critical outcome of the 2000 BFOR Consensus Forum was the consolidation of best practices into a systematic research process template (reproduced in Manuscript I; *BFOR Development Considerations*) which provided detailed guiding principles for establishing a physical employment standard to *qualify* as a BFOR. Since the validity and reliability of a BFOR must be founded on credible scientific evidence, this led to the application of an empirical process to document the validity and reliability of physical employment standards.

1.2.2. Developmental Considerations for Physical Employment Standards

A physical employment standard can be developed using fitness components, job simulations, or a hybrid of job simulations and fitness components[3,7,14,32,39]. Fitness component tests employ select standardized laboratory fitness tests to evaluate the physical attributes necessary for safe and efficient job performance[4,7,11,14,32,39]. The tests do not simulate the specific work demands or force applications used on the job, instead they assess the strength/force applications required by the participant to accomplish the demands of the job. Job simulation tests, on the other hand, reproduce the tasks encountered on the job and are generally preferred over fitness component tests because participants and arbitrators can easily see the relationship to the job[3,14,15]. The task simulations can be performed in a discrete or serial manner. Discrete tasks are evaluated independently while serial tasks incorporate several task simulations into a continuous circuit with a single overall completion time standard. A hybrid test includes both job simulation tasks and one or more fitness component tests[14,39]. Hybrid physiological employment standards with a separate aerobic fitness assessment are typically used for applicant screening, whereas job simulation circuits with an embedded aerobic fitness requirement are more commonly used for the annual assessment of incumbent workers[14,39].

A criticism of fitness component tests is their lack of content/face validity, that is, fitness component tests do not subjectively appear to evaluate the component they purport to assess. Additionally, fitness component tests are disparaged because of the performance decrements associated with aging[3,7,14,40]. The use of task simulations is generally preferred because of their face validity and they provide a more exact evaluation of the ability to meet the occupational demands. This approach takes into account differences in work efficiency that are observed in workers with differing levels of training and experience[40]. Contrary to the Meiorin Decision[3,7,10,14,32,40], the performance standards and/or ‘cut-points’ for fitness component tests are generally based on the characteristics (for example, maximal force production) of incumbents, rather than the criterion performance necessary for safe and efficient job completion. An additional benefit of task simulation tests includes simple administration and the provision of a dichotomous “pass” or “fail” outcome[15]. It has been argued that there should also be a ‘borderline’ test outcome zone when candidates are very close to meeting the cut-score. That is, on any given day a candidate could underperform due to variation in motivation, effort or simple biological variability. However, if the administrator of the protocol provides second and third attempt opportunities, then a pass/fail cut-score is desirable because the influence of biological variability will be negated through this familiarization opportunity.

Though there are many benefits of task simulation assessments, they are not without criticisms. Tipton et al.[5] identified a number of potential issues with task simulations; *i)* the validity of the test is dependent on the accuracy of the simulation; *ii)* it is difficult to simulate some critical tasks in a way that allows the simulations to be undertaken in a variety of locations and within controlled environmental conditions; *iii)* there is no way of knowing what percentage of their maximum work rate an individual is working at when they undertake a simulation; *iv)* it is not viable to use simulations requiring significant skill components that should be acquired as a result of performing the job[15]. Research methodology in Manuscript II; *Identification and Characterization* details how these test considerations have been addressed in the development of the WFX-FIT protocol.

The use of a continuous circuit in fitness screening protocols for physically demanding occupations is not uncommon. For example, they are included in the fitness screening protocols for police officers[23], correctional officers[7,12,41], nuclear power emergency workers[24], structural fire fighters[21,42] and military fire fighting personnel[28,30,43]. Lord et al.[44] combined critical bushfire suppression tasks into a circuit to replicate core actions and movements and reflect the intermittent nature of fire suppression duties. As well, Phillips et al.[45] identified tasks that should form the basis for a representative work task circuit for personnel fighting wildfires. Although these authors recommend the use of a job-simulation circuit for assessing the fitness of WFF, certain critical considerations such as the effect of differences in terrain on the associated physical demands was not considered in their circuit development.

1.2.3. Adverse Impact and Accommodation

In 1988, the BC Forest Service introduced a mandatory physical fitness test for IA crews. The test was a variant of the US Forest Service Smokejumpers test, developed by Dr. Brian Sharkey[46]. It consisted of four components: 24 pushups in 60 seconds (sec), 24 situps in 60 sec, 7 pullups in 60 sec followed by a 2.5 km (1.56 mi) run completed in under 11:49 (min:sec). Tawney Meiorin, a veteran IA WFF who received "good annual job performance evaluations from her supervisor, was dismissed on the grounds of recurrent failure of the aerobic fitness component of a pre-employment physical fitness test required by the employer. Meiorin's counsel argued that the fitness standard was an example of indirect discrimination because females generally have a lower aerobic fitness than males and that even with training, females will have difficulty attaining the required level of fitness, meaning fewer females are able to successfully complete the 2.5 km run in the required time[17]. On September 9, 1999, the Supreme Court of Canada delivered a ground breaking decision in British Columbia (BC) *vs. British Columbia Government Employees Union* that significantly impacted labour law in Canada[10]. Justice McLachlin of the Supreme Court unanimously found that the fitness test used in British Columbia, was not a BFOR, and had discriminated against Tawney Meiorin on the basis of sex when evaluated against step three of the three-part test.

Adverse impact describes "the circumstance in which group differences in performance, relative to a common standard, results in a disproportionate failure rate in a sub-group"[9,11,12]. Although the determination of a "disproportionate" failure rate is subject to court judgements, researchers and courts have commonly recognized the "80% rule"(or four-fifths rule), which specifies that adverse impact exists when the pass rate of a sub-group of participants (typically female incumbents) is less than 80% of the pass rate of the majority group of participants[9–12,16,18,47–49]. When adverse impact is present, the employer must either accommodate the impacted sub-group or demonstrate that accommodation is not possible because the safety risk of lowering the standard would constitute undue hardship[10,18,50]. The Meiorin Decision had a significant impact on exercise physiologists who are at the forefront of physical employment standards. At the landmark 2000 BFOR Consensus Forum, it was concluded that if the accommodation to be provided for adverse impact undermines the due diligence responsibility of the employer, it constitutes undue hardship[3,12,14,18,29].

In 2002, an Ontario Human Rights Commission grievance was filed by a female police applicant requesting accommodation for adverse impact of the Physical Readiness Evaluation for Police (PREP)[20]. At the Commission hearing, it was argued by the employer that females have the capacity to markedly improve their ability to pass the PREP by engaging in both test familiarization opportunities and a customized exercise training program. Citing evidence from the exercise training literature, the employer proposed that the resultant improvements would be sufficient to ameliorate the adverse impact on female participants. This argument was accepted and the grievance of the claimant was dismissed by the Human Rights Commission[20]. Subsequent to this decision, researchers have confirmed experimentally that through familiarization and customized exercise training it is possible to overcome the potential adverse impact of an applicant/incumbent test on female participants[12,14]. The focus of Manuscript IV; *Familiarization and Training* is to determine if the WFX-FIT performance standard has an adverse impact on female participants, and to evaluate the extent to which test familiarization and customized exercise training can overcome adverse impact.

1.2.4. Determination of Cut-Scores

A variety of methods have been used for the determination of cut-scores. One such method is to use the norm-referenced interpretation based on the statistical distribution of test scores[51,52]. Using this method, the cut-score is derived from the mean + 1 SD of the completion times of all safe and efficient female incumbent workers who were confirmed by supervisory subject matter experts to be working at an appropriate rate[7]. Another accepted process involves utilizing expert judges to observe video recordings of actors performing the test protocol at difference paces, known as the Bookmark procedure. Rogers et al.[28] described in detail the Bookmark procedure in their paper on establishing performance standards and cut-score for the Canadian Forces Firefighter Physical Fitness Test. In brief, a panel of judges rate the video performances completed at varying speeds as being acceptable or unacceptable by inserting bookmarks where appropriate. After each ‘round’ of bookmarking, the results are compiled by the researchers and presented to the panel. Each round concludes with a discussion and the process is repeated until a consensus is achieved on a distribution of acceptable performance speeds (cut-scores)[28,53].

Despite the methodological differences in setting cut-scores, the ultimate goal is to limit the number of false-positives and false-negatives[28,31,54]. In a false-positive decision (passing a worker who should fail), the safety of the worker, a co-worker or the public may be compromised and the employer may be at risk of ‘workplace negligence’ and could be deemed liable if they fail to take reasonable measures ‘‘to ensure the bodily safety of persons doing the work or task”. When public safety workers require physiological attributes necessary to avoid foreseeable risks, an employer has a duty of care or due diligence responsibility to ensure that those physiological attributes are present’’[8,14]. A false-negative decision (failing a worker who should pass), has the costly potential of failing a viable candidate. With these considerations in mind, the norm-referenced interpretation method used in Manuscript III; *Construction and Validation* to determine the cut-scores for the WFX-FIT involved a thorough process based on a robust sample of incumbent workers and supervisory subject matter experts, who verified the performance speed as appropriate, to determine the acceptable level of performance required for safe and efficient job completion. It is also important to note that Rogers et al. used the Bookmarking procedure to derive a distribution of acceptable scores, and then formulated the final cut-score using a statistical derivation approach similar to that used in Manuscript III; *Construction and Validation*.

1.2.5. Reliability

An important consideration when determining the scientific accuracy of the physiological employment standard is test–retest reliability. Reliability refers to a measure of consistency (reproducibility) within test-retest data. It could be related to the equipment used to determine the physical demands of a critical task or the tests that make up a physical employment standard or to the test itself. A common method used to determine reliability is the test–retest process, in which the first measure is compared with a second or third measure using the same participants and conditions[3,7,14,32,55]. Though there is inherent variability with any test protocol due to differences in effort and biological variability, minimizing random events and other confounding issues increase the reliability of a participant's performance[30,32]. Test administrators are responsible for controlling technical variability which includes factors such as test standardization, equipment set-up and calibration, and environment. Systematic variability describes the performance improvements owing to learned behaviours and pacing strategies. Biological variability, or non-fitness factors, refers to elements of sleep patterns, hydration status, nutrition and fatigue[26,56].

Test–retest reliability refers to consistency of test performances by the same individuals on different occasions, under conditions that are as similar as possible[55]. In addition to test–retest, Milligan et al.[32] present several additional factors that can affect test reliability, these include consistency: *(i)* between testers (inter-rater), *(ii)* of participants (intra-subject), and, *(iii)* of tester's performance (intra-rater). To fulfil each of these considerations, the test-retest reliability of the WFX-FIT was established when the impact of familiarization on completion time had been eliminated. Study participants in Manuscript IV; *Familiarization and Training* were instructed to perform both the WFX-FIT test and re-test at a speed that they considered to be a "purposeful expeditious pace", given that participants in this project phase were not WFF and would not fully appreciate a "safe and efficient emergency pace". By conducting test performances at the same time of day and in the same location the biological variability which could affect study participants outcomes was minimized. Consequently, performance on the WFX-FIT was found to be highly reliable.

1.2.6. Familiarization

It was argued at a 2002 Ontario Human Rights Commission (OHRC) hearing[20], citing evidence from the literature that female applicants have the capacity to improve their ability to pass a physical fitness BFOR standard by engaging in familiarization and customized exercise training to thereby overcome adverse impact. This argument was accepted in the OHRC decision[20]. The combination of familiarization and exercise training to overcome adverse impact was subsequently confirmed experimentally in investigations of female correctional officer applicants[12], nuclear power plant fire fighters[13] and in Manuscript IV; *Familiarization and Training*, WFF. Very few investigators have addressed the issues of adverse impact and accommodation for a physical employment standard using familiarization and exercise training. Jamnik et al.[12] studied female and male correctional officer applicants (n=48) performing the Fitness Test for Correctional Officer Applicants (FIT*CO*) after familiarization and a 6 week customized exercise training program. Over three familiarization trials, females improved FIT*CO* completion times by 10.7% and males improved 9.1%. After six weeks of fitness training customized to the demands of the FIT*CO*, females improved circuit completion time by 22.9% and males improved by 14.0%. The Jamnik et al. study is significant because the FIT*CO* was *designed* to *qualify* as a BFOR and therefore the authors specifically addressed adverse impact and accommodation. The authors concluded that by taking advantage of familiarization opportunities and engaging in a customized exercise training program, female correctional officer applicants can overcome the potential adverse impact of the FIT*CO*.

Gumieniak et al.[13] similarly examined familiarization and exercise training as modalities to provide accommodation for adverse impact on the Emergency Service Maintainer Physical Abilities Test (ESPA). Participants (n=41) were familiarized to the test protocol and engaged in a supervised six week ESPA-customized exercise training program. Owing to familiarization, females improved ESPA completion time by 11.8% and males improved by 11.2%. The combined improvement in completion times from familiarization and exercise training was 31.6% for females and 32.6% for males.

More recently, Boyd et al.[30] examined the effects of six repeat trials on the Canadian Forces Fire Fighter Physical Fitness Maintenance Evaluation (FF PFME) on completion time. The authors reported significant decreases in completion time between Tests/Trials 1 and 6 for a cohort of 51 (20 female) participants. Similar to the work by Jamnik et al. and Gumieniak et al. cited above, the largest improvement in performance was from Test 1 to 2 (8.2%) and the total improvement from Test 1 to 6 was 18.7%. The authors also report that after three practice trials, most subjects were approaching their best completion time. Though significant differences were observed beyond Test 3, relative changes decreased (from 3.1% to 2.4% to 1.4%). The authors concluded by stating that the results indicate the importance of practice on performance and the potential for false-positive or false-negative decision errors if biological variability is not taken into account. The practical implications of these collective findings highlight the significance of providing familiarization and exercise training opportunities to individuals at risk for adverse impact.

1.2.7. Exercise Training for Physically Demanding Occupations Encompassing Load Carriage Tasks

Emergency responses in physically demanding public safety occupations frequently impose a strenuous physical demand on the individual. There is considerable literature to support applicant/incumbent fitness screening as an integral part of the pre-employment process for applicants in occupations such as military[57–59], policing[23], fire fighting[21,25,30,60–63], and correctional services[12]. In several such occupational activities external weights are carried for prolonged periods. Under such circumstances, high demands are placed on physical performance capacity. Structural fire fighters, for example, have to carry external loads due to breathing apparatus, personal protective equipment (PPE) and hand tools[60,61]. Similarly, military infantry and WFF are encumbered with heavy equipment required during operations[58,64]. Therefore, load carriage (LC) is an important, physically demanding occupational requirement and it can be an important factor during emergency situations and first-responder operations.

Research conducted by Ruby et al. identified aerobic fitness level (VO_2 max) and load carriage as critical factors to WFF safety[64] and reported that WFF are often expected to carry equipment from a vehicle or helicopter drop-zone to a fire line. The consequences of external LC include adverse effects on gait, metabolic efficiency, fatigue and increased risk of musculoskeletal injury[65]. In addition to load mass, its' positioning relative to the body governs the physiological impact of the load. Research in the field of occupational fitness screening has documented that candidates/incumbents must possess a sufficiently high aerobic capacity and musculoskeletal strength, power and endurance to effectively perform physically demanding tasks during emergency scenarios. The manual handling of materials involving lifting and carrying, is amongst the most common physically demanding tasks performed by individuals in these occupations. For this reason, the muscular strength of applicants is generally assessed, often using simulations of on-the-job tasks (ie. ladder lift, victim relocation, etc.). Load carrying performance can therefore be viewed as an important factor when assessing candidate's abilities.

Previous research illustrates that the consequences of LC have long been studied[66–71]. Physiological and biomechanical research has resulted in the development of general guidelines for best practices under varying situations. Improving load distribution across the body, the use of load carts and exercise training have been demonstrated to improve mobility and economy[58,72,73]. There are many ways to carry loads, and the technique used will depend on the characteristics of the load (size, shape, mass, etc.), the distance the load must be carried, previous (learned) experience, and the equipment available to the individual. There is little research on exercise training for wildland fire fighting and therefore in the context of physical employment standards, comparisons must be made with previous literature on LC and exercise training in other occupations.

The physical fitness of personnel in public safety occupations is an important attribute that may directly influence the effectiveness of the response. This is particularly true for many high-risk occupations (military, police, fire fighting), where heavy equipment and supplies must be carried frequently and for long durations. The high metabolic demands observed during occupational load carriage highlight the need for fitness screening tests to protect the employee from being overburdened and the employer from placing excess demands on the employee. The increased physical demands associated with LC are well established, what is lacking however, are practical guidelines on how to condition/evaluate individuals in physically demanding public safety occupations for LC tasks.

The most commonly studied modes of physical training include aerobic exercise, resistance training, interval training, high intensity interval training (HIIT), and task-specific LC exercise. There are several commonalities in the training requirements for physically demanding public safety occupations. In particular, they all require a combination of whole body muscle-specific aerobic, aerobic-anaerobic and anaerobic power and the job-related tasks involve vigorous compound movements using large muscle groups. Therefore, the components of an exercise training program should mimic these movements and the training intensity should simulate the demands of the tasks.

Knapik et al.[73] report on a systematic literature review examining the influence of physical training on LC performance. The most commonly studied modes of physical training included aerobic exercise, resistance training, HIIT, and LC exercise. For aerobic training, many studies used endurance running, with progressive overload achieved by increasing running distance[34,35]. Some studies include both HIIT training on flat surfaces and hills to challenge both the aerobic and anaerobic energy systems[34,35,74]. In the studies using HIIT training, progressive overload was achieved by increasing the number of intervals, reducing rest time between sets, and manipulating distances[34,75]. Types of resistance training can be highly variable. Kraemer et al.[76] used a linear program in which the number of sets and repetitions were the same throughout the training period and progressive overload was achieved by increasing the amount of weight lifted. Hendrickson et al.[34] used periodized resistance training in which the number of repetitions and loads were manipulated to emphasize muscular endurance (higher repetitions, lower resistance) at some points in the training program, and muscular strength (lower repetitions, higher resistance) at other points. A commonality between the reviewed studies is that a combination of upper body and lower body resistance training was used. Importantly, the inclusion of specific LC tasks was incorporated into the training program[74].

The results of the Knapik et al. review[73] indicate that combined modes of physical training can considerably improve LC performance. Substantial training effects were apparent when progressive resistance training was combined with aerobic training and that training was conducted at least three times per week over a minimum of four weeks. When progressive LC exercise was part of the training program, much larger training effects were obtained. Aerobic training alone or resistance training alone had smaller or more variable effects. The largest overall improvements in LC performance were found when once weekly progressive LC exercise was part of the training program[74]. Progressive LC exercise likely involves the skills, muscle groups, energy systems and related components of fitness that are important for the performance of the task. However, physical training without LC is also beneficial for improving LC performance, albeit to a lesser extent. Effective gains in LC performance were observed with combined resistance-aerobic training (running), suggesting that a combination of strength and cardiovascular fitness are important components of an overall program to improve LC performance.

While these findings suggest that physical conditioning may improve LC task performance, to be of practical value, the exercise prescription needs to be applied in a manner which is consistent with the approach used for conventional exercise training. Using the common FITT principle (Frequency, Intensity, Time/Duration, Type/Mode)[77] is one such approach. With respect to frequency, it is recommended that LC be incorporated once weekly, or at a minimum twice monthly[73]. To stimulate aerobic fitness adaptations, the LC intensity needs to be sufficient enough to elicit a training response. A training intensity between 55/65-90% of age-predicted maximum heart rate (HRmax) or 40/50-85% of HR-Reserve for 20-60 min, 3-5 times per week has been recommended to improve cardiorespiratory fitness[78]. It is recommended that the training program needs to ensure that individuals are being trained to carry loads at the intensities that are required for operations, while being mindful of the fact that intensive LC training can result in the potential for injury[59]. The considerations for time (distance) include both intensity and outcome requirements. Short duration, high intensity training can be used to develop the ability to move rapidly for finite periods, long duration sessions are needed to develop cardiovascular endurance. The principle of specificity identifies the need for training to meet the requirements of the performance outcome. However, the concept of concurrent training also suggests that other forms of physical training may be useful to supplement the training program. The results of the studies presented above suggest that exercise which increases upper body and lower body strength, aerobic fitness and has a LC component may be of benefit for LC performance. Therefore, the exercise prescription structured in Appendix G is consistent with the literature citing recommendations for occupations requiring LC performance.

1.2.8. Current Best-Practice Consensus

Physical employment standard research has been of interest for several decades[9,21,23], notably in public safety occupations such as, policing, structural fire fighting and military. In theory, physical employment standards should be able to differentiate between those candidates who are capable of meeting the physical demands of the job from those who are not. The threat to life and property associated with of improper employment decisions are significant. Until recently, there have been few existing resources to advance knowledge and dissemination of best practice guidelines or methodology, despite there being severe consequences of poor practice and placing a significant financial burden on employers. Much of the research in the occupation-specific employment testing field has not been published in peer reviewed journals, which for many reasons is problematic.

More recently however, there has been greater effort to address critical questions in the field of physical employment standards. In August 2012, The University of Wollongong hosted the first dedicated conference on the development, implementation and justification of employment standards within physically demanding occupations[27] (Canberra, Australia). A major outcome of the conference was a series of reviews that would influence the development and implementation of valid physiological employment standards. In August 2015, *The Second International Conference on Physical Employment Standards*[54] was hosted in Canmore, Canada. The second conference was highlighted by a series of invited review papers, knowledge translation sessions, and original research presentations. The outcomes of which represent an updated state of knowledge which includes recommendations and current best practices; the first includes an updated framework for developing physical employment standards (Table 1). Originally, developed by Gledhill and Bonneau[3] and referred to throughout the manuscripts as the

BFOR Consensus Forum Template, the updated framework was developed to promote continuity and consensus amongst researchers.

Table 1. Modified procedural framework for developing employment standards and cut-scores for physically demanding jobs.

Phase	Step	Description
1	1	Justify establishing an employment standard
	2	Appoint a management team with appropriate knowledge and experience
2	3	Familiarize the research team with job requirements and duties
	4	Preliminary job review and analysis
	5	Identify the essential and physically demanding tasks
	6	Approve and validate the list of essential and demanding tasks
	7	Produce a subset of tasks using employee surveys or focus groups
3	8	Characterize those tasks: observe, measure, quantify
	9	Identify the criterion tasks
	10	Approve and validate the criterion tasks
4	11	Develop physiological screening tests
	12	Standardize screening tests, including administrative procedures
	13	Approve and validate screening tests and procedures
5	14	Evaluate screening test validity and reliability
	15	Approve standard development for test performances
6	16	Develop test performance standards and cut-scores
	17	Approve and validate test performance cut-scores
	18	Implement screening test(s)
7	19	Develop instructional and preparatory guidelines for candidates
	20	Review the screening process and outcomes as the job changes

Reproduced from Taylor et al.[25] and Petersen et al.[26]

Additional recommendations from the Conferences on physical employment standards include the clarification of terminology and the clear and consistent use of terms and phrases. For example, *'performance standards'* are defined as qualitative descriptions of the necessary attributes (knowledge, skills, competencies) exhibited by individuals at distinct performance levels[26,28]. In the context of physical fitness screening, the standards describe levels of capability that make a distinction between acceptable and unacceptable performance with respect to the safe and efficient performance of the critical job demands[26,28]. These descriptions do not include the setting of pass and fail scores. *'Cut-scores'* refer to a point (usually time) used to differentiate the levels of performance described in the performance standards and to identify acceptable and unacceptable performances[26,28]. The performances of individuals at, or below, a cut-score should be noticeably different from those above. Lastly, the term *'minimal standard'* which is common in occupational physiology, implies a level of performance that has been considered necessary to achieve a performance standard. It has been recently argued that "minimal" implies a low level of performance when in reality it should indicate a reasonably necessary expectation for safe, efficient and effective work performance. Importantly, the job requirement and associated performance requirement may indicate that high levels for some physiological components are necessary. Therefore, it is recommended that *minimal standard* be replaced with *acceptable standard*[26,28]. Additionally, the term physical employment standards is commonly accepted to include both physical and physiological attributes, where 'physical fitness' refers to morphological characteristics, such as body mass, height, percent body fat (e.g. body composition). 'Physiological fitness' refers to musculoskeletal components such as strength, power, endurance, range of motion, and aerobic plus anaerobic fitness. We therefore use 'physical employment standards' to broadly describe the physical and physiological employment standards and exercise considerations throughout the manuscripts. Where applicable, the following recommendations have been used throughout this manuscript to reflect the current best practice in the field of physical employment standards.

CHAPTER 2: OVERALL STUDY DESIGN and METHODOLOGY

SUMMARY

The following chapter outlines common methodologies across all phases of the project. The specific outcomes of each project phase are different and, thus, detailed descriptions of all methodologies specific to each phase are included in the manuscript for each study.

2.1. OVERALL RESEARCH METHODOLOGY

2.1.1. Overall Objectives

The Wildland Fire Fighter Exchange Fitness Test (WFX-FIT) project has three major objectives; the first being the identification and characterization of the important, physically demanding and frequently occurring tasks experienced by IA WFF. The second objective of the project is the development of the WFX-FIT protocol and the establishment of construct and content validity. Construct validation was assessed by quantifying that the physical/physiological demands involved in performing the test were the same as the physical/physiological demands encountered while performing the associated on-the-job tasks. Content validation (face validity) was determined by administering a questionnaire to subject matter experts (experienced incumbent workers) following their completion of the protocol. The third and final aim of the WFX-FIT project was to examine whether the protocol could adversely impact a sub-group of the WFF population, traditionally female applicants. When adverse impact is evident, the employer must either accommodate this sub-group or demonstrate that accommodation is not possible because the safety risk of lowering the standard would constitute undue hardship[4,6,10,12,14,50,60]. Therefore the final objective was to determine whether female participants are at risk of adverse impact and, if so, can familiarization and exercise training be used to provide accommodation to overcome the adverse impact. The WFX-FIT Project and associated Manuscript involve Studies 1-3, detailed below.

PDA	Create initial task list, scenario development, focus group interviews: *October to December, 2011*
PDA	Job analysis questionnaire and Identification of the tasks: *September to December, 2011*
Study 1	Characterization of physically demanding tasks: *May to June 2011*
Study 2	Construction and validation: *June to July 2011*
Study 2	Establishing criterion-related reliability: *July 1-14 2011*
Study 2	Derivation of performance standards: *July to August 2011*
Study 3	Examining the potential for adverse impact (training study): *September to May 2012-2013, September to May 2013-2014, September to May 2014-2015*

2.1.2. General Hypothesis

It is hypothesized that given the unique and sometimes arduous terrain differences across Canada, performing wildland fire fighting tasks in steep/mountainous jurisdictions such as British Columbia (BC) will pose the greatest challenge to cardiovascular fitness and that the BC performance standard will be the National Exchange Fitness Standard (National WFX-FIT). It is also hypothesized that the WFX-FIT assessment protocol will have high content and construct validity and although it may have an adverse impact on female applicants, familiarization practices and five weeks of customized exercise training will enable participants to overcome the adverse impact.

2.1.3. Statement of Ethics

The WFX-FIT project adhered to guidelines that are in accordance with the York University Human Participants Review Subcommittee and York University Biosafety regulations. All participants in the project provided written informed consent. All protocols were reviewed and approved by the York University Human Participants Research Sub-committee prior to participant recruitment for each phase of the project. Certificates of approval are included in Appendix A.

2.1.4. Participant Recruitment and Screening

During all phases of the research project, participants provided written informed consent and exercise clearance for physical activity/exercise participation via the Physical Activity Readiness

Questionnaire for Everyone (PAR-Q+), and if necessary the ePARmed-X (www.eparmedx.com). The PAR-Q+ consists of seven questions designed to identify persons for whom an increase in physical activity may be hazardous, based on prior health status and symptoms of limiting conditions[79,80]. Informed consent documents and PAR-Q+ are included in Appendix B-C.

During Study 1 and 2 (Manuscripts II; *Identification and Characterization*, and III; *Construction and Validation*), all participants in the WFX-FIT project were incumbent WFF who took part voluntarily following PAR-Q+ screening and their provision of Informed Consent. The Canadian Interagency Forest Fire Centre (CIFFC) was responsible for co-ordinating recruitment strategies across provincial jurisdictions and securing the requisite number of volunteers. Considerable effort was made to involve a sample of WFF in all phases of the project that were representative of the sex, age and Aboriginal status of the incumbent WFF population across Canada.

During Study 3 (Manuscript IV; *Familiarization and Training*), recruitment was conducted throughout the York University campus by class announcements, signage, networking opportunities with student organizations and email communications. The study participants represented students from various Faculties, staff and non-academic professionals. Considerable effort was made to ensure a broad participant representation, not a convenient and certainly not a fit sample. Participants maintained their current physical activity/exercise levels, including those participants who were students in Kinesiology and Health Science who are required to participate in active practica. Participants were selected for inclusion if they met the following criteria; no previous WFF work history or knowledge of the job-specific physical demands of wildland fire fighting and were not engaged in a structured exercise program prior to or during the study (e.g. varsity athletes).

2.2. MEASUREMENTS

2.2.1. Field Measurements; Characterization and Validation

In Manuscript II; *Identification and Characterization*, the characterization involved the use of precision measurement devices to determine *i)* the weight of wildland fire equipment commonly carried by WFF during the IA of a wildland fire, *ii)* the forces required in tasks such as laying dry hose and advancing charged hose and *iii)* the energy demands associated with performing the tasks. The weights and forces were assessed using a specialized strength dynamometer (Back-A Strength Dynamometer, Takei, Japan). The energy demands were assessed by instrumenting the participants with heart rate (HR) monitors (Polar Electro KP4, Kempele, Finland) and a portable oxygen utilization (VO_2) measurement apparatus[81] (Cosmed Fitmate PRO, Rome, Italy) that recorded breath-by-breath VO_2 assessments at 5 second intervals. Standard equipment calibrations were performed prior to instrumenting each participant and the participating WFF also provided subjective RPE ratings while performing each task (Borg Scale, 6-20)[82].

In Manuscript II; *Identification and Characterization*, the energy demands associated with performing the tasks were assessed by instrumenting the participants with the same equipment utilized in the characterization: HR monitors (Polar Electro KP4, Kempele, Finland) and a portable VO_2 measurement apparatus[81] (Cosmed Fitmate PRO, Rome, Italy). The participating WFF also provided subjective RPE while performing each task (Borg Scale, 6-20)[82]. The content validity of the WFX-FIT was established based on objectively-scored feedback from incumbent WFF[7,14]. That is, Likert Scale ratings ranging from 1 (strongly disagree) to 7 (strongly agree) were utilized to solicit feedback regarding whether the demands of performing the WFX-FIT accurately reproduce the tasks, physical demands, task sequencing and work rate experienced on the job.

2.2.2. Physical and Physiological Fitness Measures

In Manuscript IV; *Familiarization and Training*, physical and physiological fitness were assessed on participant's pre and post a five week intervention. The assessment included measures of anthropometry, body composition, resting heart rate (HR) and blood pressure as well as upper body strength, lower body power and aerobic fitness.

Resting blood pressure and resting HR using the BpTRU™ device (Medical Devices Ltd. *BC Canada*). Body composition was assessed using traditional techniques; height (m) was measured using a wall-mounted stadiometer (Fitness Precision, *Toronto, Ont*.), body mass (kg) and percent body fat were assessed using a bioelectric impedance instrument (Tanita Scale, model TBF-612, *Arlington Heights, Ill*.), BMI (kg/m^2) was calculated from height and body mass. Waist circumference (cm) was measured using the National Institutes of Health landmark[83] using anthropometric tape. Sum of five skinfolds (mm) were derived from the biceps, triceps, subscapula, iliac crest and medial calf skinfold landmarks using a Harpenden calliper (Baty International, *West Sussex, UK*). Musculoskeletal fitness components (muscular strength, endurance and power) were quantified by measuring grip strength using a hand-held dynamometer (Smedley Spring Dynamometer, *Ventura, Ca.*), pushups, vertical jump (Vertec, Sports Imports, *Columbus, Ohio*) and upper body maximal push-pull force using a force gauge[84].

Leg power was assessed with a maximal vertical jump recorded to the nearest 1.3 cm (0.5 in.) using the Vertec jump and reach device. Leg power in watts was calculated from jump and reach height minus standing reach height using the Sayers equation[85]. Upper body push-pull force was measured using a force meter attached to the torso by a harness and incorporates a highly accurate digital caliper to quantify the precise amount of spring compression during a push or pull[84].

Maximal oxygen uptake (VO_2max) was measured on a treadmill using an incremental to maximum plus supramaximal protocol with direct gas analysis using the open circuit technique[86,87]. Expired gas was directed through a 3.5 cm (1.4 in) diameter corrugated plastic hose into a 120 L (31.7 gal) Tissot gasometer (Warren E. Collins Ltd., *Braintree, Mass.*). Immediately upon completion of the gas collection, expired air was analyzed for the fractional concentration of oxygen (F_EO_2) and carbon dioxide (F_ECO_2) via rapid response analyzers (Applied Electrochemistry, Model S-3A and CD-3S respectively, *Sunnyvale, Cal*.). The attainment of VO_2 max was confirmed when VO_2 achieved a plateau (within 150 $mL·min^{-1}$ of the previous workload) or decreased with progressively increasing workloads[77,86,87].

2.3. RESEARCH TEAM

The research team for this project consists of members with a background in establishing job specific physical employment standards for physically demanding public safety occupations. Members of the research team include:

- Robert Gumieniak, MSc, PhD *Candidate*
- Norman Gledhill, PhD
- Veronica Jamnik, PhD
- Jim Shaw, MEd
- Research assistants; Chris Korte (BA), Michael Haddock (MFSc), Colby Hathaway (MFSc), Chip Rowan (PhD, MFSc).

Dr. Gledhill and Dr. Jamnik have considerable expertise in the field of occupational fitness testing and have been responsible for the development of fitness screening protocols for Police Constables (Ontario and Alberta), Structural Fire Fighters, Correctional Officers, Emergency Service Maintainers (Nuclear Power Plant Fire Fighters), and Wildland Fire Fighters (Ontario). Drs. Gledhill and Jamnik assisted with participant recruitment, coordination of travel and all intangibles relating to Studies 1 and 2. Mr. Jim Shaw has expertise in leading focus group discussions, task list identification and analysis and was the advisor for the PDA. Mr. Gumieniak lead and co-ordinated Studies 1-3 and was the contributor to all project phases. Each research assistant assisted during the various project steps/phases. They were all Certified Exercise Physiologists and were selected to participate in the project based on their familiarity with the project investigators, familiarity with the measurement equipment and proficiency in physical fitness assessments.

The coordination of personnel, scheduling and recruitment from all fire jurisdictions across Canada was arranged by Mr. Serge Poulin, *CIFFC Operations Manager*. Mr. Poulin served as the project liaison and facilitated correspondence with the research team and local fire jurisdictions. The characterization of physically demanding tasks identified in the PDA began in May 2011 and took place in Fredericton and Bathurst (NB), Wayakwin (SK) and Merritt, Vernon, Salmon Arm and Kamloops (BC). The ambient temperature during this period was 11-18°C. The development, validation and reliability phases of the protocol occurred during the months of June and July 2011 and involved incumbent WFF in Sudbury and Dryden (ON), Prince George, Fort St. John (BC) and Whitehorse (YK). During the derivation of performance standards phase, scheduled for July and August 2011, incumbent WFF in Swan Hills (AB), Prince Albert, La Ronge, and Buffalo Narrows (SK), Snow Lake (MB), Hay River and Yellow Knife (NWT), Maniwaki and Roberval (QC), Charlottetown (PEI), Truro and Shubenacadie (NS), Fredericton (NB) and Gander and Corner Brook (NFL) were recruited to participate. For the final phase of the project; examining the potential for adverse impact, and evaluating familiarization and training as accommodation, York University community members were recruited between the years 2012-2015.

2.4. MANUSCRIPT I – Objectives and Hypothesis

Objectives

To identify the overriding considerations in the development of a physical employment standard, the categories of physical employment standards, the scientific considerations in developing a physical employment standard, to establish performance standards and associated cut-scores, and to meet the Meiorin Decision requirements to qualify as a BFOR.

Hypothesis

Manuscript I is intended to be a summary of scientific best practice and methodology for developing a BFOR, therefore no hypothesis is provided.

2.5. MANUSCRIPT II – Objectives and Hypothesis

Objectives

The first objective of this investigation was to undertake a PDA to compile a rank-ordered list of the most important, physically demanding, and frequently occurring tasks encountered by WFF during an IA emergency wildfire response together with the associated arduous terrains that are encountered across Canada during a wildfire response. To confirm the rank order of the demands of the tasks and terrains provided by the PDA, the second objective was to characterize the weights, forces, heart rates (HR), oxygen utilization (VO_2) and ratings of perceived exertion (RPE) while incumbent WFF were performing these tasks in each of the identified arduous terrains.

Hypothesis

It was hypothesized that given the substantial terrain differences across Canada, performing wildland fire fighting tasks in steep/mountainous jurisdictions such as British Columbia will pose the greatest physical challenge and that the British Columbia performance standard will become the National WFX-FIT performance standard.

2.6. MANUSCRIPT III – Objectives and Hypothesis

Objectives

The first objective of this investigation was to develop a draft WFX-FIT protocol based on the outcomes of the PDA and characterization, then to refine the protocol by subject matter expert consensus as required. The second objective was to establish the content and construct validity of the WFX-FIT protocol using best practice scientific methodology and lastly, to establish the performance standards and cut-scores of the WFX-FIT based on the self-selected safe and efficient performance of incumbent female and/or older male WFF.

Hypothesis

The investigators hypothesized that the WFX-FIT assessment protocol would have high content and construct validity and that the jurisdictional/provincial cut-score for BC, based on the performance of safe and efficient female and/or older male incumbent WFF in steep mountainous terrain, will be the national exchange fitness standard.

2.7. MANUSCRIPT IV – Objectives and Hypothesis

Objectives

The objectives of this investigation were *(i)* to establish the reliability of the WFX-FIT circuit, *(ii)* to determine if the Ontario WFX-FIT performance standard has an adverse impact on female participants, and *(iii)* to determine the extent to which *a)* test familiarization, *b)* customized exercise training and *c)* weekly WFX-FIT circuit performance trials impact WFX-FIT completion times, can overcome adverse impact.

Hypothesis

It was hypothesized that the WFX-FIT circuit would have high test-retest reliability. In addition, although the WFX-FIT circuit could have an adverse impact on female participants, familiarization and five weeks of customized exercise training would enable female candidates to overcome any adverse impact of the Ontario WFX-FIT.

CHAPTER 3

MANUSCRIPTS

MANUSCRIPT I

Physical Employment Standard for Canadian Wildland Fire Fighters***; Physical Fitness Bona Fide Occupational Requirements for Safety-Related Physically Demanding Occupations – Test Development Considerations***[1]

Robert J Gumieniak, MSc., Norman Gledhill, PhD., Veronica K Jamnik, PhD.[2,3]

OVERVIEW

To qualify as a Bona Fide Occupational Requirement (BFOR), a Job Specific Physical Fitness Protocol (physical employment standard) must conform to the requirements delineated in the 1999 Supreme Court of Canada's Meiorin Decision and the 2004 amendment to the Criminal Code of Canada. It is also highly recommended that the development of BFORs follow the template created in the 2000 BFOR Consensus Forum with attention to the precedent established in the 2002 decision of the Ontario Human Rights Commission. Validation of a physical employment standard is achieved by a combination of construct and content validation procedures and reliability is established via a test-retest process. To overcome the potential adverse impact of a physical employment standard on a sub-group of participants, it is possible to markedly improve the ability of a participant to pass a BFOR standard by engaging in test familiarization opportunities and in a job-specific physical fitness training program, which together can provide "accommodation" for the adverse impact.

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3.1. INTRODUCTION

3.1.1. Overriding Considerations in the Development of a Physical Employment Standard

It has become common practice in public safety occupations to establish a job-specific physical employment standard and performance standard as a Bona Fide Occupational Requirement (BFOR) that conforms to legislation, court judgments and Human Rights Tribunal decisions. A physical employment standard can only be implemented for occupation in which “ineffective job performance can result in a loss of life or property”[12].

Since the safety of the worker, co-workers and the general public depends on successful job performance in public safety occupations, it is essential that participants have the physical capabilities required to meet the demands of the job. The intent of a physical employment standard is to determine whether an applicant or incumbent possesses the necessary physical attributes to safely and efficiently perform the critical, physically demanding on-the-job tasks encountered in a public safety occupation[12]. This distinction is based on the 1988 Government of Canada definition that a BFOR is a condition of employment imposed in the belief that it is necessary for the safe, efficient and reliable performance for the job and which is objectively, reasonably necessary for such performance[19] . The 1999 Supreme Court of Canada’s Meiorin Decision[10] obliges employers to follow a three step process to prove that a BFOR standard is not discriminatory. To do so, an employer must ensure:

1. That the standard was adopted for a purpose rationally connected to the performance of the job;
2. That the standard was adopted in an honest and good faith belief that it was necessary to the fulfillment of that legitimate work-related purpose; and
3. That the standard is reasonably necessary to the accomplishment of that legitimate work-related purpose. To show that the standard is reasonably necessary, it must be impossible to accommodate individual employees without imposing undue hardship on the employer.

In addition, a 2004 amendment to the Criminal Code of Canada legislated that employers and/or management would be deemed criminally negligent should they fail to ensure that “when public safety workers require the physical and physiological attributes necessary to avoid foreseeable risk, an employer has the duty of care to ensure that those physical and physiological attributes are present”[8].

The 2000 BFOR Consensus Forum provided detailed guiding principles for establishing a physical employment standard that will qualify as a BFOR (Table 1)[3]. Since the validity and reliability of a BFOR must be founded on credible scientific evidence, this led to the application of scientific principles to document the validity and reliability of physical employment standards.

Table 2. Template for developing and validating a BFOR.

1	Justify the need for a BFOR and clarify underlying issues.
2	Form a project management team.
3	Job familiarization including relevant professional manuals, reports and subject matter experts.
4	Job review: in the order of critical/essential, physically demanding and frequently occurring tasks.
5	Representative subset of physically demanding tasks,
6	Characterization of tasks (simulated): time, distance, weight, measured forces etc.
7	Development of test protocol: job simulation, fitness components or combination.
8	Standardization of test protocol: including consistent instruction.
9	Establish scientific accuracy of test protocol.
10	Develop performance standards (mean+/-SD) and Evaluate incumbent pass rate. - Rationally connected to work - Employed in good faith - Address adverse impact, accommodation, undue hardship
11	Implement test protocol.
12	Ongoing review: to accommodate the changing workforce.

Adapted from Gledhill and Bonneau[3] 2000 BFOR Consensus Forum.

3.1.2. Categories of Physical Employment Standards

There are three different categories of physical employment standards. Fitness component or construct validity physical employment standards employ standardized laboratory fitness tests to evaluate the physical attributes necessary for safe and efficient job performance. The tests do not simulate the specific work demands or force applications used on the job, instead they assess the strength/force applications required by the participant to accomplish the demands of the job. Examples of construct validity test components are; pushups, hand grip, bench press and the aerobic shuttle run[88]. Content validity physical employment standards are composed of task simulations that replicate the work demands and force applications of the job. Job simulation tests are generally preferred over fitness component tests because participants or arbitrators can easily see the relationship to the job. The task simulations in a physical employment standard can be performed in a discrete or serial manner. Discrete tasks are evaluated independently while serial tasks incorporate several task simulations into a continuous circuit with a single overall completion time standard. An example of a content validity test is that for nuclear emergency response incumbents which incorporates several emergency task simulations into a continuous circuit that must be completed in 11 minutes or less.

Hybrid physical employment standards incorporate a combination of construct and content components[3]. Examples of hybrid tests include the Physical Readiness Evaluation for Police and the York University Structural Fire Fighter Applicant Fitness Assessment. These protocols combine a task simulation circuit with a valid and reliable assessment of aerobic fitness using either a directly measured VO_2max or the estimation of VO_2max from the Leger 20m shuttle run[88]. Each of these three test methodologies has associated strengths and weaknesses. However, in all cases, to qualify as a BFOR it must be demonstrated that the test is rationally connected to the accomplishment of the job and that the standard is reasonably necessary to the accomplishment of that legitimate work-related purpose[3].

3.1.3. Scientific Considerations in Developing a Physical Employment Standard

To qualify as a BFOR, a physical employment standard must be valid and reliable. Test validation is customarily accomplished using two well-established approaches. The first, construct validation, refers to scientifically quantifying that the physical demands involved in performing the test are the same as the physical demands that are encountered while incumbents are performing the related on-the-job tasks. The content validity (also called face validity) of a test can be determined by administering a questionnaire to the subject matter experts (experienced incumbent workers) following their completion of a physical employment standard. A Likert-type scale from 1 (strongly disagree) to 7 (strongly agree) is generally used to solicit the workers' perceptions of the "likeness" of the test to the actual on-the-job tasks as well as the appropriateness of the physical employment standard to assess the candidate's ability to accomplish the job safely and efficiently.

To establish test-retest reliability, participants undergo a test and retest on the physical employment standard on two separate days. A reliable test will produce similar results on the test and retest. Reliability is tested statistically by evaluating the repeat determinations for a high r^2 (>0.7)[89]. Additional steps to enhance reliability include preparing a standardized script for test administrators to follow, routinely maintaining/calibrating equipment and ensuring appropriate test administrator training and related ongoing professional development. Collectively, these initiatives ensure standardized administration of the physical employment standard to provide an equal and unbiased assessment of the candidates.

3.1.4. Establishing a Cut-Score for a Physical Employment Standard

Physical employment standards must embody appropriate standards of acceptability that are the same for all participants. The development of such standards must be based on the performance of experienced safe and efficient incumbent workers[21,60]. In accordance with the Meiorin requirements, the task simulations must be criterion based; founded on job performance, not based on the physical characteristics of the participants[3]. The landmark Meiorin Decision on BFORs stipulated that, for a fitness test to qualify as a BFOR, the associated performance standard must be based on the performance of any sub-group of workers in that job who perform the job safely and efficiently but have different physical attributes than the majority group of the workers[10]. This requirement was made in specific reference to a female claimant whose grievance was the basis of the Meiorin case. Generally, the sub-group of workers who fit the description of this Meiorin requirement are the female incumbent workers.

The statistical computation that is conventionally applied when deriving performance standards for completion of a circuit to qualify as a BFOR is the mean+1 standard deviation of the sub-group's circuit completion time, which, in a one-tailed distribution, incorporates 83.3% of the participants' completion times. In addition, it has recently been established that after participants are orientated or familiarized to a physical employment standard they have an improvement in completion time of 10-12% and therefore this improvement is taken into account in calculating a performance standard[12,13].

3.1.5. Meeting the Meiorin Decision Requirements for a BFOR

Passing the first two Meiorin Decision tests to qualify as a BFOR is relatively straightforward. If the methodology described above is adhered to, courts will easily be persuaded that a physical employment standard and the associated performance standard were adopted "for a purpose rationally connected to the performance of the job" and that the employer "did so in an honest and good faith belief that it was necessary to meet the physical demands encountered by workers on the job". However, passing the third Meiorin test necessitates considerably more attention; the employer must show that it is impossible to accommodate an individual employee who is adversely impacted without imposing undue hardship on the employer.

Adverse impact is defined as; "the circumstance in which group differences in performance, relative to common standard, results in a disproportionate failure rate in a sub-group"[9–12] . Although the determination of a "disproportionate" failure rate is subject to court judgments, researchers and courts have commonly recognized the 80% rule, which specifies that adverse impact exists when the pass rate of a sub-group of participants is less than 80% of the pass rate of the majority group of participants. When adverse impact is evident, the employer must either accommodate this sub-group or demonstrate that accommodation is not possible because the safety risk of lowering the standard would constitute undue hardship[10,50].

It is important to reiterate that a physical employment standard can only be implemented for workers in occupations in which the personal safety, the safety of a co-worker or the general public could be compromised by inefficient performance or failure to complete the required task. If the approach described above is utilized to establish a performance standard, then by design the standard cannot have an adverse impact on the sub-group of female workers. Nevertheless, it is still possible that an incumbent or applicant might not meet the performance standard.

At the BFOR Consensus Conference, it was concluded that if the accommodation provided for adverse impact undermined the due diligence responsibility of the employer, this constitutes undue hardship[3,29]. Physical employment standards are based on critical, physically demanding emergency tasks in which personal safety, the safety of a co-worker or the safety of the general public may be compromised by inefficient performance or failure to complete. Lowering a physical employment standard to provide accommodation could result in a front line worker being unable to complete critical tasks during an emergency with a possible catastrophic consequence, for which the employer would likely be deemed liable[29]. That is, lowering the performance standard would constitute undue hardship because the employer has a due diligence responsibility to ensure that all workers are capable of meeting the emergency demands encountered on the job[3,29]. In fact, under the 2004 revision to the Criminal Code of Canada, employers can be deemed criminally negligent if they fail to take reasonable measures to ensure the safe and efficient performance of workers[8,12].

In responding to a claimant's grievance for accommodation from adverse impact, an employer argued at a 2002 Human Rights Commission hearing that participants have the capacity to markedly improve their ability to pass a physical employment standard by engaging in both test familiarization opportunities and a customized training program. Citing evidence from the physical fitness training literature, the employer proposed that the resultant improvements would be sufficient to ameliorate the adverse impact on female participants. This argument was accepted and the grievance of the claimant was dismissed by the Ontario Human Rights Commission[20]. Subsequently, researchers have confirmed experimentally that it is possible through familiarization and physical fitness training to overcome the potential adverse impact of a physical employment standard on correctional officer applicants[12] and on nuclear power emergency response incumbents[13].

MANUSCRIPT II

Physical Employment Standard for Canadian Wildland Fire Fighters*; Identifying and Characterizing the Important, Physically Demanding and Frequently Occurring IA Response Tasks in Wildland Fire Fighting*[4]

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OVERVIEW

The Canadian Interagency Forest Fire Fighter Centre (CIFFC) must ensure that Initial attack (IA) wildland fire fighters (WFF), who can be deployed to fight fires anywhere in Canada, possess the physical ability to perform emergency WFF tasks safely and efficiently in all possible terrains. A major problem is that IA WFF from fire jurisdictions that do not have mountains or muskeg are often unable to meet the demands of fighting wildland fires if they are exchanged to provinces or territories that have these arduous terrains. The development of the IA WFF Fitness Test (WFX-FIT) began with a physical demands analysis (PDA) to itemize all IA emergency tasks performed and terrains encountered by WFF across Canada. Experienced WFF (subject matter experts) from all jurisdictions rank-ordered a list of the most demanding emergency tasks and also identified steep mountains (British Columbia), muskeg (Saskatchewan) and rolling hills plus forest blow-downs (New Brunswick) as the most challenging terrains. The oxygen cost (VO_2) while performing the tasks identified as the most demanding was measured on a representative sample of incumbent WFF in all arduous terrains. Example VO_2 values while performing the hose pack back carry were 40±7 $mL \cdot kg^{-1} \cdot min^{-1}$ in British Columbia, 34±5 $mL \cdot kg^{-}$

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$^{1}\cdot min^{-1}$ in Saskatchewan and 34±2 $mL\cdot kg^{-1}\cdot min^{-1}$ in New Brunswick. Back-carrying and hand-carrying a 28.5 kg pump, back-carrying a 25 kg hose pack and advancing charged hose were identified in the PDA and confirmed in the characterization as the most demanding emergency IA WFF tasks. These tasks must become the basis of the WFX-FIT test. As well, performing the same emergency IA WFF tasks was significantly more demanding in British Columbia than in New Brunswick and Saskatchewan *($p \leq 0.05$)*, and the higher demands of arduous terrains must be taken into account when developing the WFX-FIT protocol.

Key words: BFOR, fitness screening, public safety occupation, job-related, arduous terrains

3.2. INTRODUCTION

Wildland fire fighting is a physically demanding public safety occupation that is conducted during 6 to 7 months of the year throughout Canada. To illustrate the gravity of fighting wildland fires across Canada, in 2013 a total of 6479 wildland fires that affected 4.2 million hectares of land were reported. Of these fires, 1854 were in British Columbia and 1214 were in Alberta - two mountainous fire jurisdictions. As well, over the ten year period 2003-2013, British Columbia and Alberta were the most fire-ravaged jurisdictions in Canada. The immediate response to suppress a wildland fire is called an Initial Attack, and this emergency response is carried out by Initial Attack Wildland Fire Fighters (IA WFF). To combat the disproportionately high number of fires in these jurisdictions (also referred to as agencies or provinces/territories), the exchange of IA WFF (also known as Type 1 WFF among agencies is often relied upon, and in 2013, 997 IA WFF were exchanged to other jurisdictions in Canada[90].

The Canadian Interagency Forest Fire Centre Inc. (CIFFC) is a federal non-profit corporation operated by the provincial and territorial wildland fire management agencies. The primary function of CIFFC is to coordinate wildland fire fighting resources across Canada. The seasonal nature of wildland fire fighting, plus the impact on job demands imposed by regional differences in terrain are major concerns for CIFFC. CIFFC has a due diligence responsibility to both WFF workers and the general public to ensure that all WFF who are exchanged across Canada are capable of meeting the physical demands that could be encountered in all fire jurisdictions[14,29]. Therefore, for WFF to be eligible for exchange to fight wildland fires in all fire jurisdictions across Canada, CIFFC must be confident that WFF are able to meet a national exchange fitness (National WFX-FIT) standard.

A job-related fitness standard can only be required for occupations in which "ineffective or inefficient job performance can result in loss of life or property"[4,12,14,21]. Since the safety of the WFF, co-workers and the general public depends on successful job performance, it is essential that WFF have the physical capabilities required to meet the demands of the job[6,10]. The intent of a National WFX-FIT standard is to determine whether an applicant or incumbent possesses the necessary physical abilities to safely and efficiently perform the critical, physically demanding on-the-job tasks encountered during the IA of a wildland fire[4,5,14,41,60]. This requirement conforms to the 1988 Government of Canada's definition that a bona fide occupational requirement (BFOR) is a condition of employment imposed in the belief that it is necessary for the safe, efficient and reliable performance of the job and which is objectively, reasonably necessary for such performance[19]. Owing to the 2004 revision to the Criminal Code of Canada, both CIFFC and fire agency management could be deemed criminally negligent if they failed to take reasonable measures to ensure the safe and efficient performance of WFF[4,8,14]. Lowering the physical fitness requirements for an individual WFF who cannot meet the standard could compromise the safety of the WFF, co-workers and the general public which would undermine the due diligence responsibility of CIFFC[4,11,12,14].

Historically, fire jurisdictions across Canada have not utilized a standardized fitness screening protocol for the annual hiring and re-hiring of WFF. Instead, each agency has implemented a jurisdictional fitness screening protocol that often included the one-mile timed pack hike test[1] together with selected job-related tasks[2]. In 2010 CIFFC resolved that for WFF to be eligible for exchange across Canada, member agencies must provide evidence that the WFF is capable of meeting the physical demands encountered during the worst case emergency scenario of an IA response to a wildland fire conducted in the most arduous terrains across Canada. This decision led to the need to develop National WFX-FIT standard for IA WFF.

Wildland fire fighting involves carrying heavy fire suppression equipment over long distances while encumbered with personal protective equipment (PPE), and performing hand tool work in difficult terrains with high temperatures. To identify candidates who are able to safely and efficiently perform the physically demanding wildland fire fighting tasks encountered during emergencies, CIFFC contracted a research group with demonstrated expertise in establishing job-specific physical fitness screening protocols that qualify as a BFOR, to develop a valid and reliable fitness screening test for IA WFF to qualify for exchange across Canada.

CIFFC required that the WFX-FIT protocol be designed so that it would be legally defensible from a Human Rights perspective and be in accordance with the Supreme Court of Canada's Meiorin Decision[10]. In addition, the test had to conform to the '*best practices*' template for developing physiological employment standards to qualify as a BFOR[4,12,14]. After scrutinizing the Meiorin Decision, it was the consensus of the Forum participants that to *qualify* as a BFOR, a physical employment standard must be based on both "safe" (properly executing the critical life threatening physically demanding emergency tasks) and "efficient" (completing these tasks in a time frame that is suited to the emergency circumstance) job performance. Briefly, Step 1 of the template involves the formation of a project management team (PMT) including all stakeholders with age and sex considerations. Step 2 requires familiarization with all of the job descriptions and associated requirements. Step 3 necessitates conducting a physical demands analysis (PDA) of all IA emergency tasks. Step 4 establishes a representative rank-ordered subset of the critical, most physically demanding and frequently occurring IA emergency tasks, and Step 5 is the physical and physiological characterization of this subset of tasks.

3.2.1. OBJECTIVES

The first objective of this investigation was to undertake a PDA to compile a rank-ordered list of the most important, physically demanding, and frequently occurring tasks encountered by WFF during an IA emergency wildfire response together with the associated arduous terrains that are encountered across Canada. To confirm the rank order of the demands of the tasks and terrains provided by the PDA, the second objective was to characterize the weights, forces, heart rate (HR) responses, oxygen utilization (VO_2) and ratings of perceived exertion (RPE) while incumbent WFF were performing these IA tasks in the identified arduous terrains.

3.2.2. HYPOTHESIS

It was hypothesized that given the substantial terrain differences across Canada, performing IA wildland fire fighting tasks in steep/mountainous jurisdictions such as British Columbia will pose the greatest physical challenge and that the British Columbia performance standard will become the National WFX-FIT performance standard.

3.2.3. METHODS

3.2.3.1. Physical demands analysis

At the onset of the study, a PMT was formed to include all stakeholders in the exchange of IA WFF across Canada with due consideration for age and sex in the team's composition. A PDA was then undertaken to identify the most important, physically demanding and frequently occurring emergency tasks performed by WFF during the IA of a wildland fire as well as the most arduous terrains encountered by IA WFF in fire jurisdictions across Canada[15,41,55,63]. Two rounds of focus group meetings were held in all provinces/territories to provide the information for a cross-Canada statistically-based survey in which IA WFF rank-ordered the demands of the emergency tasks and workplace scenarios. The initial round of cross-Canada focus group meetings involved consultation with WFF training managers and union representatives (subject matter experts) to develop a list of all tasks in wildland fire fighting that represent critical response requirements of WFF in IA fire suppressions. Specific IA wildfire scenarios were further developed in a second round of focus group discussions involving WFF in all fire jurisdictions (for a combined 48 management and 109 union male and female representatives) a hierarchy of all of the identified emergency IA wildland fire fighting tasks was established. These follow-up focus group sessions also provided jurisdictionally-specific details relating to the terrain conditions under which these incidents occur, the equipment used during wildland fire scenarios and the fire risk plus forest value priorities. The fire risk index refers to the extent of threat to life and property in populated areas and the fuel index refers to the value of the forest (E.g. Crown land or corporate/logging ownership)

The list of on-the-job tasks and scenarios were then rated in a survey questionnaire completed by incumbent WFF from all 13 fire agencies across Canada using a Likert-type 5-point rating scale to provide a rank-ordering of the tasks. The *importance* of the task or scenario was rated as follows: 1 = critically important, 2 = very important, 3 = important, 4 = somewhat important, and 5 = not very important. The *physical exertion* required of the task or scenario was rated as follows: 1 = very high demand, 2 = high demand, 3 = moderately high demand, 4 = low demand, and 5 = no demand. The *frequency of occurrence* of important tasks was evaluated as follows: 1 = continuously or daily, 2 = frequently or weekly, 3 = occasionally or monthly, 4 = seldom or yearly, and 5 = rarely, if ever. The importance and difficulty associated with differences in terrains, environmental conditions (fire risk and fuel value indices) and resource availability for fire suppression (water and aircraft) were also rated. Considerable effort was made by the researchers and CIFFC management to ensure that the WFF who participated in the survey represented the Canadian WFF work force by sex, age, years of experience and Aboriginal status.

The outcome of the cross-Canada PDA survey was a statistically derived rank-ordered list of the most important, physically demanding, and frequently occurring on-the-job emergency tasks in which ineffective or inefficient completion could compromise public safety and property. When analyzing the results, particular attention was given to possible differences in responses from the above group representations. The PDA also highlighted that the WFX-FIT test protocol should involve a sequencing of tasks that simulate as closely as possible working in a live IA wildland fire scenario and that the test must be completed within a minimum IA time standard. As well, the survey highlighted the need to take into account the diversity in terrain and differences in fire suppression policy across Canada when developing the associated performance standard and cut-score. The PMT and CIFFC then approved the resultant proposal of the researchers that the WFX-FIT protocol would be comprised of simulations of emergency WFF tasks combined into a continuous circuit in the same sequence that they are performed in the IA of a wildland fire with the circuit embodying an aerobic-anaerobic fitness demand that is essential for safe and efficient wildland fire fighting.

3.2.3.2. Physical and Physiological Characterization

The next phase of the project was to characterize the most important, physically demanding wildland fire fighting tasks identified in the PDA in terrains that are representative of all fire jurisdictions across Canada. The characterization involved the use of precision measurement devices to determine *i)* the weight of wildland fire equipment commonly carried by WFF during the IA of a wildland fire, *ii)* the forces required in tasks such as laying dry hose and advancing charged hose and *iii)* the energy demands associated with performing the tasks. The energy demands were assessed by instrumenting the participants with HR monitors (Polar Electro KP4, Kempele, Finland) and a portable VO_2 measurement apparatus[81] (Cosmed Fitmate PRO, Rome, Italy) that recorded breath-by-breath VO_2 assessments at five second intervals. Illustration 1 shows a participant being outfitted with the lightweight (2kg/4.4 lb) metabolic unit. Standard equipment calibrations were performed prior to instrumenting each participant and the participating WFF also provided RPE ratings while performing each task (Borg Scale, 6-20)[82].

The characterization measurements were conducted in wildland terrains that were ranked in the PDA as the most physically demanding and frequently encountered in fire jurisdictions across Canada. These included steep mountains in British Columbia, muskeg or swamps in Saskatchewan and rolling hills plus forest blow-downs in New Brunswick. Scenarios were developed by the subject matter experts in the focus groups who ordered the tasks in a manner consistent with the order in which they are performed during the emergency IA of a critical wildland fire. During the characterization, incumbent WFF were instructed to perform the tasks at a self-selected safe and efficient emergency pace and their selected pace was confirmed to be appropriate by supervisory subject matter experts. The tasks were performed over the specific response distances identified in the PDA using wildland fire fighting tools and equipment employed in all fire jurisdictions.

All of the front-line incumbent IA WFF who participated in the characterization were on non-accommodated job duty and therefore would be expected to perform front-line emergency job duties. In addition, considerable effort was made to ensure that the participants were representative of the sex, age, years of experience and Aboriginal status of the incumbent Canadian IA WFF population. All aspects of this project were approved by the York University Committee on Research Ethics and all WFF participated voluntarily following PAR-Q+ screening[79,80,91] and if necessary the ePARmed-X (www.eparmedx.com), and provision of informed consent (Appendix B-C).

Illustration 1. Participant being outfitted with portable metabolic unit.

3.2.3.3. Statistical analyses

Because the study used a multi-method research design that included survey, observational, correlational, and group comparisons, there were specific statistical analyses associated with each outcome as detailed below. The SPSS statistical package 20 (SPSS Inc., Chicago, Ill.) was used to compute the statistics, with a threshold for statistical significance of $p \leq 0.05$.

The statistics used to rank order the most important, physically demanding, and frequently occurring on-the-job tasks provided by the survey respondents are descriptive (mean ± standard deviation (SD)). Independent samples *t* test and Levene test of variance were used to examine possible differences in sex, age, years of experience and Aboriginal status. Dependent and multiple comparisons among means and analysis of variance with Bonferroni post-hoc comparisons were used to determine whether there were differences in the job task rankings with reference to the importance, physical demands, and frequency of occurrence of the essential job tasks among the demographic groups.

The demographics, physical, and physiological performances of the participants were summarized using descriptive statistics (mean ± SD). Independent samples *t differences* test and Levene test of variance were used to examine possible differences between jurisdictions as well as sex, age, years of experience and Aboriginal status in the physiological responses (VO_2, HR, and RPE) when performing the important, physically demanding, and frequently occurring tasks.

3.2.4. RESULTS

3.2.4.1. Physical demands analysis

The objective of the PDA was to compile a rank-ordered list of the most important, physically demanding, and frequently occurring tasks encountered by WFF during an IA emergency response along with the relative difficulty of the associated terrains. A total of 946 questionnaires were completed by IA WFF from across Canada, which provided a robust sample for analysis. The demographics of the questionnaire respondents are summarized in Table 3. There were no differences in the ratings of task importance, level of physical demand, and frequency of occurrence when analysed by sex, age, years of experience and Aboriginal status. This was also true for terrain difficulty, and the jurisdictional priority index (extent of threat to life and property in populated areas and forest value) and fire suppression resource availability (water, aircraft). From this statistical analysis, the list of tasks to be studied during the characterization was determined by applying the following guidelines out of a possible lowest score of 5:

1. Identify the tasks that are VERY IMPORTANT to public safety (rating ≤ 2.0).
2. Identify those VERY IMPORTANT tasks that have a high level of EXERTION or PHYSICAL DEMAND (rating ≤ 3.0).
3. Consider the FREQUENCY OF OCCURRENCE of the tasks that are considered VERY IMPORTANT (rating ≤ 3.5).

The complete list of tasks including importance, physical demands and frequency ratings, is contained in Table 4.

Table 3. Demographics of the IA wildland fire fighters who responded to the survey questionnaire.

Sex	*n*
Male	796
Female	150
Undeclared	33
Total	946
Status	
Aboriginals	202
Metis	64
Disability	6
Racial Minority	15
Caucasian	559
Undeclared	100
Age	
Less than 25 years	304
25-34 years	331
35-44 years	124
45-55 years	111
Over 55 years	40
Undeclared	36
Years of Experience	
Less than 5 years	496
5-10 years	196
11-20 years	122
More than 20 years	99
Undeclared	33

Table 4. Summary of the ratings provided by experienced IA wildland fire fighters for the most important, physically demanding and frequently occurring tasks encountered during the IA of a wildland fire.

Task	Importance	Exertion	Frequency
Using a chainsaw, cut a helicopter landing pad approximately 40m by 40m	1.54	2.45	3.21
Using a chainsaw, cut a 200m escape path for fire fighters through dense forest	1.57	2.68	3.23
Lay/extend 400m of 1½-inch hose from pump to anchor point of fire through the forest	1.68	2.92	2.66
Carry a medium pump and pump tool box 100m to water source at value	1.69	3.03	2.78
Using a chainsaw, remove standing trees and fuel from the area surrounding the value	1.70	2.89	3.37
Carry a medium pump and pump tool box 200m to suitable water site over uneven terrain	1.74	2.65	2.65
Retrieve equipment for immediate dispatch to second fire	1.77	3.16	3.16
Carry fuel can and intake/suction hose 200m to suitable water site or uneven terrain	1.81	3.05	2.64
On the nozzle, create a fire line, down to mineral soil (earth), along a 500m flank to head of fire	1.82	3.10	2.95
Using a chainsaw, clear snags, aerial and surface fuels from either side of a 500m-long fire line	1.88	2.64	3.26
Lay 500m (one person hose lay) of center-folded hose around flank of fire in advance of nozzle, through the forest	1.94	2.72	3.10
On the nozzle, perform a back pass along a 500m fire line	1.95	3.19	2.96
Make three trips of 700m in each direction to staging area and back to bring additional hose packs (4 lengths of hose per pack) to fire line	1.95	2.38	3.10
Using a chainsaw clear a 500m control line for better access around flank of fire	1.97	2.48	3.40
Using hose for 12 hours to prepare a fire line	1.99	2.73	3.21
In support of chainsaw, move logs, snags and cut material away along a 500m fire line	2.02	2.74	3.20
On the nozzle, perform a second forward pass (in the black) along a 500m fire line	2.08	3.21	3.01
Drag charged hose behind nozzle along a 500m flank, while carrying a hose pack (4 lengths of hose per pack)	2.20	2.44	3.19
Using a Pulaski, chop away roots and other flammable material along a 500m fire line	2.24	2.68	3.21

Values expressed as the mean score for Importance where 1 = Very Important, 5 = Not Very Important, Exertion where 1 = very high demand, 5 = no demand and Frequency where 1 = continuously or daily, 5 = rarely, if ever.

3.2.4.2. Terrain Priority Ranking

Table 5 contains the Terrain Priority ranking for each terrain across Canada. The rankings were created by combining the level of importance and the level of exertion ascribed by WFF to each terrain to provide a Terrain Priority Index (lowest possible Terrain Priority Index = 10). There were no significant differences in the resultant Terrain Priority rankings based on sex, age, years of experience and Aboriginal status. WFF survey respondents identified working in; *i)* steep mountainous terrains, *ii)* swamp or muskeg and *iii)* rolling hills/uneven ground plus forest blow-downs as the most difficult terrains encountered (from highest to lowest). Because of the diversity of terrains across Canada, it was decided that each of the highly important, physically demanding and frequently occurring tasks must be characterized in each of the high priority terrains (1-4).

Table 5. Survey ranking of the physical demands required to IA wildland fires in different terrains (Priority Index based on importance and exertion with the lowest possible Priority Index of 10).

Tasks	Terrain Priority	Priority Index
Working in Steep Mountainous Terrain	1	3.93
Working in a Blowdown or Slash fuel area	2	4.07
Working in rolling, uneven ground	3	4.48
Working in Swamp or Muskeg	4	4.59
Working in Black Spruce	5	4.68
Working in Coastal Forests	6	4.86
Working in Old Pine forest	7	5.08
Working on the Canadian Shield	8	5.11
Working in Boreal Forest	9	5.14
Working in a Hardwood forest	10	5.53

3.2.4.3. Ranking of Fire Jurisdictions from the Physical Demands Analysis

Given the jurisdictional differences in the presence of these terrains across Canada, it is reasonable to assume that wildland fire fighting in some fire agencies is likely to be more difficult than others. The ranking of fire agencies in Table 6 is based on the Jurisdictional Priority Index which was created by combining the Terrain Index from Table 5 with the frequency of exposure to that terrain in each fire agency. The lowest rank indicates the agency that had the highest exposure to the terrain that was ranked as the most Important (fire risk and forest value index), and highest demands. Survey respondents identified British Columbia, Parks Canada and Alberta as the agencies with the highest Jurisdictional Priority Index. Agencies with swamps or muskeg (Manitoba, Saskatchewan and Ontario) were ranked next followed by rolling hills and forest blow-downs (New Brunswick and Quebec). Therefore, it was decided that the characterization of tasks and the WFX-FIT test development should take part in jurisdictions that represent the terrains of these three groupings.

Table 6. Survey ranking of the 13 fire agencies based on the Terrain Priority Index from Table 5 plus the frequency of exposure to each terrain (lowest possible Index = 15).

Agency	Index	Rank
British Columbia	9.5	1
Parks Canada	9.6	2
Alberta	10.6	3
Yukon Territory	10.8	4
Ontario	11.1	5
Nova Scotia	11.2	6
Northwest Territories	11.5	7
Manitoba	12.0	8
Saskatchewan	12.0	9
Quebec	12.7	10
New Brunswick	12.9	11
Newfoundland and Labrador	14.2	12
Prince Edward Island	14.6	13

3.2.4.4. Sequencing of Tasks during the Characterization

The sequencing of tasks provided from the PDA for physical and physiological characterization detailed in Table 7 is based on the performance of an IA during wildland fire fighting. The sequences are composed of individual tasks that were rated as important, physically demanding and frequently occurring in the PDA.

Table 7. Sequence of the IA wildland fire fighting tasks identified during the physical demands analysis (focus groups and survey results) for characterization.

Tasks	Sequence	Description
Carry Hose Pack	1	- Carry hose pack on back for 700 m
Chainsaw Clearing	2	- Using a chainsaw, cut a helicopter landing pad approximately 40m by 40m - Using a chainsaw, cut a 200m escape path for fire fighters through dense forest - Using a chainsaw, clear snags, aerial and surface fuels from either side of a 500m-long fire line - Using a chainsaw clear a 500m control line for better access around flank of fire - Using a chainsaw, remove standing trees and fuel from the area surrounding the value
Chainsaw Support	3	- In support of chainsaw, move logs, snags and cut material away along a 500m fire line
Pulaski Work	4	- Using a Pulaski tool, chop away roots and other flammable material along a 500m fire line
Carry Fuel Tank and Intake/Suction Hose	5	- Carry fuel can and intake/suction hose 200m to suitable water site or uneven terrain
Carry Medium Pump and Pump Tool Box	6	- Carry a medium pump and pump tool box 200m to suitable water site over uneven terrain - Carry a medium pump and pump tool box 100m to water source at value
Walk Back to Carry 3 Sections of 1½-Inch Hose	7	- Make three trips of 700m in each direction to staging area and back to bring additional hose packs (4 lengths of hose per pack) to fire line
Set up Pump	8	- Prime, set up and start a medium pump
Lay 4 Sections of Dry Hose uphill	9	- Lay/extend 400m of 1 ½-inch hose from pump to anchor point of fire through the forest
Advance Two Sections of Charged Hose into Bush	10	- Drag charged hose behind nozzle along a 500m flank, while carrying a hose pack (4 lengths of hose per pack)

The 10 groupings contain similar tasks that meet the following criteria; Importance $\leq$ 2.0, Exertion $\leq$ 3.0 and Frequency $\leq$ 3.5.

The information gathered from all demographic groups of WFF during the focus group discussions and from the cross-Canada survey results also indicated that the important, physically demanding tasks performed in isolation may be highly anaerobic, but not fully engage the aerobic energy system. However, when they are performed in sequence during a continuous scenario, they impose a significant aerobic requirement. As well, in the survey responses, endurance or cardiovascular fitness was the most consistently cited physical fitness requirement by WFF for effective job performance. It was also specified by IA WFF in the PDA that the wildland fire fighting scenarios identified for characterization should be completed within a time consistent with an conducting an IA on a wildland fire.

3.2.4.5. Characterization of Tasks

All participants in the characterization phase of the WFX-FIT project were incumbent IA WFF and considerable effort was made to involve a sample of participants who were representative of the sex, age, years of experience and Aboriginal status of incumbent WFF across Canada. Demographics of the IA WFF who participated in the physical and physiological characterization are summarized in Table 8.

Table 8. Demographics of the IA wildland fire fighters who participated in the characterization.

	Total (n)	Males (n)	Females (n)	Aboriginals (n)	Age (yr) Mean ± SD	Experience (yr) Mean ± SD
New Brunswick	53	46	7	2	43 ± 9	17 ± 9
Saskatchewan	50	47	3	23	35 ±11	11 ± 10
British Columbia	65	55	10	25	31 ± 7	8 ± 6
Combined	168	148	20	40	36 ± 10	12 ± 9

An initial task in the characterization was to determine the average weight of wildland personal protective equipment (PPE), including fire-line boots, apparel, gloves, hard hat and belt with radio, flashlight and water bottle etc. which accounted for most of the weight (collectively referred to as fire-line work wear). The difference between the body mass of IA WFF in fitness attire and their body mass while wearing wildland PPE without work boots was measured in four fire jurisdictions, and the mean combined weight was 4.1 kg (9 lb). The PDA report specified that the encumbrance of the weight of this PPE (Table 9) must be built in to the WFX-FIT circuit. Hence, the participants wear a 4.1 kg (9 lb) weighted belt throughout the WFX-FIT performance.

The next task was to determine the weight of wildland fire equipment commonly carried by IA WFF while supressing wildland fires, plus the forces required to lay dry hose and to advance charged hose (Table 9). The forces recorded at discrete time points throughout the task of advancing hose were both the peak force and mode force during the performance of this task. Since IA WFF did not exert the peak force throughout the on-the-job task, it was decided that when this task simulation is built into the WFX-FIT circuit it should require the most commonly measured (mode) force (which was approximately 75% of the peak force). It is also important to note that the force exerted by IA WFF while advancing hose was not determined from the force characteristics (maximal strength) of WFF. Rather, it was the mode force requirement to successfully perform the task. As indicated in the Meiorin Decision[10], this force represents the *criterion* force required to perform the task, not the force characteristics of the workers.

Table 9. Weight of IA wildland fire fighters' personal protective equipment, weight of suppression equipment commonly carried by IA WFF and the force required to accomplish critical IA wildland fire fighting tasks.

	Fire Jurisdiction				
	Ontario (n=5)	New Brunswick (n=5)	Sask. (n=5)	British Columbia (n=5)	Combined Mean (n=25)
Personal Protective Equipment (without fire-line boots) (kg):	4.1	4.2	4.1	4.2	4.1
Equipment Weight (kg):					
Pulaski	2.4	2.2	2.3	2.3	2.3
Medium Pump	28.7	28.0	28.3	29.0	28.5
Dry Hose (1 length)	6.4	6.1	5.9	5.9	6.1
Hose Pack (4 lengths; 38 mm hose)	27.2	24.2	23.6	25.3	25.0
Fuel Container	19.9	20.4	20.3	20.0	20.2
Intake/Suction Hose	4.5	4.1	4.2	4.3	4.3
Chain Saw	7.3	7.5	8.2	7.8	7.7
Task Forces (kg):					
Lay 4 Lengths Dry Hose	-	24.2	23.0	22.5	23.2
Advance Charged Hose;					
- peak force	25.0	23.8	24.0	25.0	24.5
- most frequent (mode) force	19.0	17.9	18.2	18.9	18.5

Note: All hose lengths used throughout this project were 38 mm (1½ in) diameter X 30.5 m (100 ft) in length with quick connect couplings.

The VO_2, HR response and RPE results of the WFF while performing each of the critical IA wildland fire fighting tasks in British Columbia, Saskatchewan and New Brunswick which represented *i)* steep mountainous terrain *ii)* swamp or muskeg and *iii)* rolling hills with forest blow-downs respectively are summarized in Table 10. The PDA observed that some WFF tasks were not always performed in the identical manner across all fire agencies. For example, in New Brunswick a medium pump was not affixed to a back-board and therefore cannot be carried on the back. Conversely, in British Columbia and Saskatchewan a medium pump was fastened to a back-board thereby enabling WFF to carry the pump on the back. In circumstances such as this, the task was only characterized in that jurisdiction if it was performed in the manner recommended by CIFFC. The omission of some measurements in Table 10 reflects these jurisdictional differences in task performance. CIFFC subsequently standardized such equipment carrying across all fire jurisdictions.

Each task was evaluated during an overall sequence, with the sequences completed in an average of 15 to 20 minutes. The average incline of the steep terrains over which the sequences were performed was 35 degrees, which is equivalent to the slope of an intermediate ski hill and terrains of ≥ 45° were often encountered. The ambient temperature throughout the May/June testing was 11-18°C and all participants were cautioned to be well hydrated. The mean VO_2 of all emergency tasks was 30 ± 4 $mL·kg^{-1}·min^{-1}$ (range 20±2 to 40 ± 7). The most demanding of the 11 tasks identified in the PDA were confirmed in the characterization to be carrying a medium pump on the back (38 ± 7 $mL·kg^{-1}·min^{-1}$), hand carrying a medium pump (36 ± 4 $mL·kg^{-1}·min^{-1}$), hand carrying rolls of hose (34 ± 6 $mL·kg^{-1}·min^{-1}$), carrying a hose pack on the back (37 ± 6 $mL·kg^{-1}·min^{-1}$) and advancing charged hose (36 ± 5 $mL·kg^{-1}·min^{-1}$).

There was a significantly lower VO_2 during Pulaski trenching, chain saw clearing/support, carrying intake/suction hose and set-up/starting a medium pump than each of the four most demanding tasks. When considered together with the data in Table 4 in which subject matter experts rated Pulaski trenching as the lowest priority, with moderate exertion and a moderate frequency of occurrence during an IA, this task was not included in the WFX-FIT circuit. Further, when Pulaski trenching was initially included in the WFX-FIT during pilot testing, it provided no differentiation between participants. One-way analysis of variance indicated a significant difference between agencies in VO_2 for the hose pack carry and the advance charged hose *($p \leq 0.05$)*. Post hoc Bonferroni tests using indicated that the VO_2 for the hose pack carry was greater in British Columbia than both Saskatchewan and New Brunswick and the VO_2 while advancing the charged hose was greater in British Columbia than Saskatchewan. The mean HR response while performing all tasks was 160 ± 16 bpm, and the RPE ratings from the WFF indicated that performing these most demanding emergency tasks was "somewhat hard" to "very hard"[82].

Table 10. Summary of physiological measurements of IA tasks from the characterization (Mean ± SD) by fire jurisdiction.

	FIRE JURISDICTION											
	New Brunswick (n = 53)			Saskatchewan (n = 50)			British Columbia (n = 65)			Combined (n = 168)		
Fire Fighting Tasks	VO_2 (mL·kg^{-1}·min^{-1})	HR (bpm)	RPE (out of 20)	VO_2 (mL·kg^{-1}·min^{-1})	HR (bpm)	RPE (out of 20)	VO_2 (mL·kg^{-1}·min^{-1})	HR (bpm)	RPE (out of 20)	VO_2 (mL·kg^{-1}·min^{-1})	HR (bpm)	RPE (out of 20)
1. Chain Saw Clearing	20 ±2	139 ±19	12 ±2	-	-	-	-	-	-	20* ±2	139 ±19	12 ±2
2. Chain Saw Support	20 ±3	141 ±19	11 ±1	-	-	-	-	-	-	20* ±3	141 ±19	11 ±1
3. Pulaski Trenching	26 ±4	156 ±16	14 ±2	-	-	-	29 ±6	152 ±15	13 ±2	28* ±5	152 ±15	13 ±2
4. Carry Medium Pump on Back	-	-	-	36 ±5	178 ±14	16 ±2	38 ±5	175 ±10	16 ±2	38 ±7	177 ±11	16 ±2
5. Hand Carry Medium Pump	36 ±4	168 ±15	15 ±2	-	-	-	-	-	-	36 ±4	168 ±15	15 ±2
6. Carry Intake/Suction Hose & Fuel	26 ±4	161 ±17	14 ±2	28 ±4	171 ±20	15 ±3	-	-	-	27* ±4	164 ±18	14 ±2
7. Set-up & Start Medium Pump	22 ±4	153 ±18	12 ±1	-	-	-	-	-	-	22* ±4	153 ±18	12 ±1
8. Hand Carry Rolls of Hose	34 ±6	162 ±15	15 ±2	-	-	-	-	-	-	34 ±6	162 ±15	15 ±2
9. Carry Hose Pack on Back	34** ±2	152 ±10	14 ±1	34** ±5	174 ±12	15 ±2	40** ±7	181 ±9	17 ±2	37 ±6	170 ±15	15 ±2
10. Lay 4 Lengths of Dry Hose	32 ±4	170 ±14	15 ±2							32 ±4	170 ±14	15 ±2
11. Advance Charged Hose	36 ±4	167 ±15	16 ±3	35*** ±3	166 ±14	15 ±2	38*** ±8	167 ±14	15 ±2	36 ±5	167 ±14	15 ±2

* Significantly lower VO_2 that the four most demanding tasks (4, 5, 9, 11)
** British Columbia significantly different from New Brunswick and Saskatchewan.
*** British Columbia significantly different from Saskatchewan.

The VO_2, HR response and RPE measurements determined that the following four tasks identified in the PDA were the most physically demanding and therefore justified inclusion in the WFX-FIT protocol - carry a medium pump on the back , hand carry a medium pump, carry a hose pack containing four sections of hose and advance charged hosed. It also confirmed that the physical demands of IA wildland fire fighting in steep mountainous terrain were higher than in other terrains.

3.2.5. DISCUSSION

The major outcome of the PDA was a rank-ordered list of the most important, physically demanding and frequently occurring tasks and associated terrains, which would become the basis of the physical and physiological characterization. From a Human Rights perspective, decisions regarding task inclusion and/or exclusion must be based on the tasks directly related to the objectives of the job[15]. The involvement of both management and union subject matter experts in the first round of focus groups resulted in the initial identification of such tasks, which were then further refined into IA scenarios in a second round of focus group discussions, again with subject matter experts. The resultant evidence was then assembled into an objectively measurable questionnaire that was completed by a representative sample of experienced WFF from across Canada. This overall process provided a prioritized list of the most important, physically demanding and frequently occurring tasks plus a ranking of the most demanding and frequently encountered terrains. There were no differences in the rankings based on sex, age, years of experience or Aboriginal status.

The physical and physiological characterization of the critical physically demanding tasks were measured during the performance of these tasks by experienced IA WFF at a self-selected safe and efficient emergency pace which was confirmed as an appropriate pace by supervisory subject matter experts[21,41,60]. The WFF participants were stratified by age, sex, years of experience and Aboriginal status. All of the front-line incumbent IA WFF who participated were on non-accommodated job duty and therefore would be expected to be able perform front-line emergency job duties. Physical measurements determined the average weight of PPE, the weight of wildland fire fighting equipment, the force applications required by IA WFF while conducting the tasks, and the times associated with performing the critical physically demanding on-the-job tasks. In addition, measurements of HR response, VO_2 and RPE were made on experienced IA WFF while performing the important initial attack emergency scenarios. The precision and calibration of all measurement apparatus involved were verified regularly.

Measurements that were made on the equipment carried, forces applied, VO_2, HR, and RPE, while front-line incumbent IA WFF were performing the critical physically demanding on-the-job tasks are consistent with those demonstrated in other prominent Canadian public safety occupations[14,39]. The emergency equipment carried in previous studies ranged from a mean weight of 4.2 to 31.8 kg compared to 2.3 to 29.0 kg in the present study. The mean sustained VO_2 during the on-the-job performance in the previous studies ranged from 36 to 42 $mL \cdot kg^{-1} \cdot min^{-1}$ compared to 20 to 40 $mL \cdot kg^{-1} \cdot min^{-1}$ in the present study. The corresponding mean HR ranged from 162 to 181 bpm in the previous studies compared to 139 to 181 bpm in the present study and the mean RPE ranged from 14.5 to 16 compared to 11 to 17 in the present study.

A large body of research has been published in which the physical demands of structural fire fighting have been identified[14,39,60–62,92–99]. However, a comparatively small body of information is available regarding the physical demands associated with wildland fire fighting. Additionally, few studies have attempted to characterize IA wildland fire fighting scenarios on a national level, incorporating multiple jurisdictions, terrains and a diverse work force. Ruby et al.[100] quantified the physiological responses of 13 wildland fire fighters during a simulated escape to safety. The authors reported mean VO_2 values of 41.1 ± 6.0 $mL \cdot kg^{-1} \cdot min^{-1}$ for males and 32.5 ± 6.6 $mL \cdot kg^{-1} \cdot min^{-1}$ for females during a loaded (16 kg/35 lb) pack carry. The associated HR responses were 181 ± 6 for males and 188 ± 12 for females, which corresponded to approximately 97% of participants age-predicted HRmax. In the present investigation, 168 IA WFF (20 females) performed a similar pack carry evaluation (25 kg/55 lb) across variable terrain. The mean VO_2 while performing the hose-pack carry was 37 ± 6 $mL \cdot kg^{-1} \cdot min^{-1}$ for males and females combined. The mean HR response while performing all tasks was 160 ± 16 bpm which corresponded to 87% of the participants' age-predicted HRmax. Although there is some consistency between the results of the two investigations, Ruby et al. focussed on the physiological demands of load carriage walking at an average 11.7 degree incline, while the load carriages measured at the representative mountainous inclines in the present investigation were much steeper, with an average of 35 degrees.

Rodriguez-Marroyo et al.[101] quantified the physiological work demands of Spanish wildland fire fighters during live wildfire suppression. The authors reported a range of HR responses for fire-line activities lasting between <1 hr and >5 hr. During the shorter duration suppression activities mean HR was 133 ± 2 bpm and during the long duration activities, HR was 116 ± 3 bpm. The HR responses presented by Rodriguez-Marroyo et al. are considerably lower than those reported in the present investigation, likely due to methodological differences. In the present investigation HR was analyzed throughout the work phase only, while Rodriguez-Marroyo et al. averaged HR from both the work and recovery phases and these researchers made the measurements over a considerably longer duration, which does not simulate an emergency initial attack response.

Budd[102] quantified the physiological responses of 28 WFF during fire-line construction. The author reported a mean HR of 152 ± 14 bpm which corresponds to 78% of the age-predicted HRmax with an RPE of 13.6 ± 1.7 (somewhat hard). These results are very similar to the results of the present investigation in which Pulaski trenching (a fire-line construction task) elicited a mean HR response of 152 ± 15 bpm (83% age-predicted HRmax) and an RPE of 13 ± 2 (somewhat hard). More recently, Phillips et al.[45] quantified the frequency, intensity, duration and type of tasks performed by Australian WFF. The authors reported HR responses from 28 WFF ranging from 97 ± 16 bpm to 157 ± 15 bpm during 6-hour work shifts. Similar to Rodriguez-Marroyo et al.[101], the reported demands are considerably lower than those observed in the present investigation. As well, Cuddy et al. also reported low mean HRs (112 ± 13 bpm) in a sample of 15 WFF over work shifts lasting 11.4 ± 0.7 hours in duration[103]. Again, these differences are likely attributable to the long shift duration over which the demands were examined by these researchers, while demands and HR responses in the present study were only examined during the performance of emergency initial attack fire fighting tasks.

It appears, therefore, that the variability in physiological responses reported in wildfire suppression studies may be attributable entirely to methodological differences. While previous work has focussed on the job demands over an extended period of time, such as a work shift, the present investigation captured the physiological responses during a worst-case emergency scenario - the initial attack of a wildland fire. Tasks that were deemed non-essential, not physically demanding or frequently occurring during an IA were not examined in the present study.

It has been argued that characterizing physically demanding occupations such as wildland fire fighting during job simulations may not accurately reflect real front-line demands and hence, assessing candidates' physical capacities under thermonetural conditions may be a poor predictor of on-the-job performance[104]. However, while developing a fitness test for Ontario IA WFF (1996; Ontario Ministry of Natural Resources - Evaluation for IA Fire Fighters) Gledhill and Jamnik observed no significant differences in the physiological responses while IA WFF were performing simulated versus live wildland fire suppressions.

A major outcome of the PDA and physiological characterization in the present study was to identify the impact of regional terrain differences on the physical demands of IA wildland fire fighting. To our knowledge, this is the first investigation to recognize and quantify the impact of terrain differences. As well, we believe this is the first investigation to recommend the use of a job simulation circuit into which regional terrain differences are built. Brotherhood et al.[105] found close agreement in physiological responses during fire-line digging despite 'differences in terrain'. Phillips et al.[106] identified advancing hose over 'variable terrain' as a physically demanding task. However, additional fire-line tasks and terrains with different demands were not characterized in these studies, nor were the terrain types clearly identified.

The use of a continuous circuit in fitness screening protocols for physically demanding occupations is not uncommon. For example, they are included in the fitness screening protocols for police officers[39], correctional officers[7,12,41], nuclear power emergency workers[24], structural fire fighters[21,42] and military fire fighting personnel[28,30,43]. Lord et al.[44] combined critical bushfire suppression tasks into a circuit to replicate core actions plus movements and reflect the intermittent nature of fire suppression duties. As well, Phillips et al.[45] identified tasks that should form the basis for a representative work task circuit for personnel fighting wildfires. Although these authors recommend the use of a job-simulation circuit for assessing the fitness of WFF, the effect of terrain differences on the associated physical demands was not considered in the circuit development.

Research conducted by Ruby et al. identified aerobic fitness level (VO_2 max) and load carriage as critical factors to WFF safety[64] and reported that WFF are often expected to carry equipment from a vehicle or helicopter drop-zone to a fire line. They report that the consequences of external load carriage include adverse effects on gait, metabolic efficiency, fatigue and increased risk of musculoskeletal injury. In addition to load mass, the positioning of the mass relative to the body governs the physiological impact of the load. The physical and physiological characterization of tasks in the present investigation were completed under load carriage conditions (carrying pumps and hose packs) while WFF were also encumbered with PPE in terrains that are normally encountered during emergency IA response to a wildland fire.

The next phase of the overall WFX-FIT research project involves developing a job-simulation circuit that incorporates simulations of the very important, physically demanding on-the-job tasks identified in the PDA and confirmed to be highly demanding by the characterization measurements. The tasks will be sequenced in a circuit which closely represents an emergency scenario commonly performed in the same order as the IA of a wildland fire. As well, all equipment utilized in the WFX-FIT circuit will replicate as closely as possible the common equipment used by WFF on the job during emergency wildland fire scenarios (both weight and load distribution). While performing the WFX-FIT circuit, in addition to being loaded with wildland fire fighting equipment, participants will also be encumbered by a weighted belt with the average load of PPE (4.1 kg/9 lb). Measurements will be made while WFF perform the WFX-FIT protocol to determine whether the VO_2 of performing the tasks in the WFX-FIT is the same as the VO_2 measured while performing the related on-the-job tasks during the characterization.

3.2.6. CONCLUSION

Based on the feedback received from subject matter experts during the focus group meetings, the WFF responses to the cross-Canada PDA questionnaire and the results of the physical and physiological characterization, it was concluded that the following four most important and physically demanding tasks should be the basis of the WFX-FIT protocol; carry a medium pump (portable 2-cycle 4-stage fire pump) on the back (28.5 kg/62.7 lb), hand carry a medium pump, carry a hose pack containing four 30.5 m (100 ft) sections of 1 ½ inch FIREBREAK hose (25 kg/55 lb) and advance charged hosed requiring 18.5 kg (40.7 lb) of force. These four tasks must be combined into a continuous circuit in the same sequence and time frame that they are performed in the IA of a wildland fire and the protocol must embody both an aerobic and anaerobic fitness demand that is required for safe and efficient wildland fire fighting. In addition, the average weight of WFF PPE must be built in to the WFX-FIT protocol and the diversity in terrain across Canada must be taken into account when developing the associated performance standards.

Competing Interests

The authors declare that there were no conflicts of interest during this study.

MANUSCRIPT III

Physical Employment Standard for Canadian Wildland Fire Fighters*; Constructing and Validating the Test Protocol* [7]

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OVERVIEW

To assess whether Initial Attack wildland fire fighters (WFF) possess the physical and physiological ability to perform emergency WFF tasks safely and efficiently in all terrains across Canada, the development of the WFF Fitness Test (WFX-FIT) began with a physical demands analysis (PDA). WFF across Canada identified rolling hills, forest blow-downs, muskeg and steep mountains as the most challenging terrains for fighting fires, and ranked both hand and back carrying a 28.5 kg pump, carrying a 25 kg hose pack and advancing charged hose as the most demanding emergency tasks (Manuscript II; *Identification and Characterization*). The physical demand (VO_2) of performing these tasks was measured on a representative sample of incumbent WFF in all terrains. The mean ± SD VO_2 of performing the same Initial Attack wildfire tasks was; 35±5 $mL \cdot kg^{-1} \cdot min^{-1}$ in forest blow-downs on rolling hills, 35±4 $mL \cdot kg^{-1} \cdot min^{-1}$ in muskeg and 39±7 $mL \cdot kg^{-1} \cdot min^{-1}$ on steep mountains, the latter of which was significantly more demanding *($p \leq 0.05$).* That is, regional terrain differences caused the same tasks to be more physically demanding and therefore, these demands must be built into the WFX-FIT protocol. A circuit was developed incorporating task simulations of the critical, physically demanding and frequently occurring tasks identified in the PDA with higher demands for provinces with more arduous

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[9] *Contribution of Authors for this manuscript, Robert Gumieniak was the primary author and was the primary facilitator of data collection and entry, data analysis and interpretation as well as the primary contributor to overall project design and manuscript preparation. RG, VKJ and NG all provided guidance regarding project design and were involved in the interpretation of the data analysis as well as revision of the manuscript VKJ and NG also helped to facilitate travel during project recruitment and support with data collection and interpretation.*

terrains. The mean ± SD VO_2 of performing the tasks sequentially on the job was 37±6 $mL \cdot kg^{-1} \cdot min^{-1}$. The mean ± SD VO_2 of performing the same tasks in the WFX-FIT circuit was 37±4 $mL \cdot kg^{-1} \cdot min^{-1}$ indicating strong construct validity. Content validity ratings provided by WFF of the "likeness" between tasks performed on the job and tasks embodied in the WFX-FIT were "Strongly Agree". These two validation methods together indicate that the physical demands involved in performing the WFX-FIT are the same as the physical demands involved in wildland fire fighting thereby providing convincing evidence for the validity of the WFX-FIT protocol.

Key words: BFOR, screening, demanding occupation, public safety, job-related

3.3. INTRODUCTION

Wildland fire fighting in Canada is a physically demanding public safety occupation in which ''ineffective or inefficient job performance is a threat to the safety of self, co-workers, the public and property''[4,7,8,10,11,14,19]. In accord with legal precedents[10,17,18] and scientific best practice[3,5,7,25,26,39], appointing a project management team (PMT) who then provide a sound justification for the need for a physical employment standard are essential first steps in the development of a physical employment standard. Subsequently, a comprehensive physical demands analysis (PDA) is conducted, followed by a characterization of the resultant task list of the most important, physically demanding, and frequently occurring on-the-job tasks[3,12,14,15,25,26]. We reported previously that the PDA and characterization for this project provided a rank-ordered list of the physically demanding emergency tasks performed by Canadian Initial Attack (IA) wildland fire fighters (WFF) and identified the most demanding emergency WFF tasks that must become the basis of the WFX-FIT test. Additionally, the higher demands of arduous terrains must be taken into account when developing the WFX-FIT protocol (Manuscript II; *Identification and Characterization*).

Pre-employment fitness screening tests must embody appropriate standards of acceptability that are the same for all participants[7,14,18,32]. The development of such standards must be based on the performance of experienced safe and efficient incumbent workers[21]. In accordance with the requirements of the Meiorin Decision[4,10,12,17,18], the fitness components tests or task simulations must be criterion based, founded on job performance, not based on the physical characteristics of the participants[3]. In conformance with these requirements, the forces built into the fitness test (WFX-FIT) for IA WFF must replicate the criterion forces measured while female and male WFF perform the critical, physically demanding on-the-job tasks encountered during the IA of a wildland fire[4,12,14,15]. It was documented during the characterization (Manuscript II; *Identification and Characterization*) that there was a significant difference in the mean oxygen utilization (VO_2) while performing the same emergency WFF tasks in steep mountains compared to muskeg and forest blow-downs on rolling hills ($p \leq 0.05$). That is, regional terrain differences cause the same tasks to be more demanding and it was concluded that these higher demands must be built into the WFX-FIT protocol for wildland fire fighting in different terrains.

In physically demanding public safety emergency occupations such as IA wildland fire fighting, successful job completion is dependent on the ability to perform strenuous physical activity within acceptable time constraints[6,38,101,107,108]. The primary consideration of the Canadian Interagency Forest Fire Fighter Centre (CIFFC) in developing the WFX-FIT was to be able to safely deploy WFF to fight IA wildland fires across Canada. CIFFC's goal was that IA WFF candidates must demonstrate that they are capable of safely and efficiently attacking a wildland fire in their provincial jurisdiction and, as required for exchange, in other jurisdictions across Canada[6,39]. Based on the rank-ordered tasks from the PDA, physiological measurements from the characterization, and feedback from incumbent IA WFF, it was concluded that the most important, physically demanding and frequently occurring tasks should be embodied in the WFX-FIT protocol.

Whether the WFX-FIT should be a fitness components test, a job-simulation test or a hybrid of these approaches was deliberated by the PMT. Fitness component tests employ job-specific standardized laboratory fitness tests to evaluate the physical attributes deemed necessary for safe and efficient job performance[4,7,11,14,32,39]. The tests do not simulate the specific equipment carried or force applications used on the job, instead they assess the strength/force applications required by the participant to accomplish the tasks encountered on the job. On the other hand, job simulation tests reproduce, as accurately as possible, the tasks encountered on-the-job and are generally preferred over fitness component tests because participants and arbitrators can easily see the relationship to the job[3,14,15]. The task simulations can be performed as discrete components or in a continuous sequential manner. Discrete tasks are evaluated independently while sequential tasks incorporate several task simulations into a continuous circuit with a single overall completion time cut-score. A hybrid test includes both job simulation tasks and one or more fitness component tests[14]. The decision of the PMT was that the WFX-FIT be a job simulation test with the most important, physically demanding and frequently occurring IA WFF tasks built into a continuous circuit.

To qualify for wildland fire fighting, within each fire jurisdiction, IA WFF must meet the provincial/territorial performance standard and to be eligible for exchange to other jurisdictions they must meet the national exchange performance standard (National WFX-FIT). Owing to regional differences from mountainous terrains muskeg and flat/rolling hills and the resultant differences in physical demands, a range of cut-scores is required to account for these jurisdictional differences. Meeting the criterion time standard in different terrains indicates that the WFF achieved a work rate equivalent to the energy demands during IA emergency responses on-the-job in that terrain/jurisdiction.

The physical and physiological characterization of the critical physically demanding tasks which provided the basis of the test development, were measured during the on-the-job performance of these tasks by experienced WFF at a self-selected 'safe and efficient' emergency pace which was confirmed to be an appropriate pace by supervisory subject matter experts. Physical measurements determined the average weight of personal protective equipment (PPE), the weight of wildland fire fighting equipment, the force applications required by WFF while conducting wildland fire fighting tasks, and the times associated with performing the critical, physically demanding on-the-job IA tasks. In addition, measurements of heart rate (HR), VO_2 and rating of perceived exertion (RPE) were made on experienced WFF while performing the important IA emergency scenarios.

The Meiorin Decision stipulated that for a fitness test to qualify as a BFOR the associated performance standard and cut-score must be based on the performance of any sub-group of workers in that job who perform the job safely and efficiently but have different (lower) physical attributes than the majority group of the workers[7,10,11,14]. When the fitness test performance cut-score is determined from the female and/or older male incumbent workforce, the minimum performance requirement is said to be age and sex 'neutral'[5]. The present research is designed to convincingly demonstrate a valid physical employment standard for Canadian IA WFF both within jurisdictions/provinces and for national exchange. The associated cut-scores must therefore be objectively established with subject matter expert consensus, founded on scientific best practice and with consideration for possible physiological differences with respect to age, sex and Aboriginal status.

3.3.1. OBJECTIVES

The first objective of this investigation was to develop a draft WFX-FIT protocol based on the outcomes of the PDA and characterization, and then refine the protocol by subject matter expert consensus as required. The second objective was to establish the content and construct validity of the WFX-FIT protocol using best practice scientific methodology and lastly, to establish the performance standards and cut-scores of the WFX-FIT based on the self-selected safe and efficient performance of incumbent female and/or older male IA WFF with the emergency pace confirmed by subject matter experts.

3.3.2. HYPOTHESIS

The investigators hypothesized that the WFX-FIT assessment protocol would have high content and construct validity and that the jurisdictional/provincial cut-score for BC, based on the performance of safe and efficient female and/or older male incumbent IA WFF in steep mountainous terrain, will be the national exchange fitness standard.

3.3.3. METHODS

3.3.3.1. Protocol development

The development and validation of the WFX-FIT involved voluntary participation of incumbent IA WFF across Canada who were representative of the sex, age and Aboriginal status of the entire IA WFF population. All phases of this project were approved by the York University Committee on Research Ethics (Appendix A) and all WFF participated with informed consent (Appendix B) and exercise clearance for physical activity/exercise participation via the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (Appendix C). The process followed throughout the research was in accordance with Steps 6 to 9 of the template for developing physiological employment standards to qualify as a BFOR which has been previously published[4,14,26,41]. In short, Step 6 involves developing a draft fitness test protocol based on the most important, physically demanding, and frequently occurring IA WFF tasks, then pilot testing and refining the protocol as required with expert subject matter feedback. Step 7 establishes a standardized, objective assessment procedure for administering the test protocol. Step 8 establishes the reliability and validity (accuracy) of the test protocol and Step 9 develops the associated performance standards and cut-score(s) for the test protocol.

3.3.3.2. Drafting and Refining the WFX-FIT Protocol

It was concluded from the previous PDA and task characterization that the following four most important and physically demanding tasks should be the basis of the WFX-FIT protocol; carry a medium pump (portable 2-cycle 4-stage fire pump) on the back (28.5 kg/62.7 lb), hand carry a medium pump, carry a hose pack containing four 30.5 m (100 ft) sections of 1 ½ inch FIREBREAK hose (25 kg/55 lb) and advance charged hosed requiring 18.5 kg (40.7 lb) of force. These four tasks must be combined into a continuous circuit in the same sequence that they are performed in the IA of a wildland fire and the protocol must embody an aerobic fitness demand that is required for safe and efficient IA wildland fire fighting. In addition, the average weight of PPE worn by IA WFF must be built in to the WFX-FIT protocol and the diversity in terrain across Canada must be taken into account when developing the associated performance standards.

The four recommended tasks were combined into a continuous circuit replicating the sequence of emergency tasks when working the IA of a wildland fire. Consistent with the recommendations for developing a BFOR, the incumbent's performance in the WFX-FIT circuit is "compensatory"[22,63]. That is, a weakness (or inefficiency) encountered in completing one component of the circuit can be made up for by superior ability in completing another component of the circuit and only the overall WFX-FIT cut-score (completion time) must be met. Although, expeditious completion of one circuit component can compensate for slower completion of another component, all tasks in the circuit must be completed.

A draft WFX-FIT circuit was initially constructed and feedback was received from experienced IA WFF (subject matter experts) to refine the draft protocol. The equipment utilized in the WFX-FIT circuit accurately simulates the actual equipment used by IA WFF while fighting wildland fires and was confirmed by WFF and management to accurately duplicate mass and load distribution. The tasks were ordered in the circuit to replicate a series of emergency tasks commonly performed in this sequence by WFF during the IA of a wildland fire. Performance of the circuit required a substantial anaerobic-aerobic fitness involvement, with progressively faster completion times requiring a progressively higher aerobic power contribution to simulate more arduous terrains.

3.3.3.3. Standardization of Test Protocol

Throughout the performance of the WFX-FIT, candidates wear exercise-appropriate attire (with either running shoes or work boots) plus a weighted belt (2 kg; 4.4 lb) that represents the weight of normal fire line PPE and equipment worn on the waist. The WFX-FIT circuit is performed over a 20 m (65.6 ft) course as described in detail below. To standardize the assessment protocol, the hose pack, which was found to vary among jurisdictions, was designed based on feedback from subject matter experts and supervisory personnel from all fire jurisdictions to be the most comfortable and biomechanically suitable of all the hose carriages encountered across fire jurisdictions. The resultant WFX-FIT hose pack is made up of a standard cardboard box containing four 30.5 m (100 ft) sections of 1 ½ inch FIREBREAK hose with quick connect couplings (25kg/55lb) and is identical to the hose packs carried during the characterization of this task. Additionally, the pump which varied marginally in weight among fire jurisdictions during the characterization depending on the amount of fuel in the tank and type of back-board, was designed to simulate the mass and load distribution of a standard medium pump with a fixed back-board (28.5 kg/62.7 lb). Rather than using actual medium pumps which are expensive and could be damaged, the simulated versions are inexpensive and easy to replace.

To simulate advancing charged hose, a weighted sled was developed with the force required to advance the sled being the mode force (measured at discrete time points during the advancement of charged hose) by IA WFF on the job. The angle (vector) of force measured during the task characterization was duplicated in the simulated charged hose advance. Since WFF do not exert the peak force throughout the on-the-job hose advance, but only close to the end of the task when the volume of water contained in the hose is greatest, the hose advance simulation in the WFX-FIT circuit was fixed at the mode force (18.5 kg/40.7 lb) which was ~75% of the mean peak force (25 kg/55 lb). It is also important to emphasize that the force exerted by WFF while advancing charged hose was not determined from the force characteristics (maximal strength) of WFF. Rather, it is the most frequent (mode) force required to successfully perform the task. As indicated in the Meiorin Decision[10], this force represents the *criterion* force required to perform the task, not the force characteristics of the workers.

To further ensure standardized, objective and unbiased test administration, CIFFC and member agencies were provided with a detailed test administration manual which included the following; *(i)* pre-test candidate information including smoking, diet and hydration, as well as exercise precautions prior to the test, physical activity readiness (PAR-Q+) clearance, resting blood pressure clearance, informed consent and release of information; *(ii)* WFX-FIT circuit description including equipment layout on a floor plan (Appendix D); *(iii)* simulated equipment construction details; *(iv)* equipment calibration details and schedule; *(v)* results reporting forms (Appendix E); *(vi)* WFX-FIT Appraiser responsibility forms; *(vii)* circuit instructions/script to be read to test candidates (Appendix F); *(viii)* the need to provide candidates with re-test opportunities, and; *(ix)* exercise training recommendations (Appendix G). The manual also details recommended indoor sites for conducting the WFX-FIT and the acceptable ambient temperature range (18-27°C)[104].

3.3.3.4. Construct and Content Validation

The construct validation measurements were computed by statistically comparing the physiological measurements while experienced IA WFF performed the WFX-FIT circuit with the same physiological measurements that were recorded for the same task performances on the job during the characterization phase. The energy demands associated with performing the tasks were assessed by instrumenting the participants with the same equipment utilized in the characterization: HR monitors (Polar Electro KP4, Kempele, Finland) and a portable VO_2 measurement apparatus[81] (Cosmed Fitmate PRO, Rome, Italy). Breath-by-breath samples were reported at five second intervals. Equipment calibrations were performed prior to instrumenting each participant. The participating WFF also provided subjective RPE while performing each task (Borg Scale, 6-20)[82].

The content validity of the WFX-FIT was established based on objectively-scored feedback from incumbent IA WFF[7,14]. Likert Scale (see Figure 1) ratings ranging from 1 (strongly disagree) to 7 (strongly agree) were utilized to solicit feedback regarding whether the demands of performing the WFX-FIT accurately reproduce the tasks, physical demands, task sequencing and work rate experienced on the job. During the administration of these questions (Figure 1), WFF were separated from their coworkers to ensure privacy and remove the potential for bias or influence.

Figure 1. WFX-FIT job simulation content validation questionnaire.

<table>
<tr><td colspan="7">Q1. Do you feel that the simulated tasks that make up this circuit represent critical, physically demanding tasks that a Forest Fire Fighter could encounter on the job?</td></tr>
<tr><td colspan="7">Q2. Do you feel that performing these simulation tasks is as physically demanding as performing the related on-the-job tasks?</td></tr>
<tr><td colspan="7">Q3. Do you feel that performing this job simulation circuit provides an appropriate assessment of your ability to meet the critical physical demands that could be encountered during a forest fire?</td></tr>
<tr><td colspan="7">Q4. Do you feel that performing this job simulation circuit at a higher work rate provides an appropriate assessment for an Exchange Performance Standard?</td></tr>
<tr><td>7
Strongly
Agree</td><td>6
Agree</td><td>5
Agree
Somewhat</td><td>4
Uncertain</td><td>3
Disagree
Somewhat</td><td>2
Disagree</td><td>1
Strongly
Disagree</td></tr>
</table>

3.3.3.5. Derivation of Performance Standards and Associated Cut-scores

Following standardization of the WFX-FIT protocol, the next undertaking was to derive the associated performance standards and cut-scores[3,7,14]. '*Meeting the standard'* or *'fit for duty'* designation for the WFX-FIT requires the successful completion of all components of the WFX-FIT circuit within a completion time within the minimum acceptable level of performance required for a passing score (ie. the cut-score)[26,32,52]. Failure to successfully complete any individual component in the circuit (carry medium pump on back, hand carry medium pump, hose pack lift and carry on back or advance charged hose) or failure to complete the circuit within the cut-score time limit, constitutes a '*Does not Meet Standard'* or an *'unfit for duty'* rating on the WFX-FIT. Within each fire agency, IA WFF must meet the jurisdictional/provincial cut-score to be employed in that province and must meet the National WFX-FIT cut-score to be eligible for exchange to all other fire jurisdictions. When attempting the WFX-FIT circuit for the derivation of cut-scores, all IA WFF participants were instructed to "*complete the WFX-FIT circuit at the same safe and efficient emergency pace that you would utilize to attack a wildland fire on the job*". Incumbent IA WFF representing all 13 fire jurisdictions volunteered for this phase of the project.

The Supreme Court of Canada's landmark Meiorin Decision on BFORs stipulated that, for a physical fitness test to qualify as a BFOR, the associated performance standards must be based on the performance of any sub-group of incumbent workers in that occupation who perform the job safely and efficiently but have different physical attributes than the majority group of the workers[10,14]. This Meiorin Decision requirement was made specifically in reference to a female WFF whose grievance brought about the Meiorin case[17,18]. A sub-group of the incumbent IA WFF who participated in the derivation of the WFX-FIT performance standards and who fit the description of this Meiorin requirement are the female and older male IA WFF participants. The WFX-FIT cut-score was initially computed based on the performance of both females and older males, however there was no difference in the completion time computed from both groups. Although Aboriginal IA WFF do not fall within the Meiorin requirements, the cut-score derived from this group which represents a large component of the IAWFF work force was faster than that of female WFF. Therefore, the final performance standards and cut-scores were derived from the mean WFX-FIT circuit completion times of ‘safe and efficient’ female IA WFF participants.

3.3.3.6. Statistical Analysis

Participant demographics are presented using descriptive statistics (mean ± standard deviation (SD)). Analysis of variance with Bonferroni post-hoc comparisons were used to determine if the VO_2, HR and RPE responses measured while performing the WFX-FIT circuit differed from the same measurements made while fighting a wildland fire on the job. This statistical analysis was also utilized to detect differences in responses to the Likert scale questions between the content validity ratings provided by demographical subsets of the IA WFF. The threshold of significance was $p \leq 0.05$. To qualify as a BFOR, the statistical computation that is conventionally applied when deriving performance standards and cut-scores from circuit completion times is the mean + 1 SD of the completion times[7,14,15,52]. In a one-tailed distribution this calculation mathematically incorporates 83.3% of all participants’ completion times. Therefore, mean circuit completion time was recorded for each fire jurisdiction and 1 SD was added to the mean completion time of the female subgroup for the establishment of each jurisdictional cut-score. Statistical analyses were performed using SPSS v.20.

3.3.4. RESULTS

3.3.4.1. Final WFX-FIT Circuit Protocol

A total of 64 incumbent IA WFF (including 11 females and 4 Aboriginals), age 27±7 years with 5±5 years work experience provided feedback on the draft WFX-FIT protocol and also participated in the physiological (construct) validation of the WFX-FIT. Based on the WFF feedback, revisions were made so that the circuit was truly representative of an emergency IA wildland fire fighting scenario. Examples of the revisions made are; lifting the hose pack from the ground rather than off a platform and adding reference points (ie. turning lines) to the simulated charged hose advance so that the participant would not need to look back over his/her shoulder while focusing forward as the task is performed on the job. The course over which the WFX-FIT circuit is performed is 20 m (65.5 ft) in length with a ramp positioned at the midpoint. This allowed a re-creation of the IA response distance to be performed indoors with the ramp and faster completion times providing the opportunity for simulating the demands of more arduous terrains. After rigorous pilot testing and modification, the WFX-FIT was standardized to the following distances and sequence:

1. The timing begins when the participant picks up a simulation medium pump (portable 2-cycle 4-stage fire pump; 28.5 kg [62.7 lb]) from a 1 m (3.3 ft) platform. For safety purposes the WFX-FIT Appraiser provides assistance with lifting the medium pump from the platform onto the participant's back at the onset and lowering the medium pump from the participant's back to the platform at the conclusion. The pump is carried on the back for a distance of 160 m (262.4 ft) (8 X 20 m/8 x 65.6 ft) traversing a ramp (35 degree pitch, 1.22 m/4 ft high) every 20 m (65.6 ft) covering the course a total of 8 times, then the pump returned to the platform.
2. Next, the participant picks up the simulation medium pump from the platform in his/her hands and carries it for 80 m (262.4ft) (4 X 20 m/4 x 65.6 ft) without traversing the ramp.
3. The participant then places the simulation medium pump back onto the platform, picks up an WFX-FIT hose pack from the ground, hoists and straps it onto his/her back, then carries the hose pack 1 km (3,281 ft) (50 X 20 m/50 x 65.6 ft) traversing the ramp every 20 m (65.6 ft) thereby covering the 20 m course a total of 50 times and then returns the hose pack to the ground at the start line.
4. In the final component of the circuit, the participant drags a weighted sled 80 m (262.4 ft) (4 X 20 m/4 x 65.6 ft) on level ground, to simulate advancing charged hose (drag force = 18.5 kg; 40.7 lb).

A main test consideration was that the WFX-FIT must be performed indoors to achieve test standardization and reduce the hazards associated with variable surfaces plus inclement weather and improve the test parity. The justification regarding the dimensions of the WFX-FIT circuit is a matter of practicality. It was determined during the test development phase that 20 m (65.5 ft) lengths would be suitable to most indoor recreational settings (E.g. gymnasium, arena, rink, airport hangar, etc.).

Two of the four tasks in the WFX-FIT protocol require participants to traverse a ramp with a 35° pitch every 20 m (65.6 ft.). The angle (slope) of the ramp was determined by documenting the average incline recorded on hill-sides and mountain-sides during the characterization phase of the project using a laser range-height meter. For example, the mountains in British Columbia had an average slope of 35° and frequently a slope of 45°. As well, when walking in muskeg, the foot had to be lifted higher than a 35° angle to extricate the foot from the bog and take the next step. To provide perspective, the 35° slope of the ramp is equivalent to the average slope of an intermediate ski hill.

3.3.4.2. Construct and Content Validation

The construct validity of the WFX-FIT was achieved by comparing the physiological measurements while 64 experienced IA WFF (including 11 females, and 4 Aboriginals), age 27±7 years, with 5±5 years of work experience representing two fire jurisdictions (Ontario and Parks Canada) performed the WFX-FIT circuit described above in an indoor venue with an average ambient temperature of 18-21°C, employing the same physiological measurements that were recorded during the on-the-job characterization (participant characteristics and physiological measurements previously reported in Manuscript II; *Identification and Characterization*). The mean ± SD VO_2 that was sustained while performing the most critical and physically demanding WFF tasks was 37±6 $mL·kg^{-1}·min^{-1}$ (n=168). Mean HR was 171±14 bpm and participants rated the on the-job-tasks as 'Hard' (RPE=15±2). The mean VO_2 of performing the same tasks over the WFX-FIT circuit was 37±4 $mL·kg^{-1}·min^{-1}$ (n=64). Mean HR was 178±11 bpm and participants rated WFX-FIT as 'Hard' (RPE=15±2). A summary of these results is presented in Table 11.

There were no significant differences between the mean VO_2, HR and RPE values recorded during the task characterization versus the validation *($p \leq 0.05$)* whether compared as isolated tasks or combined into an average circuit/scenario value. During the hand carry medium pump and hose pack lift and carry, the mean oxygen consumption measurements from the characterization (36±4 and 37±6 $mL·kg^{-1}·min^{-1}$) were very close to the values recorded during the validation (36±5 and 37±3 $mL·kg^{-1}·min^{-1}$).

However, considering individual components, the mean ± SD HR and RPE values recorded during the hose pack lift and carry (185±9 bpm, 16±2) and the charged hose advance (189±9 bpm, 17±2) were slightly higher than the values recorded while performing the same tasks during the characterization phase (170±15 and 167±149 bpm, 15±2 and 15±2). We believe this is due to 'finishing line exertion' or tendency to speed up toward the end of the circuit when the known completion point is nearing. Though this theory has not been tested, it stands to reason that the final task will likely elicit the highest cardiovascular response. Further, since the circuit is constructed to reflect the actual sequencing of events which take place on a fire line, altering the order of tasks would make the WFX-FIT less representative of an IA wildfire response. These findings indicate that the physical demands involved in performing the WFX-FIT are very close to the physical demands measured while IA WFF were performing the emergency on-the-job IA wildland fire fighting tasks during the characterization phase and provide high construct validity for the WFX-FIT circuit.

Table 11. Comparison of physical demand measurements made during the characterization and validation (mean ± SD).

IA WFF Fire Fighting Task	Characterization (*n=168*)			Validation (*n=64*)		
	VO_2 (mL·kg^{-1}·min^{-1})	HR (bpm)	RPE (out of 20)	VO_2 (mL·kg^{-1}·min^{-1})	HR (bpm)	RPE (out of 20)
Carry Medium Pump on Back	38 ± 7	177 ± 11	16 ± 2	35 ± 4	167 ± 11	12 ± 2
Hand Carry Medium Pump	36 ± 4	168 ± 15	15 ± 2	36 ± 5	171 ± 14	13 ± 2
Hose Pack Lift & Carry on Back	37 ± 6	170 ± 15	15 ± 2	37 ± 3	185 ± 9	16 ± 2
Advance Charged Hose	36 ± 5	167 ± 14	15 ± 2	39 ± 4	189 ± 9	17 ± 2
Combined	37 ± 6	171 ± 14	15 ± 2	37 ± 4	178 ± 11	15 ± 2

To establish the content validity of the WFX-FIT, 128 experienced WFF (110 male, 18 female including 19 Aboriginal) age 26±7 years with 5±5 years work experience provided Likert Scale ratings (Figure 1) of their perception of whether the WFX-FIT accurately simulates the tasks, physical demand, task sequencing and work rate that were experienced on the job. As is evident from the summary of mean ratings presented in Table 12, the scores for all four questions were very high; 6.3±0.6, 6.0±0.7, 6.1±0.7, 6.2±0.5, on a scale of; 7 (strongly agree) to 1 (strongly disagree). As well, there were no significant differences between jurisdictions or differences with respect to age, female and Aboriginal ratings *($p \leq 0.05$).* The results of the physiological (construct) validation, together with expert consensus (content) validation, provide strong evidence for the validity of the WFX-FIT.

Table 12. Ratings provided by IA wildland fire fighters on the 'equivalence' between the WFX-FIT and the associated on-the-job tasks for the content validation of the WFX-FIT reported by the fire jurisdictions in which the measurements were made (mean±SD).

Jurisdiction	Participant Group	*n*	Q1	Q2	Q3	Q4
Ontario	All participants	61	6.2 ± 0.7	5.9 ± 0.7	6.2 ± 0.8	6.1 ± 0.7
	Females	11	6.4 ± 0.7	6.3 ± 0.6	6.1 ± 0.8	6.4 ± 0.8
	Aboriginals	3	6.7 ± 0.6	5.7 ± 0.6	6.7 ± 0.6	6.3 ± 0.6
Yukon	All participants	27	6.1 ± 0.6	6.0 ± 1.2	6.1 ± 0.7	6.0 ± 0.6
	Females	1	6.0 ± 0.1	6.0 ± 0.1	6.0 ± 0.1	6.0 ± 0.1
	Aboriginals	14	6.2 ± 0.8	6.4 ± 0.9	6.2 ± 0.6	6.0 ± 0.1
British Columbia	All participants	40	6.1 ± 0.6	5.7 ± 0.7	5.9 ± 0.7	6.2 ± 0.7
	Females	6	6.3 ± 0.5	5.5 ± 0.5	5.7 ± 0.8	6.0 ± 0.6
	Aboriginals	2	6.5 ± 0.7	6.5 ± 0.7	6.0 ± 1.4	7.0 ± 0.1
Combined		128	6.3 ± 0.6	6.0 ± 0.7	6.1 ± 0.7	6.2 ± 0.4

For details on Q1-Q4, refer to Figure 1.

3.3.4.3. Derivation of Performance Standards and Associated Cut-scores

The derivation of performance standards and cut-scores for the WFX-FIT involved a total of 482 IA WFF (including 40 females and 115 Aboriginals) age 31±8 years, with 7±7 years of work experience representing all 13 fire jurisdictions. Participant characteristics are summarized in Table 13. A total of five of these incumbent IA WFF (~1% of participants) were unable to complete one or more components of the circuit due to pre-existing injury. Since these WFF did not have a circuit completion time, their results were not included in the derivation of cut-scores. All participants presented in Table 13 successfully completed all of the critical, physically demanding tasks that comprise the WFX-FIT with varying completion times. As summarized in Table 14 the mean circuit completion times ranged from 13:48 min:sec, (Parks Canada) to 18:35 min:sec, (Newfoundland).

Table 13. Characteristics of the IA WFF who participated in the derivation of performance standards by fire jurisdiction.

Fire Jurisdiction	Total (n)	Males (n)	Females (n)	Aboriginals (n)	Experience (years) Mean±SD	Age (years) Mean±SD
Alberta	47	43	4	15	6 ± 7	27 ± 7
British Columbia	40	34	6	2	4 ± 3	24 ± 5
Manitoba	38	36	2	17	7 ± 7	28 ± 9
New Brunswick	42	39	3	0	12 ± 10	39 ± 11
Newfoundland	20	16	4	0	10 ± 13	36 ± 12
Northwest Territories	26	26	0	26	9 ± 8	35 ± 10
Nova Scotia	39	36	3	1	6 ± 6	31 ± 9
Ontario	61	50	11	3	5 ± 5	26 ± 7
Parks Canada	19	18	1	9	7 ± 5	32 ± 8
Prince Edward Island	10	10	0	0	23 ± 12	48 ± 8
Quebec	46	44	2	0	11 ± 11	36 ± 12
Saskatchewan	46	44	2	25	8 ± 9	31 ± 10
Yukon	48	46	2	17	8 ± 8	33 ± 9
Combined	482	442	40	115	7 ± 7	31 ± 8

The statistical computation used to derive the performance standards and cut-scores was the conventional practice of mean + 1 SD from circuit completion times[7,14,15,52]. In a one-tailed distribution, this calculation mathematically incorporates 83.3% of all participants' completion times. When completion times of each sub-group (males, older males, females and Aboriginals) of the IA WFF were plotted, they all provided a normal distribution. Therefore, we are confident in assuming a normal distribution of completion times in each grouping for the related calculation of mean + 1 SD to achieve an 83.3% pass rate. As reported earlier in this paper, the WFX-FIT cut-score was initially computed based on the performance of both females and older males, however there was no difference in the completion time computed from these groups. Therefore, the final performance standards and cut-scores were derived from the WFX-FIT circuit completion times of 'safe and efficient' female IA WFF participants.

The completion times of 40 female IA WFF from across Canada were the basis for the derivation of performance standards for the WFX-FIT (mean ± SD age = 36.8±8.3 yrs; range = 24-49). However, in two of the thirteen fire jurisdictions (Prince Edward Island and North West Territories), there were no females IA WFF to participate, and in other jurisdictions there were an insufficient number of female IA WFF in the work force to permit the required statistical calculations for that fire jurisdiction. Despite great effort to involve a diverse representation of the IA WFF population, the reality is that there are far fewer female than male IA WFF. Therefore, for statistical analysis it was necessary to combine fire jurisdictions into "groupings" based on similar terrain difficulty, similar Fire Management Policy on fire risk and forest value index and the consequent emergency pace (completion time) of participants. The resultant groupings of fire jurisdictions that met this criterion for *similar mean circuit completion times* are summarized in Table 14.

Table 14. Groupings of fire jurisdictions based on similar mean WFX-FIT circuit completion times for female and male Initial Attack wildland fire fighters combined and the resultant jurisdictional and national exchange cut-scores based on female Initial Attack wildland fire fighters completion times.

	Groupings/Fire Jurisdictions	Total *n* (Female)	Combined Circuit Completion Time Mean (min:sec)	Female Circuit Completion Time Mean±SD (min:sec)	Female Circuit Completion Time Mean+SD–11.1% (min:sec)	Rounded Jurisdictional cut-score (min:sec)
1	Alberta	47 (4)	14:10	14:59 ±1:17	14:29	14:30
	British Columbia	40 (6)	13:58			
	Parks Canada	18 (1)	13:48			
2	Manitoba	38 (2)	15:27	17:44 ±1:06	17:14	17:15
	Nova Scotia	39 (3)	15:53			
	Ontario	61 (4)	15:36			
	Quebec	46 (2)	15:14			
	Saskatchewan	47 (2)	15:42			
3	New Brunswick	45 (3)	16:31	17:38 ±2:17	17:44	17:45
	Northwest Territories	26 (0)	16:37			
	Prince Edward Island	10 (0)	16:05			
	Yukon	48 (2)	16:01			
4	Newfoundland	21 (4)	18:35	22:08 ±0:37	20:14	20:15
	National Exchange cut- score					**14:30**

Although statistically designed to include 83.3% of all female IA WFF who participated in the derivation of the WFX-FIT cut-scores, when the cut-score was applied to each individual female IA WFF completion time, 85% of all the participating female WFF had a completion time that was equal to or faster than the mean ± 1SD WFX-FIT cut-score. Importantly, it is well established that when participants become orientated or familiarized to a physical fitness screening circuit, there is a resultant improvement in completion time due to motivation, familiarity with the test components and experience in appropriate pacing[12,14]. In a training study which was a follow-up to the present study, when examining the impact of familiarization on female WFX-FIT circuit completion times, when repeat trials were performed on separate days, the resultant improvement was 11.1%. In light of these findings, the 11.1% improvement in completion time that resulted from familiarization was taken into account when deriving the cut-scores. Based on the above considerations, the WFX-FIT jurisdictional/provincial cut-scores were calculated for each grouping using the following formula and rounded to the nearest five seconds:

Cut-score = (Mean circuit completion time + 1 SD from all female WFF in each grouping) – 11.1% to allow for familiarization

This calculation provided jurisdictional cut-scores as reported in Table 14.

The goal for CIFFC in conducting this project was to establish a National WFX-FIT performance standard that would enable CIFFC to safely exchange IA WFF among member fire jurisdiction across Canada. That is, if an IA WFF demonstrates the ability to meet the National WFX-FIT performance standard, CIFFC is assured that that IA WFF is capable of safely and effectively fighting wildland fires in any fire jurisdiction in Canada. Therefore, the National WFX-FIT cut-score must be equal to the standard in those fire jurisdictions that have the highest jurisdictional performance standards (fastest/shortest time). Consequently, the National WFX-FIT cut-score is 14:30 (min:sec) derived for Grouping 1 (Table 14). Because the performance standard required to successfully complete the WFX-FIT was derived from experienced female IA WFF performing critical, physically demanding and frequently occurring emergency on-the-job tasks, this approach provides a criterion-based physical employment standard, based on the incumbents' self-selected on-the-job emergency pace rather than from their maximal capacities, which would be characteristics-based.

3.3.5. DISCUSSION

The tasks embodied in the WFX-FIT protocol were identified by male, female and Aboriginal IA WFF of all ages and confirmed during the characterization as being the most important, physically demanding, and frequently occurring on-the-job IA tasks. These tasks were then simulated and structured into a circuit with the task sequence in the circuit matching the sequence of tasks during the IA of a wildland fire. The resultant completion time standards were very similar to that of the on-the-job completion times of IA fire suppression.

A physical employment standard can be developed using fitness components, job simulation tests, or a hybrid of job simulation tests and fitness components[3,7,14,32,39]. A criticism of fitness component tests is their lack of content/face validity; that is, fitness component tests do not subjectively appear to evaluate the component they purport to assess. Additionally, fitness component tests are disparaged because of the performance decrements associated with aging[3,7,14,40]. The use of task simulations is generally preferred because of their face validity and they provide a more realistic and exact evaluation of the ability to meet the occupational demands. This approach also takes into account differences in work efficiency that are observed in workers with differing levels of training and experience[40]. Contrary to the Meiorin Decision[3,7,10,14,32,40], the performance standards and/or 'cut-points' for fitness component tests are generally based on the characteristics (for example, maximal strength or force production) of incumbents, rather than the criterion task performance necessary for safe and efficient job completion. An additional benefit of task simulation tests includes simple administration and the provision of a dichotomous "pass" or "fail" outcome[15]. It has been argued that there should also be a *'borderline'* score zone when candidates are very close to meeting the cut-score. That is, on any given day a candidate could underperform due to variation in motivation, effort or biological variability. However, if the administrator of the protocol provides second and third-attempt opportunities to counter this variability, then a pass-fail cut-score overcomes this potential variability and is therefore more desirable.

Though there are many benefits of task simulation assessments, they are not without criticisms. Tipton et al.[5] identified a number of potential issues with task simulations; *i)* the validity of the test is dependent on the accuracy of the simulation; *ii)* it is difficult to simulate some critical tasks in a way that allows the simulations to be undertaken in a variety of locations and within controlled environmental conditions; *iii)* there is no way of knowing what percentage of their maximum work rate an individual is working at when they undertake a simulation; *iv)* it is not viable to use simulations requiring significant skill components that should be acquired as a result of performing the job[15]. In the present investigation, the researchers believe that all of the considerations presented by Tipton et al. have been addressed. For example, the task simulations and related equipment in the WFX-FIT are based on the feedback from supervisory and managerial subject matter experts as well as incumbent IA WFF. The IA wildland fire fighting tasks were derived from the PDA and subsequently characterized physiologically to be the most physically demanding. Additionally, the weight of standard fire-line PPE, equipment and emergency response distances have been duplicated and their associated demands subsequently validated. As well, the WFX-FIT was designed to account for variability in terrain differences across Canada (ie. mountains, bogland etc.).

With respect to relative exertion, it is not necessary to ascertain what percent of maximum a candidate is working when undertaking a task simulation because the simulation is criterion based, not characteristics based. That is, the IA WFF participants performed the protocol at their self-selected safe and efficient emergency pace. Additionally, the cardiovascular requirement of the WFX-FIT represents the minimum performance necessary for the IA of a wildland fire, so that a candidate must possess the requisite physical ability to complete the protocol. Lastly, any task simulation which could be made easier for some participants because of previously acquired skill (ie. starting a medium pump), was not included in the WFX-FIT. One task from the PDA and characterization which was not included in the WFX-FIT circuit was Pulaski trenching. When considered together with the data in Table 4, subject matter experts ruled Pulaski trenching as having the lowest priority, requiring only moderate exertion and occurring with only a moderate frequency during an IA. Further, when Pulaski trenching was initially included in the WFX-FIT during pilot testing, it provided no differentiation between participants. Consequently, due to jurisdictional differences in trenching techniques (ie. nozzling vs digging), variability in soil density, and an inability to accurately differentiate participants' physical capacities, the task was not included in the WFX-FIT protocol. We therefore believe that the WFX-FIT protocol provides a sequence of job simulations that accurately reflects the physical demands required to safely and efficiently carry out an IA of a wildland fire.

In a review of validity and reliability of physical employment standards, Milligan et al.[32] presented factors that can influence the content and construct validity of the tasks. These authors cautioned that failure to comply with the factors they identified may invalidate any fitness testing results. Since the present study addressed all of the considerations that these authors presented, we are confident that the methodology used to develop the WFX-FIT is consistent with current best practice; *(i) Measuring the correct physical and/or physiological attribute of the critical task; (ii) Choosing the correct sample population; (iii) Reliability and validity of the equipment used to determine the physical and/or physiological demands; (iv) Impact of the environment*.

To address the first point from Milligan et al., the physical and physiological demands of the critical tasks were replicated by simulating tasks using representative equipment performed in a similar manner with respect to duration and intensity. To address the second point, data should be collected from a “representative cohort of individuals”, a robust sample of incumbent IA WFF representing all fire jurisdictions participated in the study. Efforts were made to ensure a diverse representation of the WFF population, including sex, age, experience and Aboriginal status. It has been argued previously that standards should be based on a sample from the wider population of those that could apply for a job and those that are currently in the job[15,32]. However, since the WFX-FIT is designed to be a fitness screening test for both incumbents and applicants, using the incumbent cohort is appropriate because it is representative of potential test candidates. Additionally, the possible bias from including tasks which are dependent upon a skill which will be obtained while employed[9], has been avoided by selecting only those tasks that are fundamental to an IA scenario. To address the third point, measurements of the physical and physiological demands of the critical tasks were made with accurate and reliable equipment which were routinely calibrated to ensure precision. The fourth and final point, impact of the environment, was addressed by implementing the test standardization criteria outlined previously in this paper including appropriate test sites and surfaces, an acceptable temperature range during testing, and pre-test recommendations relating to hydration, sleep and prior exercise, with differences in terrain built into the test protocol and jurisdictional cut-scores.

Validation of the WFX-FIT was achieved using both construct and content procedures. Construct validation involved statistical comparison of the physiological demands encountered while incumbent WFF were performing critical, physically demanding and frequently occurring on-the-job tasks to the physiological demands measured during task simulations in the WFX-FIT circuit. The mean VO_2, HR and RPE measurements while incumbent IA WFF performed the on-the-job tasks compared favourably to the measurements made when IA WFF completed the WFX-FIT circuit. No significant age, sex, and Aboriginal status differences were found between the physiological measurements recorded during the characterization and the WFX-FIT circuit performance.

Content validation involved Likert scale ratings provided by experienced IA WFF that compared the 'likeness' of the WFX-FIT protocol to the actual job of IA fire fighting. This was accomplished in each of the participating jurisdictions by administering a questionnaire using Likert-scale ratings to the incumbent subject matter experts following their completion of the WFX-FIT protocol. The content validity of the WFX-FIT was confirmed by consistently high ratings (>6 on a 7-point scale) by male, female and Aboriginal incumbent IA WFF of all ages concerning the tasks, physical demand, task sequencing and work rate of the WFX-FIT for evaluating IA WFF applicants. Consistent with the recommendation made by Tipton et al. the physiological fitness standard was developed and then validated on a suitable and for the most part separate cohort of IA WFF to demonstrate that it is valid, not simply relevant, for those who contributed to its development[15]. Therefore, because the content and construct validation measurements were robust, the WFX-FIT is a valid assessment of candidate suitability for employment.

It is important to point out that during the derivation of performance standards and cut-scores, completion times of incumbent IA WFF on the WFX-FIT circuit were not the fastest times with which they were capable of completing the circuit. Rather, completion times were constrained by the instructions to instructed "*complete the WFX-FIT circuit at the same safe and efficient emergency pace that would be utilized to attack a wildland fire on the job*" and confirmed by subject matter experts to be an appropriate pace for IA wildland fire fighting. The circuit was performed without wearing any physiological measurement apparatus, with completion time being the only outcome of interest. Only successfully completed circuit trials were recorded and analyzed.

The variability in the completion times recorded among the WFF (as reflected in the resultant SD) simply reflects the variability in their self-selected "emergency pace". Further, the WFX-FIT cut-scores for each fire jurisdiction were designed statistically to provide an effective "pass rate" of 83.3% for female IA WFF, when in fact the actual pass rate of the female IA WFF participants was 85%. Therefore, by design the WFX-FIT jurisdictional cut-scores do not have an adverse impact on females. Although the determination of a "disproportionate" failure rate is subject to court judgments, researchers and courts have commonly recognized the "80% or four-fifths rule", which specifies that adverse impact exists when the pass rate of a sub-group of participants (typically females) is less than 80% of the pass rate of the majority group of participants[9–12,14,16,18,47,49,109]. As well, in accordance with the Meiorin Decision requirements, the WFX-FIT performance standards and cut-scores are criterion-based, founded on the job performance of female IA WFF, not based on the characteristics of the workforce.

The differences in physical characteristics between males and females that relate to job performance during physically demanding tasks include body size and composition, musculoskeletal strength and endurance, aerobic and anaerobic power[16]. Fundamentally, these physiological differences disadvantage females in the selection process for physically demanding occupations. Additionally, age-related declines in functional capacity tend to increase after the age of 45 years[40]. Our initial statistical derivation of cut-scores from both females and older males indicated that there were no differences in the resultant cut-scores. Therefore by basing the final cut-scores on females, we are confident that the WFX-FIT has been designed to eliminate the impact of age and sex selection bias.

It is generally accepted that cut-points must be statistically derived from this sub-group of incumbents and applying the mean ± 1 SD cut-point has been accepted in human rights challenges[20,110]. The decision to apply an 11.1% familiarization improvement to the cut-score is founded on the knowledge that participants improve performance on a physical employment standard by becoming familiar with the test protocol. The reported 11.1% improvement is consistent with literature reported by

Jamnik et al.[12,14] who studied the effects of familiarization and exercise training on female and male correctional officer applicants (n=48) while performing the Fitness Test for Correctional Officer Applicants (FIT*CO*). Similarly, in an investigation involving the Emergency Service Physical Abilities Test (ESPA) for Nuclear Power Plant Fire Fighters, Gumieniak et al.[13,14] demonstrated that familiarization improved circuit completion time by 12.7% for females and 10.2% for males. Therefore, because test familiarity may influence test performance, the effect of familiarization has been taken into account.

Consistent with the recommendations made by Rogers et al.[28] and Zumbo[52], the term performance standard has been used throughout to denote a qualitative description of the physical ability required to meet the demands of the job, or the conceptual version of competency (eg. *'fit for duty'*, *'safe and efficient'*). The cut-scores refer to the operational version, the point (eg. completion time) of minimally acceptable performance required for a passing grade/score.

A variety of methods have been used for the determination of cut-scores. In the present investigation, norm-referenced interpretation is based on the statistical distribution of test scores[51,52]. The mean + 1 SD was taken from the completion times of all safe and efficient female incumbent IA WFF who were confirmed by supervisory subject matter experts to be performing at an appropriate rate. Another accepted process for determining a performance standard involves utilizing expert judges who observe video recordings of actors performing the protocol at difference paces, known as the Bookmark procedure. Rogers et al.[28] described in detail the Bookmark procedure in their paper on establishing performance standards and a cut-score for the Canadian Forces Firefighter Physical Fitness Test. In brief, a panel of judges rate the video performances completed at varying speeds, from fastest to slowest, and insert 'bookmarks' at the first acceptable and unacceptable emergency pace. After each 'round' of bookmarking by the subject matter expert panel, the results are compiled by the researchers and presented back to the panel. Each round concludes with a discussion aimed at reducing the variability among members as to which paces are acceptable and the process is repeated until a consensus on a distribution of completion times is achieved[28,53]. They then use a normative approach similar to the present investigation to calculate the cut-score from this consensus-achieved distribution of completion times.

Despite the methodological differences in setting cut-scores, the ultimate goal is to limit the number of false-positives and false-negatives[28,31,54]. In a false-positive decision (passing a WFF who should fail), the safety of the WFF, a co-worker or the public may be compromised and the employer may be at risk of 'workplace negligence' and could be deemed liable if they fail to take reasonable measures ''to ensure the bodily safety of persons doing the work or task". When public safety workers require physiological attributes necessary to avoid foreseeable risks, an employer has a duty of care or due diligence responsibility to ensure that those physiological attributes are present''[8,14]. On the other hand, a false-negative decision (failing a WFF who should pass), has the costly potential of excluding a viable candidate. With these considerations in mind, the norm-referenced interpretation method used in the present investigation to determine the cut-scores for the WFX-FIT involved a thorough process based on a robust sample of incumbent IA WFF and supervisory subject matter experts to determine the minimally acceptable level of performance required for safe and efficient job completion. It is also important to note that although Rogers et al. used the Bookmarking procedure to derive a consensus-achieved distribution of acceptable scores, they then formulated the final cut-score using a statistically derived normative approach similar to that used in the current study.

To ensure that the WFX-FIT is standardized and unbiased, a detailed test administration manual was provided to CIFFC and fire jurisdictions. In addition to the resource material noted previously, CIFFC was provided with target completion times (ie. split times) for each lap in the circuit that the candidate must reach to achieve the jurisdictional cut-score and/or the National WFX-FIT cut-score. These lap target times will enable WFX-FIT Appraisers to provide constant motivational feedback (coaching) to unaccustomed participants throughout their circuit performance. Additional recommendations that promote standardization include WFX-FIT Appraisers being trained so that they are thoroughly knowledgeable about installation, calibration and maintenance of equipment and the directive that WFX-FIT Appraisers be audited by a qualified auditor annually to document that standardization is being maintained. Further, training workshops should be hosted on a regular basis to ensure the reaffirmation of these standards.

For numerous public safety occupations (fire fighting, policing, corrections and military), the use of protective clothing is a job-related requirement designed to protect individuals from hazards. The effects of protective clothing on heat transfer, thermal regulation and exercise tolerance have been well documented[111,112]. It has been argued that physical employment testing should include the need to wear protective clothing. However, it is not clear if simulating the load cost of protective clothing is representative of the burden associated with wearing protective clothing[112]. With respect to IA WFF, the imposition of protective clothing is less than other physically demanding occupations. Structural fire fighters for example, are encumbered with turn-out gear and SCBA weighing 15 kg (33 lb) and boots weighing 7 kg (15.4 lb)[60]. Military personnel are encumbered with body armor (independent of pack) weighing 5.3 kg (11.7 lb)[111]. During the characterization of physically demanding tasks, measurements indicated that IA WFF were wearing 4.1 kg (9.0 lb) of protective clothing including tool belt including radio, water bottle and flashlight, and this encumbrance was built into the WFX-FIT protocol in the form of a 4.1 kg (9.0 lb) weighted belt.

Though the physical constraints owing to protective clothing are apparent[111,112], the need to incorporate work-specific "protective" clothing into the WFX-FIT is challenged by several factors not the least of which is the fact that WFF only wear light coveralls. The first issue of providing coveralls to all participants is that of logistics; the WFX-FIT is designed as a national physical employment standard. As such, several thousand candidates undergo pre-employment testing annually. This would necessitate the implementation and maintenance of hundreds, if not thousands, of ensembles of varying sizes. There is an obvious financial burden of purchasing and maintaining the test ensembles and personal hygiene issues also present in such a situation. In some jurisdictions, such as British Columbia, steel-toed boots are not worn on the job, yet in New Brunswick they are worn on the job. Theoretically, a candidate would have to switch ensembles dependent on their jurisdiction or to achieve the national exchange standard. Moreover, novice candidates would have to be acclimated to the clothing ensemble because their normal movement patterns may become constrained. To overcome this disadvantage, candidates would have to be familiarized to the clothing prior to testing. Lastly, the physical and physiological performances of incumbent IA WFF were characterized while wearing normal fire-line clothing and the physical demands were the same as performing the WFX-FIT while encumbered by a weighted belt and exercise attire, so that the physiological burden imposed by WFF clothing is integrated to the WFX-FIT protocol. Therefore, for the purposes of standardization and logistics, a weighted waist belt which simulates load-bearing PPE is worn by participants when performing the WFX-FIT circuit.

In Canada, court decisions and government human rights legislation have imposed strict legal criteria for the development of applicant and incumbent physiological employment standards to qualify as a BFOR. Relating the Meiorin requirements to the development and validation of the WFX-FIT requires a brief review of these important precedents. In 1999 The Meiorin Decision of the Supreme Court of Canada provided a three-part test for determining whether a prima facie discriminatory standard is a BFOR[4,10–12,14,17,18,29]. An employer must provide justification for a discriminatory standard by demonstrating:

1) that the employer adopted the standard for a purpose rationally connected to the performance of the job;
2) that the employer adopted the particular standard in an honest and good faith belief that it was necessary to the fulfilment of that legitimate work-related purpose; and
3) that the standard is reasonably necessary to the accomplishment of that legitimate work-related purpose. To show that the standard is reasonably necessary, it must be demonstrated that it is impossible to accommodate individual employees sharing the characteristic of the claimant without imposing undue hardship on the employer.

Meeting the first two Meiorin tests is relatively straightforward. The evidence in this article details the rationale for establishing the WFX-FIT, the methodology involved in the PDA, job characterization, WFX-FIT test development and WFX-FIT test validation which convincingly illustrate that CIFFC adopted the WFX-FIT Performance Standard “for a purpose rationally connected to the performance of the job” and that CIFFC “did so in an honest and good faith belief that it was necessary” to meet the physical demands encountered by IA WFF on the job. Therefore, the WFX-FIT performance test and standard have been designed to pass the first two Meiorin tests. Passing the third Meiorin test necessitates further attention.

At the 2000 BFOR Consensus Conference (Toronto, Ontario), it was concluded that ‘undue hardship' could be demonstrated if providing accommodation for adverse impact would undermine the due diligence responsibility of the employer[3,4,12,14]. Because the WFX-FIT performance standard and cut-scores are based on critical, physically demanding emergency tasks in which personal safety, the safety of a co-worker or the safety of the general public may be compromised by inefficient performance or failure to complete, it is not possible to accommodate an individual IA WFF or applicant by lowering the WFX-FIT cut-scores. Such an accommodation could result in an IA WFF being unable to complete critical emergency tasks during a wildland fire. That is, lowering the jurisdictional or national WFX-FIT requirements would constitute undue hardship, because each jurisdiction and CIFFC has a due diligence responsibility to ensure that all WFF are capable of meeting the emergency demands encountered on the job[3,29]. Failure to maintain these standards could result in a circumstance which a jurisdiction or CIFFC is deemed liable for the foreseeable ineffective performance of an IA WFF which led to a catastrophic consequence.

A provision in the 2004 revision to the Criminal Code of Canada implies that management in a fire jurisdiction or CIFFC could be deemed criminally negligent if they failed to take reasonable measures to ensure the safe and efficient work performance of WFF[8]. If an IA WFF demonstrates that he/she meets the National WFX-FIT cut-score, then he/she is capable of safely and effectively conducting an IA on wildland fires in any fire jurisdiction in Canada. Further, if a WFF candidate does not initially pass the WFX-FIT, there is convincing evidence from the related literature that, by taking advantage of test familiarization opportunities[12–14,30–32] and by engaging in an appropriate physical training program[12–14,33–38], it is possible for incumbent female and male WFF to meet the WFX-FIT performance standard and cut-score. In a subsequent WFX-FIT research report, we will provide an examination of adverse impact and determine whether familiarization opportunities and exercise training are able to overcome adverse impact and improve the likelihood of success on the WFX-FIT circuit.

3.3.6. SUMMARY and CONCLUSIONS

In summary, the WFX-FIT protocol was developed to include simulations of the following important, physically demanding and frequently occurring tasks; carrying a medium pump on the back, carrying a medium pump in the hands for 80 m, carrying a WFX-FIT hose pack on the back, and advancing charged hose. Simulations of these emergency IA wildland fire fighting tasks are performed in a continuous circuit during which it is necessary to traverse a ramp which enables the simulation of the demands of different terrains and challenge the participants' aerobic-anaerobic fitness. Draft simulations of the on-the-job tasks that were included in the WFX-FIT were refined based on feedback from supervisory personnel and experienced IA WFF.

Measurements from the construct validation of the task simulation performances compared very favourably with the measurements made during the characterization phase while IA WFF were performing the corresponding critically important, frequently occurring and physically demanding tasks on the job. Additionally, experienced IA WFF from across Canada provided high Likert scale ratings of whether the WFX-FIT accurately simulates the tasks, physical demand, task sequencing and work rate compared to the on-the-job tasks upon which the circuit tasks were based. We conclude that the observed high construct and high content validation scores convincingly establish the validity of the WFX-FIT.

Further, the derivation WFX-FIT performance standards involved IA WFF from all fire jurisdictions across Canada using an approach that conforms to the BFOR requirements established by the Supreme Court of Canada's Meiorin Decision. That is, the cut-scores were calculated based on the completion times of female IA WFF. Jurisdictionally, completion times range from 14:30 to 20:15 (min:sec), which represent a range in intensity owing to differing terrain difficulty, different Fire Management Policy on fire risk and forest value indexes, and different emergency paces (completion time). The resultant National WFX-FIT cut-score (14:30, min:sec) is equal to the standard in those fire jurisdictions that have the highest jurisdictional performance standard.

Competing Interests

The authors declare that there were no conflicts of interest during this study.

MANUSCRIPT IV

Physical Employment Standard for Canadian Wildland Fire Fighters: *Examining Test Reliability plus Familiarization and Physical Fitness Training to Overcome Adverse Impact*[10]

Robert J Gumieniak, MSc., Norman Gledhill, PhD., Veronica K Jamnik, PhD.[11,12]

OVERVIEW

The Wildland Fire Fighter Exchange Fitness Test (WFX-FIT) is an annual fitness requirement for applicant and incumbent Initial Attack (IA) Wildland Fire Fighters (WFF) in all jurisdictions/provinces across Canada. The WFX-FIT must be performed annually whether the candidate is a new/prospective hire or a returning incumbent. The protocol was constructed to conform to the Supreme Court of Canada's Meiron Decision which obliges employers to address 'adverse impact' and 'accommodation'- when adverse impact is present, the employer must either accommodate the impacted sub-group or demonstrate that accommodation is not feasible because the safety risk associated with lowering the standard would constitute 'undue hardship'. For the Canadian Interagency Forest Fire Centre (CIFFC), the threat to life and property from lowering the WFX-FIT standard for a sub-group would countermand the employer's due diligence responsibility and thereby constitute undue hardship.

Participants in this study, who were normally active, non-WFF general population volunteers (*n*=145), were familiarized to the test protocol then randomized into two experimental groups and one control group to determine whether adverse impact was present and to examine two strategies to overcome adverse impact; *i)* familiarization and five weeks of exercise training (PFT), or *ii)*

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[12] *Contribution of Authors for this manuscript, Robert Gumieniak was the primary author and was the primary facilitator of data collection and entry, data analysis and interpretation as well as the primary contributor to overall project design and manuscript preparation. RG, VKJ and NG all provided guidance regarding project design and were involved in the interpretation of the data analysis as well as revision of the manuscript VKJ and NG also helped to facilitate travel during project recruitment and support with data collection and interpretation.*

familiarization and five weekly circuit performances (WFX), or *iii)* control (CON). At Baseline, the Ontario WFX-FIT pass rate was 11% for all female participants and 73% for all males, indicating that the WFX-FIT had an adverse impact on non-WFF general population females. Following familiarization only, significant improvements in mean WFX-FIT completion times were observed for all three study groups with males and females combined and when stratified by sex. For PFT group participants, with females and males pooled, mean circuit completion time improved by 11%, WFX group participants improved by 10% and CON group improved by 10.8%. The circuit completion time of the CON group was unchanged from Baseline to Trial 6. There were significant additional improvements in completion time from Trial 1 to Trial 6 for PFT (17.3%) and WFX group participants (10.8%) due to treatment exposure. The cumulative effect of familiarization plus treatment improved WFX-FIT circuit completion time by a total of 29.7% for all PFT participants (31.4% for females) and 20.8% for all WFX participants (22.7% for females). At Trial 6, the overall WFX-FIT pass rate was 80% for females and 100% for males in the PFT group, 72% for females and 100% for males in the WFX group and, 26% for females and 91% for males in the CON group indicating that with familiarization and training, non-WFF general population females were able to overcome the adverse impact of the Ontario WFX-FIT standard.

Key Words:
Public safety, BFOR, occupational fitness testing, training, Meiorin Decision, accommodation

3.4. INTRODUCTION

The intent of a physical employment standard is to determine whether an applicant or incumbent possesses the necessary physical attributes to safely and efficiently perform the critical, physically demanding on-the-job tasks encountered in public safety occupations[5,14,25,39,41]. This distinction is based on the 1988 Government of Canada definition that a Bona Fide Occupational Requirement (BFOR) is a condition of employment imposed in the belief that it is necessary for the safe, efficient and reliable performance for the job and which is objectively and reasonably necessary for such performance[4,12,18,19]. An important consideration when establishing the scientific accuracy of a BFOR is test–retest reliability. Reliability refers to a measure of consistency (reproducibility) within data. A common method used to determine reliability is the test–retest process, in which the first measure is compared with a second or third measure using the same participants and under the same conditions[32]. Although there is inherent variability with any protocol due to differences in participant effort and biological variability, minimizing these confounding issues increases the reliability of a participant's performance[30,32]. Initial Attack (IA) Wildland Fire Fighters (WFF) are required annually to pass the WFX-FIT test, and test appraisers are responsible for minimizing technical variability in test administration, equipment set-up, calibration and environment. Biological non fitness-related variability in participants refers to factors such as ambient temperature, sleep status, hydration status, nutrition and fatigue. This variability is mitigated in the WFX-FIT protocol by specifying an ambient temperature during testing and providing guidelines relating to smoking, diet and hydration, as well as exercise prior to the test. Systematic variability describes the performance improvements owing to learned performance and pacing strategies.

The primary reason for developing the WFX-FIT was to enable the Canadian Interagency Forest Fire Fighter Centre (CIFFC) to safely deploy IAWFF among all fire jurisdictions across Canada. That is, to provide a test protocol which would allow IA WFF candidates to demonstrate that they are capable of safely and efficiently performing the IA of a wildland fire in any jurisdiction/province[6,39]. In Canada, there is no mandatory age of retirement and the WFX-FIT must be performed annually regardless of age/years of experience. However, the WFX-FIT will screen out those applicants or returning incumbents who are unable to meet the performance standard, regardless of age. To qualify for wildland fire fighting, in each individual province, IA WFF must meet the jurisdictional performance standard for their province/territory), and to be eligible for exchange to all other jurisdictions they must meet the national exchange performance standard (National WFX-FIT standard). Owing to i) regional differences in terrain difficulty, ii) Fire Management Policy on fire risk and forest value, and iii) accepted emergency pace , there are associated differences in physical demands among provinces/territories. Therefore, a range of jurisdictional WFX-FIT circuit completion times were established to take into account these differences (Manuscript III; *Construction and Validation*). The provincial cut-scores range from 14:30 to 20:15 minutes:seconds (min:sec) and the National WFX-FIT cut-score is the same as the standard in those fire jurisdictions that have the highest provincial performance standard (14:30 min:sec). The present study will focus on the Ontario performance standard (Ontario WFX-FIT completion time) to address familiarization and training, with minimal attention to the National WFX-FIT standard.

In 1988, the British Columbia Forest Service introduced a mandatory physical fitness test for IA WFF. The test was a variant of the US Forest Service Smokejumpers test, developed by Dr. Brian Sharkey[46]. It consisted of four components: 24 pushups in 60 seconds (sec), 24 situps in 60 sec, 7 pullups in 60 sec followed by a 2.5 km (1.56 mi) run completed in under 11:49 min:sec. Tawney Meiorin, a veteran WFF, was dismissed on the grounds of recurrent failure of the aerobic fitness component of the pre-employment physical fitness test. Meiorin's counsel argued that the fitness standard was an example of indirect discrimination because females generally have a lower aerobic fitness than males and that even with training, females will have difficulty attaining the required level of fitness, meaning fewer females are able to successfully complete the 2.5 km (1.6 mi) run in the required time[17]. The case was deliberated in a series of arbitrations and courts, and in 1999, the Supreme Court of Canada delivered a groundbreaking decision in British Columbia *vs. British Columbia Government Employees Union* that significantly impacted labour law in Canada. The Supreme Court unanimously found that the fitness test had discriminated against Tawney Meiorin on the basis of sex and had an adverse impact on females.

Adverse impact describes "the circumstance in which group differences in performance, relative to a common standard, results in a disproportionate failure rate in a sub-group"[9,11,12]. Although the determination of whether a failure rate is "disproportionate" is subject to court judgments, both researchers and courts have commonly recognized the "80% rule"(or four-fifths rule), which specifies that adverse impact exists when the pass rate of a sub-group of participants (typically females) is less than 80% of the pass rate of the majority group of participants[9–12,16,18,47–49]. When adverse impact is present, the employer must either accommodate the impacted sub-group or demonstrate that accommodation is not possible because the safety risk of lowering the standard would constitute undue hardship[10,18,50].

The Meiorin Decision also had a significant impact on those exercise physiologists who were involved in the development and implementation of physical employment standards. Shortly after the

Supreme Court ruling, a Forum on *Establishing BONA FIDE Occupational Requirements for Physically Demanding Occupations* (BFOR Forum) was organized. It brought together scientists, legal experts, human resources personnel and management with the goal of clarifying the implications of the Meiorin Decision on pre-employment physical fitness testing and in particular the interpretation of 'undue hardship'. It was concluded at the BFOR Forum that if the accommodation to be provided for adverse impact undermines the due diligence responsibility of the employer, it constitutes undue hardship[3,14,18,29]. As well, the Forum created a best-practice template for developing physical employment standards for physically demanding public safety occupations[3,4,12,14] (reproduced in Manuscript I; *BFOR Development Considerations*).

In 2002, an Ontario Human Rights Commission grievance was filed by a female police applicant requesting accommodation for adverse impact of the Physical Readiness Evaluation for Police (PREP). At the Commission hearing, it was argued by the employer that females have the capacity to markedly improve their ability to pass the PREP by engaging in both test familiarization opportunities and a customized exercise training program. Citing evidence from the exercise training literature, the employer proposed that the resultant improvements would be sufficient to ameliorate the adverse impact on female participants. This argument was accepted and the grievance of the claimant was dismissed by the Human Rights Commission[20]. Subsequently, researchers have confirmed experimentally that through familiarization and customized exercise training it is possible to overcome the potential adverse impact on female participants of an applicant/incumbent test[12,14].

3.4.1. OBJECTIVES

The objectives of this investigation were *(i)* to establish the reliability of the WFX-FIT circuit, *(ii)* to determine if the Ontario WFX-FIT performance standard has an adverse impact on female participants, and *(iii)* to determine the extent to which *a)* test familiarization, *b)* customized exercise training and *c)* weekly WFX-FIT circuit performance trials impact WFX-FIT completion times, can overcome adverse impact.

This research project was designed to fulfil Step #10 of the BFOR Forum template for developing physiological employment standards, which requires an evaluation of the impact of applying the physical employment standard and addressing any adverse impact and the possibility of accommodation[4,12–14]. As well, the WFX-FIT protocol was developed with the goal of limiting the effect of biological variability on completion time by informing participants to engage in appropriate healthy behaviours (smoking, diet and hydration and exercise) prior to testing, ensuring that WFX-FIT trials occur at a similar time of day and under the same environmental conditions, and allowing participants to undergo WFX-FIT re-trials.

3.4.2. HYPOTHESIS

It was hypothesized that the WFX-FIT circuit would have high test-retest reliability. In addition, although the WFX-FIT circuit could have an adverse impact on female participants, familiarization and five weeks of customized exercise training would enable female candidates to overcome any adverse impact of the Ontario WFX-FIT.

3.4.3. METHODS

3.4.3.1. Participants and Recruitment

Recruitment was conducted throughout the York University campus by class announcements, signage (Appendix H), networking opportunities with student organizations (social and recreational) and email communications. Participants were selected for inclusion if they met the following criteria; no previous WFF work history or knowledge of the job-specific physical demands of wildland fire fighting and were not engaged in a structured exercise program prior to or during the study (e.g. varsity athletes). The study participants included students from various faculties, staff and non-academic professionals. Considerable effort was made to ensure a broad participant representation, not just a convenient sample with adequate fitness levels. Participants maintained their current physical activity/exercise levels, including those participants enrolled in Kinesiology and Health Science who are required to participate in active practica. These non WFF, normal population participants provided written informed consent and exercise clearance for physical activity/exercise participation via the Physical Activity Readiness

Questionnaire for Everyone PAR-Q+ and if necessary the ePARmed-X (www.eparmedx.com) (Appendix B-C). The PAR-Q+ consists of seven questions designed to identify persons for whom an increase in physical activity may be hazardous, based on prior health status and symptoms of limiting conditions[79,80].

Overall, the study consisted of a rolling recruitment of research participants during the period 2012-2015. Participants (*n*=145) were randomly assigned to one of three groups; physical fitness training group (PFT), weekly circuit performance only group (WFX) and control group (CON). A sub-set of 40 of the PFT participants took part in an evaluation of test-retest reliability of the WFX-FIT protocol which required an extra WFX-FIT performance during week five of the intervention when they were fully familiarized with the protocol. Participants also completed pre and post laboratory fitness measurements along with their baseline familiarization WFX-FIT circuit trials. Participants in the PFT group performed three supervised exercise training sessions per week plus one WFX-FIT circuit trial per week for five weeks for a total of seven circuit trials. Participants in the WFX group performed weekly WFX-FIT circuit trials for a total of seven circuit trials. Participants in the CON group performed two baseline familiarization trials and a follow-up trial at week six for a total of three circuit trials. WFX and CON group participants were instructed to refrain from increasing or decreasing their typical amount of daily physical activity/exercise during the study period, maintaining dietary habits and sleep behaviours. Notwithstanding the increase in physical activity/exercise as a result of the fitness training prescription, PFT participants were given the same instructions.

3.4.3.2. Wildland Fire Fighter Exchange Fitness Test

The WFX-FIT protocol consists of four sequential tasks which represent the most important, physically demanding, and frequently occurring job-related tasks experienced by WFF during an IA wildland fire response; carrying a medium pump on the back (28.5 kg/62.7 lb), carrying a medium pump in hand, carrying a hose pack (25 kg/55 lb) and advancing charged hose (18.5 kg/40.7 lb of force). Each task requires walking expeditiously over a fixed distance (20 m/65.7 ft) while wearing simulation personal protective equipment (PPE; 4.1 kg/9 lb) and carrying or advancing simulated wildland fire fighting equipment[113]. The equipment used during the test accurately reproduces the loaded conditions observed within the working environment[65], which is an important consideration when assessing a test candidate's loaded working capacity.

The WFX-FIT circuit timing begins at the commencement of the first task and ends at the completion of the final task. A '*Pass'* or *'Fit for Duty'* designation is assigned to those participants who successfully complete all of the WFX-FIT components within the jurisdictional completion time or cut-score, which is the same for all WFF personnel regardless of sex or age. Those who successfully complete all tasks but do not meet the cut-score plus those who cannot complete one or more of the job tasks receive a '*Fail'*. Within each fire jurisdiction (also referred to as provinces or agencies), WFF must meet the jurisdictional performance standard as a condition of employment in that province and to be eligible for exchange to other jurisdictions they must meet the National WFX-FIT standard. Owing to regional differences in i) terrain difficulty, ii) Fire Management Policy on fire risk (population threat) and forest value, and iii) the jurisdictionally-accepted emergency pace , there are associated differences in physical demands among provinces/territories. Therefore, a range of jurisdictional WFX-FIT circuit completion times from 14:30 to 20:15 min:sec were established to take into account these differences. To achieve the National WFX-FIT cut-score, WFF must have a completion time of ≤ 14:30 min:sec. Ontario, Manitoba, Nova Scotia, Quebec and Saskatchewan all share the second most demanding jurisdictional cut-score, and participants in the present study were required to achieve the Ontario jurisdictional cut-score of 17:15 min:sec. Meeting this standard indicates that the participant successfully completed all of the important wildland fire fighting tasks at a work rate equal to the energy demands during an IA emergency wildland fire response in these jurisdictions[62]. To assess the effect of familiarization, during week one, at the commencement of the six week study period all 145 participants completed two WFX-FIT circuit trials on separate days. Both the PFT and WFX groups completed additional WFX-FIT circuit performance trials at the end of each week of the study, while the CON group only completed two trials at week one and one at week six.

3.4.3.3. Laboratory Musculoskeletal and Anthropometric Measures

Musculoskeletal fitness and anthropometric measurements were conducted according to the protocols of *The PALM; Physical Activity and Lifestyle R Medicine* [114] with the exception that no limits (i.e. cut-offs) were applied to the muscular endurance tests. Fitness tests were overseen by Certified Exercise Physiologists (HFFC-CEP™) who have a degree in Kinesiology and Health Science and advanced training in fitness assessment and exercise counselling. Pre and post intervention fitness assessment data recording form are included in Appendix I.

Body composition was assessed using traditional techniques; height (m) was measured using a wall-mounted stadiometer (Fitness Precision, *Toronto, Ont*.), body mass (kg) and percent body fat were assessed using a bioelectric impedance instrument (Tanita Scale, model TBF-612, *Arlington Heights, Ill*.), BMI (kg/m^2) was calculated from height and body mass. Waist circumference (cm) was measured following the National Institutes of Health landmark[83] using an anthropometric tape. Sum of five skinfolds (mm) were derived from the biceps, triceps, subscapula, iliac crest and medial calf skinfold landmarks using a Harpenden caliper (Baty International, *West Sussex, UK*). Grip strength was measured using a hand-held dynamometer (Smedley Spring Dynamometer, *Ventura*, *Ca.*) and pushups were measured using a standardized protocol[114].

Leg power was assessed with a maximal vertical jump recorded to the nearest 1.3 cm (0.5 in.) using the Vertec jump and reach device (Vertec, Sports Imports, *Columbus*, *Ohio*). Leg power in watts was calculated from jump and reach height minus standing reach height using the Sayers equation[85] (Appendix J). Upper body push-pull force was measured using a Force Meter attached to the torso by a harness and incorporating a highly accurate digital caliper to quantify the precise amount of spring compression during a push or pull. Over the range of 0 to 130 kg (286.7 lb), the Force Meter has a high precision (± 0.045 kg), high reliability (mean coefficient of variation of 0.6%), and high validity (*r=0.999* vs cable tensiometer)[84].

Maximal oxygen uptake (VO_2max) was measured on a treadmill using an incremental to maximum plus supramaximal protocol with direct gas analysis using the open circuit technique[86,87].

Expired gas was directed through a 3.5 cm (1.4 in) diameter corrugated plastic hose into a 120 L (31.7 gal) Tissot gasometer (Warren E. Collins Ltd., *Braintree, Mass.*). Immediately upon completion of the gas collection, expired air was analyzed for the fractional concentration of oxygen (F_EO_2) and carbon dioxide (F_ECO_2) via rapid response analyzers (Applied Electrochemistry, Model S-3A and CD-3S respectively, *Sunnyvale, Cal.*). The attainment of VO_2max was confirmed when VO_2 achieved a plateau (within 150 $mL \cdot min^{-1}$ of the previous workload) or decreased with progressively increasing workloads[77,86,87].

3.4.3.4. Musculoskeletal Fitness and Aerobic-Anaerobic Training Prescription

The exercise training prescription was designed to mimic the metabolic demands and force applications of the WFX-FIT protocol, thereby providing emergency preparedness - the capacity to repeatedly perform job-related (wildland fire) tasks without experiencing excessive stress[38]. It has been previously reported that exercise considerations for workers in safety-related occupations must include maintaining high levels of aerobic and anaerobic endurance, upper and lower body musculoskeletal fitness, with appropriate consideration given to core strength[33,115]. An additional recommendation is to include load carriage tasks into an exercise program in preparation for a load carriage test or occupation[34,35,58,59,73,74].

Participants were instructed to refrain from performing supplemental exercise and were partnered with a Certified Personal Trainer (HFFC-CPT™) based on mutual schedules. The personal trainers were responsible for providing instruction regarding correct technique, posture, execution, supervising each training session, documenting weekly reports, and monitoring progress made over the training period. During the first week of exercise training, CPT were responsible for coaching execution and establishing initial lifting loads/running speeds. Therefore, the exercise training intervention consisted of five weeks of training plus a one week run-in period. PFT group participants and trainers met 3 days per week for ~60 min. On a fourth day each week, participants performed the WFX-FIT circuit. Any missed training sessions were rescheduled on the fifth day and two rest/recovery days were included in the weekly exercise schedule. Figure 2 provides a sample of the weekly fitness training schedule. The detailed WFX-FIT fitness training guidelines are included in Appendix G. The schedule was repeated for five weeks, with a total of 24 training sessions per participant (including six WFX-FIT circuit trials, three coaching/run-in sessions, and 15 exercise sessions). The exercise prescription was designed to challenge aerobic-anaerobic power, and musculoskeletal fitness components (strength, power and endurance).

The aerobic and anaerobic training prescription consisted of an interval style graded treadmill exercise protocol. After a 5 min warm up, the initial speed and elevation were set at 5 mph with a 2% elevation. Each subsequent workload was 2 min in duration and incremental changes were made to the speed or elevation until the subject could no longer tolerate the loading sequence, at which point the participant engaged in a lighter intensity workload (active recovery) lasting 2 min, following which the loading sequence was repeated until the total training time accumulated was equal to the total volume requirement (30 min).

Figure 2. Weekly physical fitness training program for the PFT group.

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Week	Circuit Resistance Training; Flexibility	Aerobic training 30 minutes; Flexibility	Muscular Strength and Endurance; Flexibility	WFX-FIT Circuit (x1)	(make up day)	Rest	Rest

The resistance training prescription followed the classic linear periodization model[75,77] and consisted of 10 exercises (five upper body, four lower body and one core) intended to challenge all major muscle groups (legs, back, shoulders, chest, and core/trunk). Resistance exercises involved; *leg press, leg extensions, dead lifts, hamstring curls, seated row, bent over row, lateral shoulder raises, incline chest press and core strengthening exercise*. The exercises were selected based on equipment availability in most gym settings, appropriateness for novice and less experienced exercisers, and similarity in force applications (vectors) and physical demands to those utilized in the WFX-FIT circuit. As indicated previously, during week one, two resistance learning sessions were scheduled for the PFT participants to allow the personal trainers to coach execution form and establish the appropriate lifting load for each exercise. The first microcycle (week 1-4) was structured as the strength development phase. Participants performed three pyramid sets of 12, 10, 8 RM, with a 45-60 sec rest interval, increasing the weight lifted each set (~70-80% 1 RM). The second microcycle (week 5 and 6) was structured as the muscular endurance phase. Participants performed 4 sets of 10 RM, with a 30 sec rest interval, maintaining the weight for each set (~60% 1 RM). To ensure a progressive overload, CPT documented the exercises performed during each training session and increased the resistance every week.

The PFT group circuit training prescription consisted of the same exercises described above performed in series. Participants performed all 10 exercises once, rested for approximately 2-3 min and repeated the cycle of exercises two additional times. The goal of the circuit training protocol was to supplement both the aerobic/anaerobic and resistance training prescriptions while simulating the aerobic-anaerobic demands of the WFX-FIT circuit. Every training session began with a generalized whole body warm up for 5 min, and concluded with a 5 min cool down period followed by flexibility exercises targeting all major muscle groups. This training program satisfied the guiding principles for resistance training of specificity, overload, and progression[75,77] and was designed specifically to prepare participants for the physical demands of the WFX-FIT circuit.

Contemporary exercise training equipment was selected because it is more appropriate for novice resistance trainers[75]. However, based on participant experience and the availability of equipment on a day-to-day basis, CPT were also provided with exercise prescriptions which included alternative resistance training modalities including; free weight exercises only and body mass/calisthenics only (Appendix G). CPT used their discretion and confirmed their choice of exercise modality with the research team leader.

3.4.3.5. Statistical Analysis

The SPSS statistical package (Version 20.0) was used to compute the statistical analyses, with a threshold for statistical significance of $p \leq 0.05$. Descriptive statistics (mean ± SD) were used to summarize participant characteristics, the circuit completion times and physical fitness measurements. To assess reliability, interclass correlation coefficients (ICC) were performed on separate day test-retest trials. The effect of familiarization and physical fitness training on completion time was assessed by one-way repeated measures analysis of variance (ANOVA) with post-hoc Bonferroni comparisons performed on the group means between each trial over the study period. To evaluate the relative completion time improvement between groups, one-way ANOVA with post-hoc Bonferroni comparisons was used. To calculate significant differences between males and females within groups, one-way ANOVA were performed on each participant group with post-hoc Bonferroni comparisons. To determine if the pass rates differed between males and females, χ^2analysis was performed on the male and female pass rates at Baseline and post intervention. One-way ANOVA analysis was used to examine pre to post training fitness differences on all laboratory measures.

3.4.4. RESULTS

A total of 145 (71 PFT, 35 WFX, and 39 CON) healthy, nonsmoking, normally active non-WFF general population participants completed both the requisite number of circuit trials and select pre and post laboratory fitness assessments. More participants were assigned to the PFT group as our past research experience indicated that the training group has the greatest drop-out rate. However, we were wrong as the PFT group had the same low drop-out rate as the other groups. Descriptive participant characteristics are presented in Table 15. The study participants reflected a wide range of characteristics; age (18-47 years), height (1.54-1.91 m), body mass (47.6-107.5 kg) and aerobic fitness (29.8-62.0 $mL \cdot kg^{-1} \cdot min^{-1}$). Although the proportion of female participants (48%) in the study group is greater than that found in the Canadian national IA WFF population (10%) based on a 2014 CIFFC report[116], the proportionate sex distribution in the study permitted a valid stratified comparison of the female with the male study group participants.

3.4.4.1. Reliability

The test-retest reliability of the WFX-FIT was established during the fifth week of the investigation on a subset of the PFT group (*n*=40; 16 females and 24 males) who completed test-retest trials on two consecutive days at a similar time of day. Week 5 of the study was selected because at this time study participants were well familiarized with the WFX-FIT protocol. The participants were instructed to perform both the WFX-FIT test and re-test at a speed that they considered to be a "purposeful expeditious pace". Mean ± SD WFX-FIT completion time, heart rate (bpm), and rating of perceived exertion (RPE) from the separate day trials are summarized in Table 16. For the male and female combined group, the test-retest completion times differed by only 6 sec or 0.7%. The initial mean WFX-FIT circuit completion time was 14:21 ± 2:51 min:sec and the mean re-test time was 14:15 ± 2:41 min:sec. Statistically significant (*p≤ 0.01*) interclass correlation coefficients (ICC) were found for WFX-FIT completion time (*ICC=0.980*), heart rate response (*ICC=0.704*), and RPE (*ICC=0.831).* Cronbach's α is a common measure of reliability and a value of ≥ 0.8 is a well-accepted construct, with 1.0 being the highest possible score[89].

Table 15. Characteristics (mean ± SD) of non-wildland fire fighter (general population) participants in the Physical Fitness Training group (PFT), Weekly Circuit Performance group (WFX) and Control group (CON) stratified by sex (*n*=145).

Group	*n*	Age (years)	Height (m)	Body Mass (kg)	VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$)
PFT Combined	71	20.9 ± 3.7	1.71 ± 0.1	68.2 ± 11.0	45.6 ± 7.6
Females	35	20.8 ± 3.4	1.65 ± 0.1	62.9 ± 8.6	40.9 ± 5.3
Males	36	21.1 ± 4.0	1.76 ± 0.1*	73.3 ± 10.9*	50.3 ± 6.5*
WFX Combined	35	22.3 ± 3.5	1.72 ± 0.1	72.6 ± 11.7	47.9 ± 7.9
Females	16	22.5 ± 4.6	1.68 ± 0.1	64.8 ± 11.3	43.5 ± 7.4
Males	19	22.1 ± 2.3	1.75 ± 0.1*	79.2 ± 7.3*	51.6 ± 6.4*
CON Combined	39	21.6 ± 4.7	1.71 ± 0.1	68.0 ± 11.7	46.6 ± 8.2
Females	17	20.2 ± 2.0	1.65 ± 0.1	61.0 ± 10.0	39.8 ± 5.1
Males	22	22.7 ± 5.9	1.75 ± 0.1*	73.4 ± 10.0*	52.4 ± 5.4*

**Significant difference between females and males within group (p≤ 0.05)*

No significant difference was found between the test-retest completion times *(p≤ 0.05)* and the associated test-retest reliability coefficient, as indicated by Cronbach's *a* = 0.990, confirms very high reliability. Mean ± SD HR from the test and re-test were 187 ± 14 bpm, and 189 ± 13 bpm respectively and the corresponding α = 0.826. Mean ± SD RPE values were 18.0 ± 1.9 and 18.0 ± 1.9 and the corresponding α = 0.908. Therefore, these results demonstrate that all three measurements were very consistent and that repeat performances on the WFX-FIT are highly reliable.

Table 16. Test-retest comparisons for mean WFX-FIT completion times, heart rate (HR) and ratings of perceived exertion (RPE) with interclass correlation coefficients (ICC) and Cronbach's α for general population non-wildland fire fighters with males and females combined (*n*=40; 16 females and 24 males).

	Time (min:sec)		HR (bpm)		RPE (/20)	
Trials	Test	Retest	Test	Retest	Test	Retest
Mean ± SD	14:21 ± 2:51	14:15 ± 2:41	187 ± 14	189 ± 13	18 ± 1.9	18 ± 1.9
ICC single measures	0.980*		0.704*		0.831*	
(95% CI)	(0.962-0.989)		(0.506-0.832)		(0.704-0.907)	
Cronbach's α	0.990		0.826		0.908	

*Significance *p<0.001*

3.4.4.2. Examining Adverse Impact of the WFX-FIT

Table 17 contains a summary of the improvements in completion times in seconds (together with the associated % improvement) from Baseline to Trial 1 and the corresponding percent of participants who passed the Ontario WFX-FIT for the physical fitness training group (PFT), the weekly circuit performance group (WFX) and the control group (CON) stratified by sex. At the onset of the study, the pass rate for all participants combined was 11% for females and 73% for males ($\chi^2=58.4, df=1, p\leq 0.01$). When applying the 80% rule, the overall pass rate for females was 15% (11% vs 73%) of the majority group being tested, clearly demonstrating an adverse impact on females. Detailed break-down of WFX-FIT circuit performance at Baseline indicates that seven females *did not finish*, 53 successfully completed all tasks but *did not meet the cut-score* and eight *met the cut-score* (*n*=68). Of the males, three *did not finish*, 17 successfully completed the tasks but *did not meet the cut-score* and 57 *met the cut-score* (*n*=77).

Table 17. Changes in completion times in seconds (with associated % improvement) from Baseline to Trial 1 and the corresponding percent of participants who passed the Ontario WFX-FIT (due to familiarization) for the physical fitness training group (PFT), the weekly circuit performance group (WFX) and the control group (CON) stratified by sex.

Group	*n*	Change in Time (% Improvement due to Familiarization) Baseline to Trial 1	% Passed WFX-FIT at Baseline & Trial 1 (% Improvement due to Familiarization) Baseline	Trial 1
PFT Combined	71	- 128 seconds (11.0%)*	34	53 (+19%)
Females	35	- 154 seconds (11.6%) *	9	23 (+14%)
Males	36	- 107 seconds (10.8%)*	58	83 (+30%)
WFX Combined	35	- 102 seconds (10.0%)*	62	76 (+14%)
Females	16	- 121 seconds (10.5%)*	28	50 (+22%)
Males	19	- 85 seconds (9.5%)*	95	100 (+5%)
CON Combined	39	- 118 seconds (10.8%)*	43	60 (+17%)
Females	17	- 154 seconds (11.7%)*	0	21 (+21%)
Males	22	- 92 seconds (9.9%)*	78	91 (+13%)

*significant improvement in completion time *($p<0.01$)*

3.4.4.3. Effects of Familiarization on WFX-FIT Performance Outcomes

Table 17 also contains a summary of the % improvement in performance due to familiarization. Significant improvements *($p<0.01$)* in mean WFX-FIT completion times from Baseline to Trial 1 were observed for all participants combined and when stratified by sex. With the groups pooled, mean ± SD circuit completion time improved by 11.9% from 21:22 ± 3:44 to 18:50 ± 3:04 for female participants, and males improved by 10.2% from 15:55 ± 2:20 to 14:17 ± 2:03 min:sec for a combined mean improvement of 11.1%. From Baseline to Trial 1 the pass rates on the Ontario WFX-FIT standard with all groups combined increased from 11% to 29% for females and 73% to 90% for males. Although all of the study participants are included in the analysis of pass/fail rate, only participants who successfully completed all of the WFX-FIT components at Baseline were included when analyzing completion times.

3.4.4.4. Effects of Customized Exercise Training and Repeat Circuit Trials on WFX-FIT Performance

Following the familiarization trials, PFT participants engaged in a five week customized exercise training program, and WFX participants underwent a weekly circuit performance trial, and CON had no further treatment. Table 18 contains a summary of the mean ± SD Ontario WFX-FIT completion times (min:sec) at Baseline (pre-familiarization), Trial 1 (post-familiarization) and Trial 6 (post-treatment) for the PFT, WFX, and CON group participants stratified by sex. Significant improvements ($p<0.05$) in mean WFX-FIT completion times are observed for females and males in the PFT and WFX groups over the treatment period. Figure 3 illustrates the mean ± SE of WFX-FIT completion times over a six week periods for females and males in the PFT, WFX and CON groups along with corresponding (%) improvement in time from Baseline to Trial 1 and Trial 1 to Trial 6. There were significant improvements ($p<0.01$) in completion time from Trial 1 to Trial 6 for PFT females due to customized exercise training (19.8%) and and for WFX females due to weekly circuit performance trials (12.2%). There were also significant improvements ($p<0.01$) in female completion time from Baseline to Trial 6 due to the cumulative effects of familiarization plus customized exercise training in both the PFT group (31.4%) and WFX group (22.7%). For males, there were significant improvements ($p<0.01$) in completion time from Trial 1 to Trial 6 due to customized exercise training (PFT group; 16.9%) and to weekly circuit performance trials (WFX group; 9.8%).

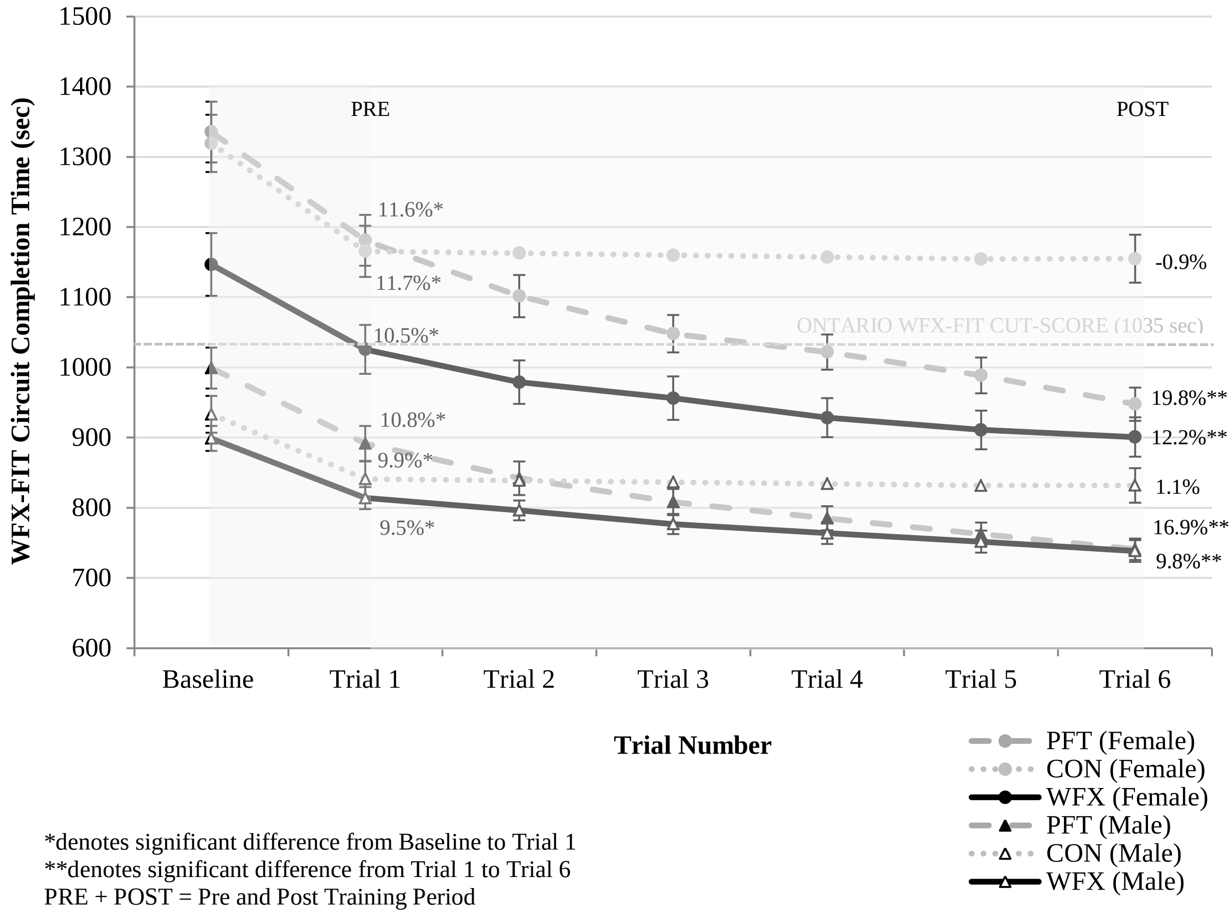
There were also significant improvements ($p<0.01$) in completion time for males from Baseline to Trial 6 due to the cumulative effects of familiarization plus customized exercise training in the PFT group (27.7%) and WFX group (19.3%). As expected, beyond the initial familiarization improvement of 11.7% for females and 9.9% for males, CON group participants had no significant change in completion time from Trial 1 to Trial 6. Figures 3b and 3c, in Appendix K, illustrate the mean ± SE of WFX-FIT completion times over seven trials for females only (b) and males only (c) in the PFT, WFX and CON groups along with corresponding (%) improvement in time from Baseline to Trial 1 and Trial 1 to Trial 6. Figure 3d illustrates mean±SE WFX-FIT circuit completion times (sec) for Combined Females plus Males, and Females only for each of PFT, WFX and CON along with percent (%) improvement in circuit completion time from Baseline to Trial 1 and Trial 1 to Trial 6. Figure 5, Appendix L, illustrates mean±SE WFX-FIT circuit completion time (sec) over 7 trials for Males only and Females only in the PFT stratified by LO/HI VO_2max, along with percent (%) improvement in circuit completion time from Baseline to Trial 1 and Trial 1 to Trial 6.

Table 18. Mean ± SD Ontario WFX-FIT completion times (min:sec), percent improvements over the 6 week intervention period and percent post treatment pass rates for non-wildland fire fighter (general population) participants in the physical fitness training group (PFT), the weekly circuit performance group (WFX) and the control group (CON) stratified by sex.

Group	*n*	Baseline Pre Treatment	Trial 1 Post Familiarization	Trial 6 Post Treatment	Trial 1-Trial 6 % Improvement	Baseline-Trial 6 % Improvement	Passed Post Treatment (%)
PFT Combined	71	19:22 ± 6:34	17:14 ± 5:27	14:15 ± 2:40	17.3†	26.4†	90.1
Females	35	22:15 ± 7:25	19:41 ± 5:44	15:48 ± 2:15	19.8	29.0	80.0
Males	36	16:39 ± 4:41	14:52 ± 4:09	12:21 ± 1:27	16.9	25.8	100
WFX Combined	35	16:56 ± 4:07	15:14 ± 3:33	13:35 ± 3:01	10.8†	19.8†	86.5
Females	16	19:06 ± 5:24	17:06 ± 4:39	15:01 ± 4:00	12.2	21.4	72.2
Males	19	14:59 ± 1:17	13:34 ± 1:09	12:19 ± 1:07	9.8	17.8	100
CON Combined	39	18:16 ± 6:36	16:18 ± 5:51	16:26 ± 4:59	-0.9*†	10.0†	61.9
Females	17	21:59 ± 8:36	19:26 ± 7:36	19:35 ± 5:05	-0.8*	10.9	26.3
Males	22	15:33 ± 3:49	14:01 ± 3:29	13:52 ± 3:27	1.1*	10.9	91.3

Participants who successfully completed all of the WFX-FIT components at baseline are included.
Trial 1-6 represents improvement due to treatment exposure.
Baseline-T6 represents the improvement from baseline to post treatment (due to familiarization and treatment exposure).
*no significant difference *($p>0.05$)* between designated trials (all other comparisons are significantly different).
†significant difference *($p<0.01$)* in the improvement between groups.

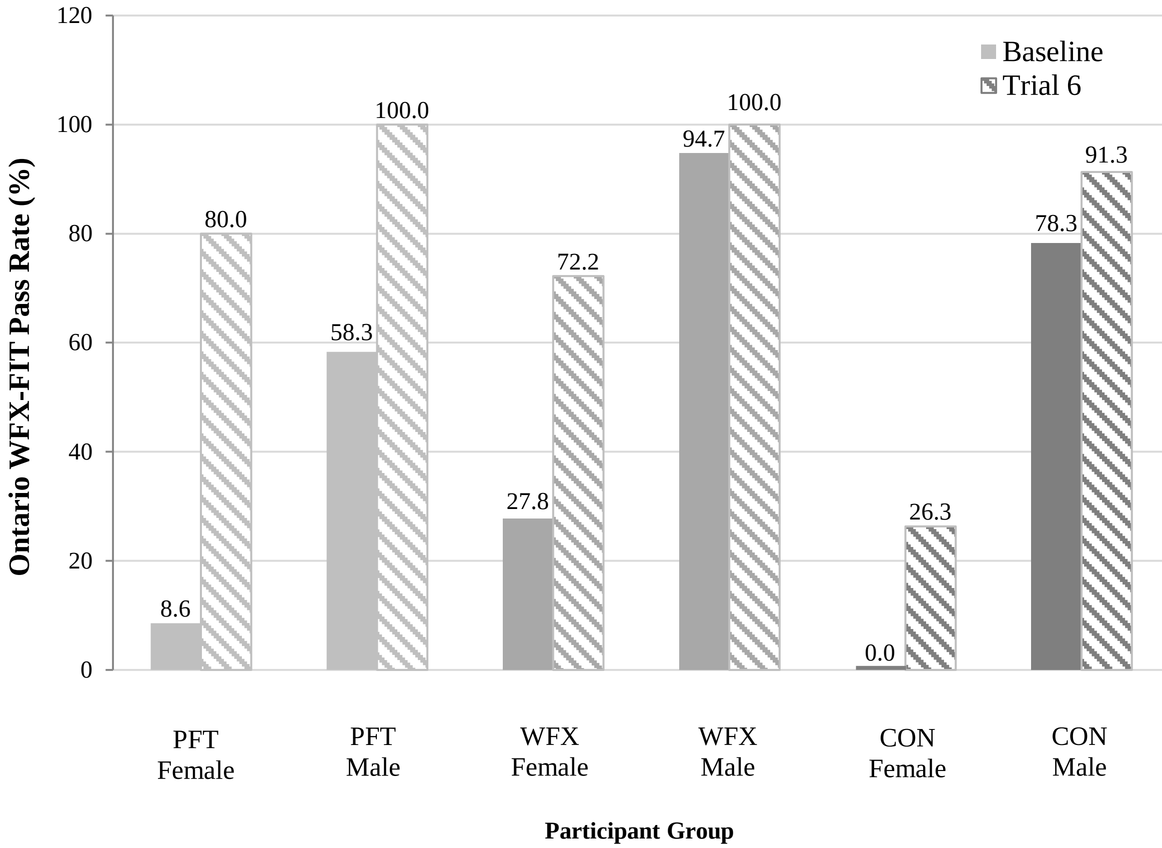
Figure 3. Mean±SE WFX-FIT circuit completion times (sec) over 7 trials for FEMALES and MALES in the physical fitness training group (PFT), weekly circuit performance only group (WFX) and control group (CON) along with percent (%) improvement in circuit completion time) from Baseline to Trial 1 (familiarization) and Trial 1 to Trial 6 (training period).



*denotes significant difference from Baseline to Trial 1
**denotes significant difference from Trial 1 to Trial 6
PRE + POST = Pre and Post Training Period

Post familiarization and intervention pass rates on the Ontario WFX-FIT are reported in Table 18 and illustrated in Figure 4. Upon completion of the final circuit trial, the pass rate on the Ontario WFX-FIT standard for the PFT groups was 80% for females and 100% for males *(χ^2=8.0, df=1, p<0.01)*,72% for females and 100% for males *(χ^2=6.1, df=1, p<0.05)* in the WFX group, and 26% for females and 91% for males *(χ^2=18.6, df=1, p<0.01)* in the CON group. Post exercise training χ^2 analyses identified a significant difference in the overall WFX-FIT pass rate between males and females (*p<0.01),* however because the pass rate for females in the PFT group is ≥ 80% of the majority group being tested (males), the adverse impact of the WFX-FIT standard on female PFT participants had been overcome.

Figure 4. Changes in percent pass rates from Baseline to Trial 6 (post-intervention) on the Ontario WFX-FIT standard for physical fitness training (PFT), weekly circuit performance only (WFX) and control (CON) group participants stratified by sex.



3.4.4.5. Physical Fitness Measures

Results of the pre and the post fitness assessments for the PFT, WFX and CON group participants (mean ± SD) are presented in Table 19. At Baseline, there were no significant anthropometric and aerobic fitness differences among PFT, WFX and CON group participants. However, WFX group participants had significantly greater number of pushups than CON, and significantly greater maximum push and pull compared to PFT. For all groups, baseline sex differences existed for all variables with the exception of age and waist circumference. Similar to the physiological differences between sexes reported by Roberts et al.[16], females in the present investigation can be characterized as shorter, having a lower body mass, greater percent body fat and sum of five skinfolds compared to males. Females also exhibited reduced musculoskeletal strength measurements (grip strength, pushups, vertical jump, leg power, maximum push and pull) and aerobic fitness measurements (VO_2max and time on treadmill) compared to males.

Post intervention, there were significant changes toward a more favorable fitness profile in the PFT group with respect to sum of five skinfolds, percent body fat, pushups, vertical jump, leg power, maximum push, maximum pull, relative VO_2max, absolute VO_2max and time on treadmill. BMI and combined grip strength was unchanged. For WFX group participants, time on treadmill significantly improved from pre to post intervention, while all other variables remained unchanged. For CON group participants, there were no significant changes.

Table 19. Changes in anthropometry and fitness measurements over the 6 week study period for the physical fitness training group, weekly circuit performance only group and the control group participants (Mean ± SD).

Anthropometric and Fitness Variables	Physical Fitness Training Group *(n = 71)*			Weekly Circuit Performance Only Group *(n = 35)*			Control Group *(n=39)*		
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ
Height, *m*	1.71 ± 0.1	1.71 ± 0.1	↔	1.72 ± 0.1	1.72 ± 0.1	↔	1.71 ± 0.1	1.71 ± 0.1	↔
Weight, *kg*	68.2 ± 11.0	68.1 ± 10.6	↔	72.6 ± 11.7	72.5 ± 11.5	↔	68.0 ± 11.7	68.7 ± 11.7	↔
BMI, kg/m^2	23.3 ± 2.8	23.2 ± 2.9	↔	24.5 ± 3.2	24.4 ± 3.2	↔	23.3 ± 3.1	23.5 ± 3.2	↔
Sum of five skinfolds, *mm*	68.2 ± 21.1	64.0 ± 25.9*	↓	68.8 ± 22.0	67.2 ± 21.6	↔	69.1 ± 26.8	70.2 ± 27.7	↔
Body fat, *%*	21.3 ± 5.5	20.7 ± 5.6*	↓	21.9 ± 4.8	22.0 ± 7.5	↔	20.4 ± 7.4	21.0 ± 7.9	↔
Waist Circumference, *cm*	79.6 ± 2.8	79.3 ± 2.9	↔	82.8 ± 10.9	82.3 ± 10.2	↔	81.5 ± 8.0	82.0 ± 9.4	↔
Combined Grip Strength, *kg*	73.1 ± 11.4	73.7 ± 20.1	↔	77.5 ± 21.4	78.5 ± 21.0	↔	73.4 ± 21.7	72.7 ± 21.2	↔
Pushups, *#*	22.2 ± 9.1	25.0 ± 8.8*	↑	26.8 ± 10.3	26.5 ± 9.3	↔	20.5 ± 11.1	20.0 ± 10.7	↔
Vertical Jump, *cm*	44.9 ± 10.5	49.2 ± 12.2*	↑	44.2 ± 12.7	44.5 ± 11.0	↔	43.0 ± 10.4	43.2 ± 10.6	↔
Peak Leg Power, *watts*	3761.4 ± 923.4	4013.9 ± 1011.5*	↑	3944.8 ± 909.5	3958.4 ± 865.8	↔	3679.9 ± 961.0	3728.8 ± 932.2	↔
Maximum Push Strength, *kg*	65.5 ± 20.2	75.9 ± 25.3*	↑	88.3 ± 42.2	86.4 ± 44.3	↔	76.5 ± 28.1	73.6 ± 26.4*	↓
Maximum Pull Strength, *kg*	68.4 ± 22.2	76.0 ± 23.9*	↑	80.2 ± 23.6	80.3 ± 24.1	↔	70.4 ± 22.8	73.1 ± 24.1	↔
VO_2, $mL{\cdot}kg^{-1}{\cdot}min^{-1}$	45.6 ± 7.6	48.8 ± 7.3*	↑	47.9 ± 6.4	47.7 ± 7.2	↔	46.6 ± 8.2	45.9 ± 8.7	↔
VO_2, $L{\cdot}min^{-1}$	3.10 ± 0.8	3.29 ± 0.8*	↑	3.47 ± 0.8	3.45 ± 0.4	↔	3.15 ± 0.8	3.11 ± 0.8	↔
Treadmill Exercise Time, *min*	14.7 ± 3.0	17.1 ± 3.4*	↑	15.7 ± 3.5	17.1 ± 3.4*	↑	14.7 ± 3.7	15.3 ± 4.2	↔

*Significant difference pre to post intervention $p \leq 0.05$

Δ Change; ↑ Increased from baseline, ↔ No statistically significant change from baseline, ↓ Decreased from baseline

3.4.5. DISCUSSION

The first objective of the present investigation was to establish the reliability of the WFX-FIT test circuit. Conforming to best practice methodology, the WFX-FIT should produce consistent times on separate occasions[32,49]. To minimize the impact of biological variability, participants in the PFT, WFX and CON group were instructed to maintain current physical activity/exercise levels, diet, sleep and hydration levels before each test. Participants were also scheduled on the same day of the week at a similar time of day. We are confident that pre-test protocols were adhered to, given the maintenance of anthropometric, musculoskeletal and aerobic fitness measures in the non-fitness training groups.

Test–retest reliability refers to consistency of test performances by the same individuals on different occasions, under conditions that are as similar as possible[55]. Milligan et al.[32] present several additional factors that can affect test reliability, these include consistency: *(i)* between testers (inter-rater), *(ii)* of participants (intra-subject), and, *(iii)* of tester's performance (intra-rater). To fulfil each of these considerations, the test-retest reliability of the WFX-FIT was established during the fifth week of the investigation when the impact of familiarization on completion time had been eliminated. Study participants (general population non-WFF) were instructed to perform both the WFX-FIT test and re-test on separate days at a speed that they considered to be a "purposeful expeditious pace". By ensuring a similar pacing strategy, repeating trials at the same time of day and in the same location, the biological variability which could affect study participants' outcomes was minimized. Therefore, the resultant test-retest scores and ICC for circuit completion times (14:21 ± 2:51 vs 14:15 ± 2:41 min:sec, ICC=0.980), indicate that repeat performances on the WFX-FIT are highly reliable.

The second objective of the present investigation was to determine whether the WFX-FIT could have an adverse impact on female participants. Based on the "80% rule", the 11% Baseline pass rate for females using the Ontario WFX-FIT cut-score is well below 80% of the pass rates for males (73%), which indicate that prior to familiarization and intervention the WFX-FIT standard had an adverse impact on female participants.

In conformance with the Meiorin Decision, the WFX-FIT criterion cut-score cannot be lowered because it would undermine the due diligence responsibility and thereby constitute undue hardship for the employer. Lawyers representing labour interests have argued that providing accommodation requires management to supply the employee with an advantage that enables him/her to overcome adverse impact. For example, hydraulic ladder lifts have been incorporated onto some municipal fire trucks to increase the ease of removing and replacing the ladder. Lawyers representing management interests have argued that any opportunity to overcome adverse impact that employees can avail themselves of constitutes accommodation. For example, employees could avail themselves of familiarization and exercise training opportunities to overcome adverse impact. We have chosen to use accommodation to describe the circumstance in which familiarization and exercise training are used to overcome adverse impact.

Because adverse impact was present, the next objective was to determine whether familiarization and five weeks of exercise training customized to the demands of the WFX-FIT protocol or weekly circuit trials could enable female participants to overcome the adverse impact. Over the separate day familiarization trials (Baseline to Trial 1), WFX-FIT completion time improved by 11.9% and 10.2% for all female and male participants respectively (combined mean 11.1%), and the overall Ontario WFX-FIT pass rate improved from 11% to 29% for females and from 73% to 90% for males. Comparatively, during the derivation of performance standards (Manuscript III; *Construction and Validation*), 218 incumbent WFF participants performed repeat WFX-FIT circuit trials *on the same day* and the resultant completion time improvement was 7.2% (14:52 vs 13:47, min:sec). The differences in improvement between incumbent WFF and general population non-WFF may be explained by participants in the present study being naïve to the demands of wildland fire fighting tasks and job-related performance requirements in addition to fatigue on same day re-trials impacting the WFF participants.

Following familiarization, participants were randomized into a supervised physical fitness training group (PFT), weekly circuit performance group (WFX) or control group (CON). Initially, examining the PFT group only, post familiarization (Trial 1) to post training (Trial 6); mean WFX-FIT completion time improved 19.8% for females and 16.9% for males (Table 18). Together, familiarization and exercise training improved Ontario WFX-FIT completion time by a total of 31.4% for females and

27.7% for males. Upon completion of the sixth and final WFX-FIT trial, the pass rate on the Ontario WFX-FIT standard was 80% for females and 100% for males indicating that females had overcome the adverse impact.

To our knowledge, this is the first investigation of the effect of training on adverse impact that included a randomized control group, robust study participant sample and multiple treatments to assess performance outcomes on a physical employment standard test circuit. The improvements in completion times and pass rates on the Ontario WFX-FIT standard demonstrate that familiarization and customized training opportunities constitute an effective accommodation strategy for both males and females and support the hypothesis that females can overcome the adverse impact of the WFX-FIT test by engaging in familiarization opportunities and a customized exercise training program. These findings also provide confidence to CIFFC's objective of developing a physical employment standard which differentiates between candidates who are 'safe and efficient' or 'fit for duty' from those who are not.

Weekly circuit performance trials (WFX group) also had a positive impact on performance outcomes. From Trial 1 to Trial 6, mean WFX-FIT completion time improved from 12.2% in females and 9.8% in males (Table 18). In the WFX group familiarization and weekly circuit performance trials together improved WFX-FIT completion time by a total of 22.7% for females and 19.3% for males. Upon completion of the final WFX-FIT performance at Trial 6, the WFX-FIT Ontario pass rate was 72% for females and 100% for males indicating that although the females in the WFX group had improved significantly, they had not improved enough to overcome the adverse impact of the Ontario WFX-FIT standard. That is, customized exercise training, beyond weekly circuit performance trials, improves WFX-FIT completion time by an additional ~8% and weekly circuit trials alone over are an insufficient stimulus to overcome the adverse impact.

The importance of physical fitness in physically demanding occupations is well documented in the literature[12,21,25,30,38,41,42,61,63,97,115,117–121]. However, very few investigations have addressed the issues of adverse impact and accommodation for a physical employment standard using familiarization and exercise training. Jamnik et al.[12] studied female and male correctional officer applicants (*n*=48) performing the Fitness Test for Correctional Officer Applicants (FIT*CO*) after familiarization and a six week customized exercise training program. Pre training, the FIT*CO* pass rate was 28.6% for females and 72.7% for males, indicating adverse impact on the females. Over three familiarization trials, females improved FIT*CO* completion times by 10.7% and males improved 9.1%. After five weeks of fitness training customized to the demands of the FIT*CO*, females improved circuit completion time by 22.9% and males improved by 14.0%. The combined improvement from familiarization and exercise training (33.6% for females and 23.1% for males) is similar to the improvement observed in the present investigation. At the end of the FIT*CO* training intervention the overall pass rate improved to 82.5% for females and 100% for males indicating that adverse impact had been overcome. The Jamnik et al. study is significant because the FIT*CO* was developed to qualify as a BFOR and therefore the authors specifically addressed adverse impact and accommodation. The authors concluded that by taking advantage of familiarization opportunities and engaging in a customized exercise training program, female correctional officer applicants can overcome the potential adverse impact of the FIT*CO*.

Gumieniak et al.[13] similarly examined familiarization and training as opportunities to provide accommodation for adverse impact on the nuclear power Emergency Service Maintainer Physical Abilities Test (ESPA). Participants (*n*=41) were familiarized to the test protocol and engaged in a supervised six week exercise training program. At Baseline, the overall ESPA pass rate was 12% for females and 79% for males, and the mean ESPA circuit completion times were 724 ± 63.5 s and 583 ± 81.8 s, respectively. Post training, the overall ESPA pass rate was 77% for females and 96% for males and the mean ESPA circuit time decreased 19.8% (580 ± 57.3 s) for females and 21.4% (458 ± 67.0 s) for males. The combined improvement from familiarization and exercise training, 31.6% for females and 32.6% for males, is consistent with the improvement observed in the present investigation. These results indicate that the female subgroup was able to overcome the adverse impact of the ESPA test and that familiarization and training can provide accommodation to overcome adverse impact when lowering a test standard is unsafe[14].

The disproportionate pass rates of males and females on the WFX-FIT protocol and the improvement in circuit performance following familiarization and exercise training is similar to that of other published reports using different physical employment standards. Williams-Bell et al.[42] characterized the demands of the Firefighter Candidate Physical Ability Test (CPAT) in 57 participants. The authors reported that at baseline, 91% of males and 15% of females were successful at completing the job simulation circuit within the cut-score. The pass rate of the females compared to the pass rate of the males indicated that adverse impact was present. The CPAT was not developed to conform to the Meiorin Decision requirements to qualify as a BFOR and therefore, adverse impact and accommodation were not examined by these investigators. Peterson et al.[38] demonstrated the effects of a nine week training intervention on fire fighter trainees (n=14) performing a job-specific test circuit. Treatment groups were divided into two periodization training models; undulating training and standard training. The authors reported a 21.3% improvement (304.4 ± 47.8 sec to 239.4 ± 26.3 sec) from undulating training and a 29% (297 ± 51.7 sec to 211 ± 21.5 sec) improvement from standard training.

More recently, Boyd et al.[30] examined the effects of six repeat trials on the Canadian Forces Fire Fighter Physical Fitness Maintenance Evaluation (FF PFME) on completion time. The authors reported significant decreases in completion time between Tests/Trials 1 and 6 for a cohort of 51 (20 female) participants. Similar to the present investigation, the largest one week improvement in performance was from Test 1 to 2 (8.2%) and the total improvement from Test 1 to 6 was 18.7%, which is very similar to the 18.6% improvement observed in the WFX group in the present study after six trials (1015.9 ± 247.3 sec compared to 827.0 ± 181.5 sec). The authors also reported that after three practice trials, most subjects were approaching their best performance. Though significant differences were observed beyond Test 3, relative changes decreased (from 3.1% to 2.4% to 1.4%). Similar findings were observed in the present investigation, however a plateau in performance was observed between Trials 5 and 6 for females (1.9%) and Trials 4 and 5 for males (1.7%) as evidenced by no significant differences between trials. The authors conclude by stating that the results indicate the importance of practice on performance and the potential for false-positive or false-negative decision errors if biological variability is not taken into account.

It was argued at a 2002 Ontario Human Rights Commission (OHRC) hearing[20], citing evidence from the literature that female applicants have the capacity to improve their ability to pass a physical fitness BFOR standard by engaging in familiarization and customized physical fitness training to thereby overcome adverse impact. This argument was accepted in the OHRC decision[20]. The combination of familiarization and physical fitness training to overcome adverse impact was subsequently confirmed experimentally in an investigation of female correctional officer applicants[12] and nuclear power plant fire fighters[13] and again in the present study on IA WFF. The practical implications of these collective findings highlight the significance of providing familiarization and physical fitness training opportunities to individuals at risk for adverse impact.

The present training intervention also resulted in several fitness and anthropometric adaptations (Table 19). Although the exercise prescription was not specifically designed to influence anthropometry or metabolic health, these findings are a positive outcome of the exercise intervention. For PFT group participants, statistically significant decreases in sum of five skinfolds, and percent body fat were observed. The decreases in subcutaneous fat measures indicate that moderate intensity exercise over five weeks, in the absence of a change in body mass, promotes healthy adaptations in adipose stores and an increase in lean (non-fat) mass to offset the weight loss associated with reductions in adipose tissue. However, dietary records were not administered, and therefore the contribution of caloric intake could not be evaluated; hence this inference is drawn with caution. The strength training effect of the exercise prescription was significant in upper and lower body measurements. Statistically significant increases in pushups (+2.8 *reps*), vertical jump (+4.3 *cm*), peak leg power (+252.5 *Watts*), maximum push (+10.4 *kg*) and pull strength (+7.6 *kg*) were observed.

In the present investigation, greater improvements in aerobic fitness might have been constrained due to the emphasis on improving muscular strength, muscular power and muscular endurance[122,123]. It has been proposed that concurrent gains in strength and aerobic power from a training intervention may have a counteracting effect[122,123]. That is, a training program focused on strength may inhibit aerobic fitness improvements and a training program focused on aerobic fitness may inhibit strength gains. However, recent evidence has confirmed that concurrent training, relative to endurance training alone, results in no decrements in VO_2max. That is, aerobic fitness is not inhibited when exercise is structured concurrently compared to endurance training alone[124]. Since the five week training intervention included only one dedicated aerobic exercise session per week, it was noteworthy that a significant increase in aerobic fitness was observed over the course of the intervention. The training program also allowed study participants to work at a higher percentage of %VO_2max enabling an increase in treadmill exercise time indicative of work tolerance.

Emergency responses in physically demanding public safety occupations frequently impose a strenuous physical demand on the individual. There is considerable literature to support applicant/incumbent fitness screening as an integral part of the pre-employment process for applicants in occupations such as military[57–59], policing[23], fire fighting[21,25,30,60–63], and correctional services[12]. In several such occupational activities external weights have to be carried for prolonged periods. Under such circumstances, high demands are placed on physical performance capacity. Structural fire fighters, for example, have to carry external loads due to breathing apparatus, PPE and hand tools. Similarly, military infantry and wildland fire fighter personnel are encumbered with heavy equipment required during operations. Therefore, load carriage (LC) is an important, physically demanding occupational requirement and it can be an important factor during emergency situations and first-responder operations.

The possible consequences of external LC include adverse effects on gait, metabolic efficiency, fatigue and increased risk of musculoskeletal injury[65]. In addition to load mass, its positioning relative to the body governs the physiological impact of the load. Researchers in the field of occupational fitness screening have documented that candidates/incumbents must possess a sufficiently high aerobic fitness and musculoskeletal strength, power and endurance to effectively perform physically demanding tasks during emergency scenarios. The manual handling of materials, such as lifting and carrying, are amongst the most common physically demanding tasks performed by individuals in these occupations. For this reason, the muscular strength of applicants is generally assessed, often using simulations of on-the-job tasks (ie. ladder lift, victim relocation, etc.). Load carrying performance can therefore be viewed as an important factor when assessing candidate’s abilities.

Previous research indicates that the consequences of LC have been studied for an extended period[66–71]. Physiological and biomechanical research has resulted in the development of general guidelines for best practices under varying situations. Improving load distribution across the body, the use of load carts and physical fitness training have been demonstrated to improve mobility and economy. There are many ways to carry loads, and the technique used will depend on the characteristics of the load (size, shape, mass, etc.), the distance the load must be carried, previous (learned) experience, and the equipment available to the individual. Since there is little research on wildland fire fighting and physical fitness training in the context of physical employment standards, comparisons can be made with previous literature on LC and exercise training.

3.4.6. LIMITATIONS

The short training duration of the intervention does not permit the authors to address long-term effects of fitness training on WFX-FIT completion time. Additionally, exercise/physical activity levels were not monitored outside of the exercise prescription, therefore the exact nature of supplemental exercise/physical activity cannot be commented on, although the lack of fitness changes in the CON group indicate that these participants did not change their exercise/physical activity habits.

3.4.7. IMPLICATIONS

Although females may be at risk for adverse impact from the WFX-FIT circuit completion time standard, it is possible to meet the Ontario WFX-FIT cut-score by engaging in familiarization and customized physical fitness training, thereby providing accommodation. The results confirm the need to provide test candidates with adequate familiarization opportunities and physical fitness training programs that are designed to increase muscular strength, muscular endurance, muscular power and aerobic-anaerobic endurance. Responses to the same exercise training stimulus may vary depending on the volume of training, base level of fitness and individual differences between high and low training responders. However, the plateau in WFX-FIT completion time toward the end of the 6 week training intervention suggests that a minimum of 5 Trials and supplemental training is required to achieve the physical fitness training adaptations to meet a performance standard cut-score. In a review of best practices in physical employment standards, Petersen et al.[26] suggest that more research on physiological adaptations and task-related performance changes from (fitness training) interventions would make valuable contributions to the employment standards field of study, especially when such interventions can be used as accommodation strategies. It is our belief that the current study, involving a broad sample of general population participants, randomized into two treatment groups and a control group, furthers the body of research on the effects of occupation-relevant physical fitness training interventions.

3.4.8. CONCLUSIONS

The study findings demonstrate that separate day test-retest trials, once participants are familiarized to the protocol, are highly reliable. Additionally, the results support the positive impact of familiarization opportunities and exercise training on WFX-FIT completion time and pass rates to overcome adverse impact. This investigation satisfies the Supreme Court of Canada's Meiorin Decision requirements to *qualify* as a BFOR by addressing the potential for adverse impact in a sub-group, thereby avoiding discriminatory selection practices. The improvements demonstrated on the Ontario WFX-FIT standard constitute accommodation and support the hypothesis that females can overcome the adverse impact by engaging in familiarization opportunities and a customized exercise training program.

Competing Interests

The authors declare that there were no conflicts of interest during this study.

CHAPTER 4

4.1. OVERALL SUMMARY and DISCUSSION OF THE RESEARCH PROJECT

4.1.1. Summary of Research

The Wildland Fire Fighter Exchange Fitness Test (WFX-FIT) project is a National research initiative to establish a physical fitness test and standard for the exchange of initial attack (IA) wildland firefighters (WFF) across Canada. Prior to 2012, wildland fire jurisdictions (provinces) across Canada did not employ a standardized job-related physical employment standard for the jurisdictional employment and exchange processes associated with wildland fire fighting. Traditionally, each jurisdiction has implemented varying fitness-related screening protocols including the 1-mile timed pack hike test[1], the 'pack-test' battery incorporating selected job-related tasks[2] and/or physician medical screening for employment selection purposes. However, the application of scientific methodology and best practice obligated by arbitration and court decisions have become essential to the development of applicant and incumbent physical fitness screening protocols for physically demanding safety-related occupations.

At the onset of the WFX-FIT project, a public safety task was defined and approved by CIFFC as *"A public safety task is a task in which the safety of the WFF, a co-worker or the public may be compromised by failure to complete or inefficient performance of the required task"*. This definition was the point of reference for all WFF emergency tasks considered throughout the project. The initial phase of the project required a detailed Physical Demands Analysis (PDA) of the critical emergency tasks encountered on the job by WFF while fighting wildland fires (Manuscript II; *Identification and Characterization*). A crucial outcome of the PDA investigation was a hierarchical list of the most important, physically demanding and frequently occurring emergency tasks performed by WFF on the job. It also highlighted the responsibility of CIFFC to ensure that those WFF who are exchanged among fire agencies across Canada have demonstrated that they have the physical ability/fitness to be able to respond safely and efficiently to emergency wildland fire tasks in the fire jurisdictions to which they may be exchanged. The PDA report also specified that the sequencing of tasks that are included in a test protocol to simulate fighting a wildland fire should be consistent with working a real initial attack of a wildland fire and that the WFX-FIT test must be completed within a minimum (efficient) time.

All of the front-line incumbent WFF who participated in the project were on non-accommodated job duty and therefore would be expected to perform front-line emergency initial attack wildland fire fighting. In addition, considerable effort was made to ensure that the participants were representative of the sex, age, years of experience and Aboriginal status of the incumbent Canadian IA WFF population. All phases of this project were approved by the York University Committee on Research Ethics and all IA WFF participated voluntarily following PAR-Q+ screening[79,80,91] and if necessary the ePARmed-X (www.eparmedx.com), and provision of informed consent (Appendix B-C).

Following the PDA, the development of the WFX-FIT test protocol began with a physiological characterization of the weights, forces, heart rate responses (HR), oxygen utilization (VO_2) and ratings of perceived exertion (RPE) while incumbent WFF were performing the most important, physically demanding tasks identified in the PDA. Measurements were conducted in wildland terrains that were ranked in the PDA as the most physically demanding and frequently encountered in fire jurisdictions across Canada. These included steep mountains in British Columbia, muskeg or swamps in Saskatchewan and rolling hills plus forest blow-downs in New Brunswick. Scenarios were developed by the subject matter experts in the focus groups who ordered the tasks in a manner consistent with the order in which they are performed during the initial attack of a critical wildland fire. During the characterization, incumbent WFF were instructed to perform the tasks at a self-selected safe and efficient emergency pace that they would use on the job, and their selected pace was confirmed to be appropriate by supervisory subject matter experts. The tasks were performed over the specific response distances identified in the PDA using wildland fire fighting tools and equipment employed in all fire jurisdictions.

The emergency tasks identified for characterization in the PDA included: chain sawing, chain saw support, Pulaski trenching, carrying a medium pump (portable 2-cycle 4-stage fire pump; 28.5 kg [62.7 lb]) on the back, carrying a medium pump in the hands, carrying an intake/suction hose and fuel container, setting up and starting a medium pump, hand carrying 3-4 lengths of rolled hose, carrying a hose pack (containing 4 lengths of hose) on the back, laying 4 lengths (38 mm [1½ in] in diameter x 30.5 m [100 ft] long) of dry hose and advancing charged hose (summarized in Table 7/Manuscript II; *Identification and Characterization*). The VO_2, HR responses and RPE measurements confirmed which tasks identified in the PDA were the most physically demanding and therefore, justified inclusion in the WFX-FIT protocol (summarized in Table 10/Manuscript II; *Identification and Characterization*). The characterization analysis also confirmed that the physical demands required while performing emergency tasks in British Columbia and Alberta (steep mountainous terrain) were higher than in other fire agencies.

The next step in the project was the construction of the WFX-FIT protocol. It was concluded from the PDA and task characterization that the following most important, frequently occurring and physically demanding tasks should be the basis of the WFX-FIT protocol; carry a medium pump (portable 2-cycle 4-stage fire pump) on the back (28.5 kg/62.7 lb), hand carry a medium pump, carry a hose pack containing four 30.5 m (100 ft) sections of 1 ½ inch FIREBREAK hose (25 kg/55 lb) and advance charged hosed requiring 18.5 kg (40.7 lb) of force. These four tasks must be combined into a continuous circuit in the same sequence that they are performed in the initial attack of a wildland fire and the protocol must embody an aerobic fitness demand that is required for safe and efficient wildland fire fighting. In addition, the average weight of WFF personal protective equipment (PPE) must be built in to the WFX-FIT protocol and the diversity in terrain across Canada must be taken into account when developing the associated performance standards. The recommended tasks were combined into a continuous circuit replicating the sequence of emergency tasks when working the initial attack of a wildland fire. Consistent with the recommendations for developing a BFOR, the incumbent's performance in the WFX-FIT circuit is "compensatory"[22,63]. That is, a weakness (or inefficiency) encountered in completing one component of the circuit can be made up for by superior ability in completing another component of the circuit and only the overall WFX-FIT cut-score (completion time) must be met. Although, expeditious completion of one circuit component can compensate for slower completion of another component, all tasks in the circuit must be completed.

A draft WFX-FIT circuit was constructed using simulations of the above tasks and feedback was received from experienced WFF to refine the draft protocol. The equipment utilized in the WFX-FIT circuit accurately simulates the weights and biomechanical characteristics of actual equipment used by WFF while fighting wildland fires and was confirmed by WFF and management to accurately duplicate mass and load distribution. The tasks were ordered in the circuit to replicate a series of emergency tasks commonly performed in this sequence by WFF during the initial attack of a wildland fire. Performance of the circuit required a substantial aerobic fitness involvement, with progressively faster completion times requiring a progressively higher aerobic power contribution to simulate more arduous terrains and Fire Management Policy on population threat/forest value. To conform to the legal requirements for establishing a BFOR, and in particular the guidelines of the Meiorin Decision, the equipment weights and force requirements built into the task simulations were derived from the weights and forces measured while incumbent WFF were performing the actual emergency wildland fire fighting tasks on the job.

To ensure that the WFX-FIT test administration is standardized and unbiased, a number of procedures were implemented including those detailed in Manuscript III; *Construction and Validation* and Appendix D-G. A detailed test administration manual was provided to CIFFC and fire jurisdictions. In addition to the resource material noted above, CIFFC was provided with target completion times (ie. split times) for each lap in the circuit that the candidate must reach to achieve the jurisdictional cut-score and/or the National WFX-FIT cut-score. These lap target times will enable WFX-FIT Appraisers to provide constant motivational feedback (coaching) to unaccustomed participants throughout their circuit performance. Additional recommendations that promote standardization include WFX-FIT Appraisers being trained so that they are thoroughly knowledgeable about installation, calibration and maintenance of equipment and the directive that Appraisers be audited by a qualified auditor annually to document that standardization is being maintained. Further, training workshops should be hosted on a regular basis to ensure the reaffirmation of these standards.

The next objective was to evaluate the construct validity of the WFX-FIT circuit. Construct validation measurements were computed by statistically comparing the physiological measurements while experienced IA WFF performed the WFX-FIT circuit with the same physiological measurements that were recorded for the same task performances on the job during the characterization phase. The measurements from the physiological assessment of the task simulation performances compared very favourably with the measurements made during the characterization phase while both male and female WFF were performing the corresponding very important physically demanding tasks on the job (summarized in Table 11/Manuscript III; *Construction and Validation*). These findings indicate that the physical demands involved in performing the WFX-FIT are very close to the physical demands measured while WFF were performing the on-the-job initial attack wildland fire fighting tasks during the characterization phase and provide high construct validity for the WFX-FIT.

The next objective was to establish the content validity of the WFX-FIT. When experienced WFF from across Canada were performing the final standardized version of the WFX-FIT, they provided objectively-scored Likert Scale ratings regarding whether the demands of performing the WFX-FIT accurately reproduce the tasks, physical demands, task sequencing and work rate experienced on the job (summarized in Table 12/Manuscript III; *Construction and Validation*). The content validity of the WFX-FIT was confirmed by consistently high ratings (>6 on a 7-point scale) by male, female and Aboriginal incumbent WFF of all ages concerning the tasks, physical demand, task sequencing and work rate of the WFX-FIT for evaluating WFF applicants. This established high content validity for the WFX-FIT. The results of the physiological (construct) validation, together with expert consensus (content) validation, provide strong evidence for the validity of the WFX-FIT.

Following standardization and validation of the WFX-FIT protocol, the next undertaking was to derive the associated performance standards and cut-scores[3,7,14]. '*Meeting the standard'* or *'fit for duty'* designation for the WFX-FIT requires the successful completion of all components of the WFX-FIT circuit within a completion time that achieves the minimum level of performance required for a passing score (ie. the cut-score)[26,32,52]. Failure to successfully complete any individual component in the circuit (carry medium pump on back, hand carry medium pump, hose pack lift and carry on back or advance charged hose) or failure to complete the circuit within the cut-score time limit, constitutes a '*Does not*

Meet Standard' or an *'unfit for duty'* rating on the WFX-FIT test. Within each fire agency, WFF must meet the jurisdictional/provincial cut-score to be employed in that province and all WFF must meet the National WFX-FIT cut-score to be eligible for exchange to all other fire jurisdictions. When attempting the WFX-FIT circuit for the derivation of cut-scores, all participants were instructed to "*complete the WFX-FIT circuit at the same safe and efficient emergency pace that you would utilize to attack a wildland fire on the job*". Incumbent WFF representing all 13 fire jurisdictions volunteered for this phase of the project.

The derivation of WFX-FIT performance standards and cut-scores from the circuit completion times was accomplished using an approach that conforms to the BFOR requirements established by the Supreme Court of Canada's Meiorin Decision. That is, the cut-scores were calculated as the mean + 1 SD from circuit completion times[7,14,15,52] of the "sub-group of IA WFF who have different physical characteristics than the majority group". When completion times of each sub-group (males, older males, females and Aboriginals) of IA WFF were plotted, they all provided a normal distribution. For statistical analysis power it was necessary to combine fire jurisdictions into "groupings" based on similar terrain difficulty, similar Fire Management Policy on population threat/forest value and resultant emergency pace (completion time) of participants. The resultant groupings of fire jurisdictions that met this criterion for *similar mean circuit completion times* are summarized in Table 14/Manuscript III; *Construction and Validation*.

Importantly, it is well established that when participants become orientated or familiarized to a physical fitness screening circuit, there is a resultant improvement in completion time due to motivation, familiarity with the test components and experience in appropriate pacing[12,14]. In the present study, while examining the impact of familiarization on female WFX-FIT circuit completion times, when repeat trials were performed on separate days, the resultant improvement was 11.1%. In light of these findings, the 11.1% improvement in completion time that resulted from familiarization was taken into account when deriving the cut-scores. The resultant computation resulted in a range of jurisdictional cut-scores from 14:30 to 20:15 minutes:seconds (min:sec) and the National WFX-FIT cut-score is the same as the standard in those fire jurisdictions that have the highest provincial performance standard (14:30 min:sec). Notably, the performance standard required to successfully complete the WFX-FIT was derived from experienced female IA WFF performing critical, physically demanding and frequently occurring on-the-job tasks, this approach provides a criterion-based physical employment standard, based on the incumbents' performances rather than from their maximal physical capacities, which would be characteristics-based.

The last phase of the WFX-FIT project involved establishing the test-retest reliability of the test circuit and evaluating whether the protocol and associated performance standard could have an adverse impact on a sub-group of the WFF population. Overall, the final study phase consisted of a rolling recruitment of non-WFF general population research participants during the period 2012-2015. Participants (*n*=145) were randomly assigned to one of three treatment groups; physical fitness training group (PFT), weekly circuit performance only group (WFX) and control group (CON). A sub-set of 40 of the PFT participants also took part in an evaluation of test-retest reliability of the WFX-FIT circuit. This evaluation took part on two separate days during week 5 of the training program at which point the participants were fully familiarized with the WFX-FIT protocol. While establishing the test-retest reliability, study participants were instructed to perform both the WFX-FIT test and re-test at a pace that they considered to be a "purposeful expeditious pace". Mean ± SD WFX-FIT completion time, HR response, and RPE from the separate day trials were found to be highly reliable (summarized in Table 16/Manuscript IV; *Familiarization and Training*).

At the onset of the training study, the pass rate for all participants combined was 11% for females and 73% for males ($\chi^2=58.4$, $df=1$, $p<0.01$). When applying the 80% rule, the overall pass rate for females was 15% of the majority group (11% vs 73%) being tested, clearly demonstrating an adverse impact on general population non-WFF females. Owing to familiarization alone, for all female participants, mean ± SD circuit completion time improved by 11.9% from 21:22 ± 3:44 to 18:50 ± 3:04 and male participants improved by 10.2% from 15:55 ± 2:20 to 14:17 ± 2:03 min:sec. From Baseline to Trial 1 the pass rates on the Ontario WFX-FIT standard with all groups combined increased from 11% to

29% for females and 73% to 90% for males (summarized in Table 17/Manuscript IV; *Familiarization and Training*).

Following the familiarization trials, the non-WFF general population study participants engaged in *i)* a 6 week customized physical fitness training program (PFT), *ii)* or a weekly circuit performance trial (WFX), or *iii)* no further treatment (CON). Significant improvements in mean WFX-FIT completion times were observed for females and males in the PFT and WFX groups over the treatment period with significant improvements in completion time from Trial 1 to Trial 6 due to customized physical fitness training (PFT group; 17.3%) and weekly circuit performance trials (WFX group; 10.8%) including when stratified by sex. There were also significant improvements in completion time from Baseline to Trial 6 due to the cumulative effects of familiarization plus customized physical fitness training in the PFT group (26.4%) and WFX group (19.8%). These improvements were even more pronounced in the female participants from these groups 19.8% and 29.0% respectively in the PFT group and 12.2% and 21.4% respectively in the WFX group. As expected, beyond the initial improvement (10.0%) from familiarization, CON group participants had no significant change in completion time from Trial 1 to Trial 6 (summarized in Table 18/Figure 3/Manuscript IV; *Familiarization and Training*).

Upon completion of the final circuit trial at week 6, the Ontario WFX-FIT standard pass rate was 80% for females and 100% for males ($\chi^2=8.0$, $df=1$, $p<0.01$) in the PFT group, 72% for females and 100% for males ($\chi^2=6.1$, $df=1$, $p<0.05$) in the WFX group, and 26% for females and 91% for males ($\chi^2=18.6$, $df=1$, $p<0.01$) in the CON group. Post physical fitness training χ^2 analyses identified a significant difference in the overall WFX-FIT pass rate between males and females ($p<0.01$), however because the pass rate for females in the PFT group is ≥ 80% of the majority group being tested (males), the adverse impact of the WFX-FIT protocol on female PFT participants had been overcome. Based on the improvements in WFX-FIT completion times achieved by familiarization and physical fitness training, it was concluded that it is possible for incumbent female WFF to meet the jurisdictional WFX-FIT performance standards.

As a result of the customized physical fitness training prescription, there were significant changes toward a more favorable fitness profile in the PFT group. For WFX group participants, only time on treadmill significantly improved from pre to post intervention, while all other physical fitness variables remained unchanged. For CON group participants, there were no significant changes in physical fitness (summarized in Table 19/Manuscript IV; *Familiarization and Training*).

In summary, the WFX-FIT project addressed the need for a valid, reliable and standardized physical employment standard for the exchange of WFF across Canada. This is the first project of such scope in Canada and will ensure that incumbent IA WFF, who are exchanged across Canada, can safely perform the job in all arduous terrains. It is expected that the implementation of standardized annual physical fitness testing will also contribute to enhanced performance, fewer injuries and the promotion of healthy behaviour.

4.1.2. Relating the WFX-FIT to the Meiorin Requirements

To examine the overall results of the WFX-FIT project in relation to the Supreme Court of Canada Meiorin Decision and scientific requirements to *qualify* as a BFOR; *i)* the components of the WFX-FIT are based on the on-the-job emergency tasks that were identified by both male and female WFF to be very important, physically demanding and frequently occurring, *ii)* the forces and energy requirements built into the WFX-FIT protocol are based on the performance of emergency tasks required by incumbent male and female WFF, not their characteristics, *iii)* in light of the detailed WFX-FIT appraiser manual, protocol instructions and supporting recording/reporting documentation, assessments can be conducted in a standardized, objective and unbiased manner, *iv)* the construct and content validity and the test-retest reliability of the WFX-FIT are robust and *v)* the WFX-FIT task simulations and cut-scores are criterion based, not characteristics based, and the jurisdictional and National WFX-FIT cut-scores are derived from the completion times of "safe and efficient" female WFF participants. Therefore, all processes throughout the WFX-FIT project were developed consistent with the Meiorin Decision requirements, and subsequent related case law using the template for developing and validating a BFOR, first established at the BFOR Consensus Forum.

4.2. SUMMARY OF CONCLUSIONS

Conclusions – Manuscript II*; *Identification and Characterization

Based on the feedback received from subject matter experts during the focus group meetings, the IA WFF responses to the cross-Canada PDA questionnaire and the results of the physical and physiological characterization, it was concluded that the following four most important and physically demanding tasks should be the basis of the WFX-FIT protocol; carry a medium pump (portable 2-cycle 4-stage fire pump) on the back (28.5 kg/62.7 lb), hand carry a medium pump, carry a hose pack containing four 30.5 m (100 ft) sections of 1 ½ inch FIREBREAK hose (25 kg/55 lb) and advance charged hosed requiring 18.5 kg (40.7 lb) of force. These four tasks must be combined into a continuous circuit in the same sequence that they are performed in the initial attack of a wildland fire and the protocol must embody an aerobic fitness demand that is required for safe and efficient wildland fire fighting. In addition, the average weight of WFF PPE and equipment worn on the waist must be built into the WFX-FIT protocol and the diversity in terrain across Canada must be taken into account when developing the associated performance standards.

Conclusions – Manuscript III

Measurements from the construct validation of the task simulation performances compared very favourably with the measurements made during the characterization phase while IA WFF were performing the corresponding critically important, frequently occurring and physically demanding tasks on the job. Additionally, experienced WFF from across Canada provided high Likert scale ratings of whether the WFX-FIT accurately simulates the tasks, physical demand, task sequencing and work rate compared to the on-the-job initial attack tasks upon which the circuit tasks were based. It is concluded that the observed high construct and high content validation scores convincingly establish the validity of the WFX-FIT.

Further, the derivation WFX-FIT performance standards involved WFF from all fire jurisdictions across Canada using an approach that conforms to the BFOR requirements established by the Supreme Court of Canada's Meiorin Decision. That is, the cut-scores were calculated based on the completion times of female IA WFF. Jurisdictionally, completion times range from 14:30 to 20:15 (min:sec), which represent a range in intensity owing to similar terrain difficulty, similar Fire Management Policy on population threat/forest value and resultant emergency pace (completion time) of participants and the resultant National WFX-FIT cut-score (14:30, min:sec) is equal to the standard in those fire jurisdictions that have the highest jurisdictional performance standard.

Conclusions – Manuscript IV

The study findings demonstrate that separate day test-retest trials, once participants are familiarized to the protocol, are highly reliable. Additionally, the results support the positive impact of familiarization opportunities and exercise training on WFX-FIT completion time and pass rates to overcome adverse impact. This investigation satisfies the Supreme Court of Canada's Meiorin Decision requirements to *qualify* as a BFOR by addressing the potential for adverse impact in a sub-group, thereby avoiding discriminatory selection practices. The improvements demonstrated on the Ontario WFX-FIT standard constitute accommodation and support the hypothesis that females can overcome the adverse impact by engaging in familiarization opportunities and a customized physical fitness training program.

4.3. LIMITATIONS AND AREAS OF FUTURE RESEARCH

4.3.1. Limitations

Though the WFX-FIT project was successful in achieving its goals, there are a few limitations to the research methodology, potentially limiting the scope of conclusions. The involvement of incumbent WFF who took part in the PDA, Study 1 and Study 2 was voluntary, therefore the participant sample is not truly random. However, the non-participation rate was extremely low and in virtually all cases was due to an existing injury. Because cross-sectional analysis only permits an examination at one point in time, it is possible that differences observed during the physiological characterization, between jurisdictions, could be attributable to factors other than those being examined. As such, the differences observed between steep mountainous terrain (British Columbia) and muskeg/bogland (Saskatchewan) and rolling hills (New Brunswick) may be the result of sampling bias. Potential sources of sampling bias may include regional (jurisdictional) differences in the WFF who participated or participant self-selection factors such that certain WFF were more or less likely to participate. Also, although considerable effort was made to ensure that the participating WFF were representative of the sex, age, years of experience and Aboriginal status, in two of the 13 fire jurisdictions (Prince Edward Island and North West Territories), there were no females WFF to participate and in other jurisdictions there were an insufficient number of female WFF participants to permit the required statistical calculations for that fire jurisdiction. Therefore, for statistical analysis it was necessary to combine fire jurisdictions into "groupings" based on similar terrain difficulty, similar Fire Management Policy on population threat/forest value, and similar emergency pace (completion time).

In Study 3, the duration of the fitness training intervention duration does not address the long-term effects of fitness training on WFX-FIT completion time. Despite the short training duration (five weeks), there was still sufficient power to determine significance. The five week timeline is likely the shortest amount of time required to detect any associated physical fitness changes, extending the training duration may be necessary for certain test candidates. This additional time would potentially increase the impact of physical fitness training on WFX-FIT circuit completion time observed in Manuscript IV; *Familiarization and Training*. Additionally, exercise/physical activity levels were not monitored outside of the exercise prescription, rather they were monitored and self-reported by the participants, and therefore the exact nature of supplemental exercise/physical activity cannot be commented on.

4.3.2. Future Research

The WFX-FIT project was novel in its aim to identify a national physical employment standard for all Canadian IA WFF. The development of a job simulation circuit which embodies a built-in aerobic component increases the novelty of the project. The examination of physical fitness training vs. weekly circuit trials including a randomized control group is also unique. With respect to developing physical employment standards for physically demanding public safety occupations, the WFX-FIT project and associated peer-reviewed publications will provide a valuable resource to advance knowledge and highlight best practice methodology. By documenting the decision making process and outlining challenges and resolutions, it is possible for future investigators to develop uniform and defensible practices consistent with the recommendations identified in the 2nd International Conference on Physical Employment Standards.

With respect to standard setting and deriving cut-scores, future research should address the extent to which biological variability may influence performance which may be resolved by the development of a 'borderline' zone for pass/fail delineation. Additionally, future investigations into physical fitness training relating to performance outcomes and overcoming adverse impact should evaluate different time course results and exercise modalities. High intensity interval training (HIIT) for example has been documented to improve physical fitness. Randomized control trials including HIIT, moderate intensity aerobic exercise and resistance training alone or in combination would help develop an optimized strategy for prescribing exercise as a tool for individuals at risk for adverse impact.

Future investigators should also evaluate the consequences to the workforce of implementing a physical employment standard. Step 12 of the BFOR Consensus Forum Template for developing physical employment standards (reproduced in Manuscript I; *BFOR Development Considerations*) requires maintaining an ongoing review. Evaluating the post-implementation pass/fail and injury frequencies would provide valuable information to employers and occupational physiologists. The nature of the job performance should also be investigated. For example, if a characteristic of the job performance becomes modified, either procedurally or through advances in technology and if this modification impacts job performance, the physical employment standard should be modified to reflect the change.

It remains to be determined how public safety is impacted by a physical employment standard such as the WFX-FIT. Research investigating the risks to public safety associated with various fitness levels and an examination of the improvements to public safety that may be achieved through the implementation of the physical employment standard. Lastly, within Canada, only IA WFF are currently required to perform the WFX-FIT for employment and/or exchange purposes. Future research may require an investigation into the nature of Type II (sustained support) wildland fire fighting duty and whether a physical employment standard is justifiable according to the Meiorin Decision requirements.

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APPENDIX A

YORK

UNIVERSITÉ
UNIVERSITY

OFFICE OF RESEARCH ETHICS (ORE)

5th Floor,
York Research Tower,
4700 Keele St.
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Certificate #:	**2010 - 123**
Approval Period:	**05/03/10-05/03/11**

Memo

To: Dr. Norman Gledhill, Faculty of Health,
Dr. Veronica Jamnik, Faculty of Health,

From: Alison M. Collins-Mrakas, Sr. Manager and Policy Advisor, Research Ethics
(on behalf of Daphne Winland, Chair, Human Participants Review Committee)

Date: **Monday 3rd May, 2010**

Re: Ethics Approval

Development of a Job-Related Fitness Test for Canadian Forest Fire

---

I am writing to inform you that the Human Participants Review Sub-Committee has reviewed and approved the above project.

Should you have any questions, please feel free to contact me at:
via email at:

Yours sincerely,

Alison M. Collins-Mrakas M.Sc., LLM
Sr. Manager and Policy Advisor,
Office of Research Ethics

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Memo

Certificate #:	**2010 - 245**
Approval Period:	**09/09/10-09/09/11**

To**:** Professor Norman Gledhill, Faculty of Health,

From: Wendy Jokhoo, Coordinator, Research Ethics Review

Cc: Alison M. Collins-Mrakas, Manager, Research Ethics

Date: **Thursday 9th September, 2010**

Re: **Ethics Approval**

Can fitness training provide a significant improvement in the performance of untrained, unfamiliar participants on a fitness screening test for forest fire fighters

---

I am writing to inform you that the Human Participants Review Sub-Committee has reviewed and approved the above project.

Should you have any questions, please feel free to contact me at:
via email at:

Yours sincerely,

Alison M. Collins-Mrakas M.Sc., LLM
Sr. Manager and Policy Advisor,
Office of Research Ethics

RENEWAL

YORK UNIVERSITÉ UNIVERSITY

OFFICE OF RESEARCH ETHICS (ORE)

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Certificate #:	**2012-196**
3rd Renewal Approved:	**08/18/15**
2nd Renewal Approved:	**08/11/14**
Renewal Approved:	**08/20/13**
Approval Period:	**08/18/15-08/18/16**

Memo

To: Dr. Veronica Jamnik, Faculty of Health,

From: Alison M. Collins-Mrakas, Sr. Manager and Policy Advisor, Research Ethics
(on behalf of Daphne Winland, Chair, Human Participants Review Committee)

Date: **Tuesday, August 18, 2015**

Re: Ethics Approval

Can Fitness Training Provide a Significant Improvement in the Performance of Untrained, Unfamiliar Particiants on a Fitness Screening Test of Forest Fire Fighters

---

With respect to your research project entitled, "Can Fitness Training Provide a Significant Improvement in the Performance of Untrained, Unfamiliar Particiants on a Fitness Screening Test of Forest Fire Fighters", the committee notes that, as there are no substantive changes to either the methodology employed or the risks to participants in and/or any other aspect of the research project, a renewal of approval re the above project is granted.

Should you have any questions, please feel free to contact me at:
via email at:

Yours sincerely,

Alison M. Collins-Mrakas M.Sc., LLM
Sr. Manager and Policy Advisor,
Office of Research Ethics

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Certificate #:	**STU 2014 - 123**
Approval Period:	**09/25/14-09/25/15**

Memo

To: Robert Gumieniak, Kinesiology and Health Science - Graduate Program,

From: Alison M. Collins-Mrakas, Sr. Manager and Policy Advisor, Research Ethics
(on behalf of Denise Henriques, Chair, Human Participants Review Committee)

Date: **Thursday, September 25, 2014**

Re: Ethics Approval

Establishing a National Fitness Standard for Wildland Fire Fighters

---

I am writing to inform you that the Human Participants Review Sub-Committee has reviewed and approved the above project.

Should you have any questions, please feel free to contact me at:
via email at:

Yours sincerely,

Alison M. Collins-Mrakas M.Sc., LLM
Sr. Manager and Policy Advisor,
Office of Research Ethics

APPENDIX B

Informed Consent

Development of a Job Simulation Circuit for Forest Fire Fighters

Researchers: Dr N. Gledhill and Dr V. Jamnik

Overall Objectives of the Research:

1) To measure the physical demands involved while Forest Fire Fighters (FFF) perform important physically demanding on-the-job tasks.
2) To develop a job simulation circuit (JSC) that simulates the physical demands measured while FFF performed on-the-job tasks.
3) To compare the physical demands while FFF performed the JSC with the physical demands measured while FFF performed on-the-job tasks.
4) To establish a performance time standard for the JSC from the completion times of incumbent FFF of all ages and both genders.

Requirements of Participants:

1) Your participation in this study is voluntary. You can discontinue participating at any time. However, your participation is very important.
2) In the JSC, you will perform simulations of i) Pulaski work, ii) carrying a hose pack iii) carrying a pump both in a back pack and in the arms and iv) advancing a charged hose. While performing the Pulaski task you will wear your personal protection boots and helmet. While performing the JSC, you will be wearing gym gear (shorts, T-shirt and running shoes).
3) You will perform the JSC twice to establish JSC performance times.

Risks and Discomforts: As with any vigorous physical activity, there are some inherent risks of participation which include (but are not limited to): dizziness, nausea, soft tissue damage and muscle soreness, injury from falling, increased heart rate, sweating and heavy breathing. With exercise there is always the potential that an underlying cardio-pulmonary condition could be aggravated leading to breathing problems, chest pain, unconsciousness or even a heart attack – though such cases are extremely rare, every possible precaution to avoid such an instance will be taken, including the use of pre-screening tests. The research team members are trained in first aid and CPR and standard on-site fire centre emergency measures will be in place in case of an emergency.

Benefits of the Research and Benefits to You: The results of this research will provide you with confidence in your ability and the ability of other members of your crew to meet the demands of forest fire fighting.

Voluntary Participation: Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to volunteer will not influence the nature of the ongoing relationship you may have with the researchers or your relationship with York University, either now or in the future.

Withdrawal from the Study: You can stop participating in the study at any time, for any reason, if you so decide. Your decision to stop participating will not affect your relationship with the researchers, York University, or any other group associated with this project. If you withdraw from the research, all of your associated data will be immediately destroyed.

Confidentiality: Confidentiality will be provided to the fullest extent possible. All information you supply during the research will be held in confidence and your name will not appear in any report or publication of the research. Your data will be safely stored in a locked cabinet or on a password protected computer for a period of five years and then destroyed. Only research staff will have access to your information.

Questions About the Research? This research has been reviewed by the Human Participants in Research Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have questions about this process or about your rights as a participant in the study, please contact the Senior Manager and Policy Advisor of the Office for Research Ethics (416-737-5914 or email ore@yorku.ca).

Legal Rights and Signatures:

I___________________________ consent to participate in the study conducted by Dr N. Gledhill to develop a fitness test circuit for forest fire fighters. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

_________________________________ _______________________________

Participant Signature Date

_________________________________ _______________________________

Principal Investigator Signature Date

This research is sponsored by the Canadian Interagency Forest Fire Centre (CIFFC)

INFORMED CONSENT FORM

Date: August, 2015

Study Name: *Can familiarization provide a significant improvement in the performance of untrained, unfamiliar participants on a fitness screening test for forest fire fighters?*

Researchers:

Robbie Gumieniak;
Dr. Norman Gledhill;
Dr. Veronica Jamnik.

Purpose of the research:

The purpose of this project is to examine the extent to which unfamiliar participants are able to improve their performance on a standardized, pre-employment fitness test for Forest Fire Fighters.

What you will be asked to do in the Research:

1. You will attempt a fitness screening circuit designed for Forest Fire Fighters <u>once a week for 7 weeks</u>. The tasks within the circuit consist of, i) you will walk 160 m wearing a 60 lb back pack (simulated pump) climbing over a 35 degree 4 foot high ramp each 20 m, ii) next you walk 80 m while carrying in your hands the same 60 lb pack on flat ground iii) next you will walk one kilometer while carrying a 55 lb back pack (simulated hose pack) climbing over a 35 degree 4 foot high ramp each 20 m iv) following which you will walk 80 m dragging a sled weighing 70 lb (simulated hose drag).

Risks and Discomforts:

As with any vigorous physical activity, there are some inherent risks of participation which include (but are not limited to): dizziness, nausea, soft tissue damage and muscle soreness, injury from falling, increased heart rate, sweating and heavy breathing. With exercise there is always the potential that an underlying cardio-pulmonary condition could be aggravated leading to breathing problems, chest pain, unconsciousness or even death – though such cases are extremely rare. Every possible precaution to avoid such an instance will be taken, including the use of a pre-participation medical risk assessment. A Certified Exercise Physiologist who is trained in emergency interventions will be present during the fitness circuit testing to deal with any problems that may arise.

In case of an emergency, researchers will operationalize standard University protocol that involves contacting campus security. All of the researchers have standard first aid and CPR (plus defibrillator) training and have attended required WHIMIS and Biosafety Training sessions.

Voluntary Participation: Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to volunteer will not influence the nature of the ongoing relationship you may have with the researchers or your relationship with York University, either now or in the future.

Withdrawal from the Study: You can stop participating in the study at any time, for any reason, if you so decide. Your decision to stop participating, or to refuse to answer particular questions, will not affect your relationship with the researchers, York University, or any other group associated with this project.

Confidentiality: All information you supply during the research will be held in confidence and your name will not appear in any report or publication of the research. Your data will be safely stored in a locked facility and only research staff will have access to this information. Your data will be retained for a period of 3 years following which it will be shredded. Confidentiality will be provided to the fullest extent possible.

Questions About the Research? If you have questions about the research in general or about your role in the study, please feel free to contact Robbie Gumieniak. This research has been reviewed by the Human Participants Review Sub Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have questions about this process or about your rights as a participant in the study, please contact the Senior Manager and Policy Advisor for the Office of Research Ethics Fifth Floor, York University Research Tower at 416-736-2100 ext 55201 or email ore@yorku.ca.

Legal Rights and Signatures:

I___________________________ consent to participate in the study conducted by Dr N. Gledhill to develop a fitness test circuit for forest fire fighters. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

_________________________________ _________________________________

Participant Signature Date

_________________________________ _________________________________

Principal Investigator Signature Date

INFORMED CONSENT FORM

Date: August, 2014

Study Name: *Can fitness training provide a significant improvement in the performance of untrained, unfamiliar participants on a fitness screening test for forest fire fighters?*

Researchers:

Dr. Norman Gledhill.

Purpose of the research:

The purpose of this project is to examine the extent to which untrained, unfamiliar participants are able to improve their performance on a standardized, pre-employment fitness test for Forest Fire Fighters.

What you will be asked to do in the Research:

1. You will attempt a fitness screening circuit designed for Forest Fire Fighters <u>once a week for 7 weeks</u>. The tasks within the circuit consist of, i) you will walk 160 m wearing a 60 lb back pack (simulated pump) climbing over a 35 degree 4 foot high ramp each 20 m, ii) next you walk 80 m while carrying in your hands the same 60 lb pack on flat ground iii) next you will walk one kilometer while carrying a 55 lb back pack (simulated hose pack) climbing over a 35 degree 4 foot high ramp each 20 m iv) following which you will walk 80 m dragging a sled weighing 70 lb (simulated hose drag).
2. Over the same period of time, you will be guided (personally trained) by an advanced level Kinesiology - Fitness Specialization student through 6 wk (3 days a week) of cardio-respiratory and strength training customized to the demands of the fitness test.

Risks and Discomforts:

As with any vigorous physical activity, there are some inherent risks of participation which include (but are not limited to): dizziness, nausea, soft tissue damage and muscle soreness, injury from falling, increased heart rate, sweating and heavy breathing. With exercise there is always the potential that an underlying cardio-pulmonary condition could be aggravated leading to breathing problems, chest pain, unconsciousness or even death – though such cases are extremely rare. Every possible precaution to avoid such an instance will be taken, including the use of a pre-participation medical risk assessment. A Certified Exercise Physiologist who is trained in emergency interventions will be present during the fitness circuit testing to deal with any problems that may arise.

In case of an emergency, researchers will operationalize standard University protocol that involves contacting campus security. All of the researchers have standard first aid and CPR (plus defibrillator) training and have attended required WHIMIS and Biosafety Training sessions.

Benefits of the Research and Benefits to You:

This research will provide an effective training program for forest fire fighter applicants. It will also provide the researchers with an evaluation of the effectiveness of physical training in preparing Forest Fire Fighting applicants for the fitness screening test.
By participating, you will benefit from the guidance of a trained fitness practitioner through a 6 week training program and receive you hands-on experience with proper training techniques. The benefits of increased physical fitness include possible weight loss, improved cardiovascular and musculoskeletal

health, improved perception of self-appearance and elevated self-confidence. You will also receive hands-on experience with fitness testing and the administration of a fitness screening protocol for a physically demanding occupation.

Voluntary Participation: Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to volunteer will not influence the nature of the ongoing relationship you may have with the researchers or your relationship with York University, either now or in the future.

Withdrawal from the Study: You can stop participating in the study at any time, for any reason, if you so decide. Your decision to stop participating, or to refuse to answer particular questions, will not affect your relationship with the researchers, York University, or any other group associated with this project.

Confidentiality: All information you supply during the research will be held in confidence and your name will not appear in any report or publication of the research. Your data will be safely stored in a locked facility and only research staff will have access to this information. Your data will be retained for a period of 3 years following which it will be shredded. Confidentiality will be provided to the fullest extent possible.

Questions About the Research? If you have questions about the research in general or about your role in the study, please feel free to contact Dr. Gledhill. This research has been reviewed by the Human Participants Review Sub Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have questions about this process or about your rights as a participant in the study, please contact the Senior Manager and Policy Advisor for the Office of Research Ethics Fifth Floor, York University Research Tower at 416-736-2100 ext 55201 or email ore@yorku.ca.

Legal Rights and Signatures:

I___________________________ consent to participate in the study conducted by Dr N. Gledhill to develop a fitness test circuit for forest fire fighters. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

________________________________	______________________________
Participant Signature	Date
________________________________	______________________________
Principal Investigator Signature	Date

APPENDIX C

2014 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

2014 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?
If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you have Cancer of any kind?
If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm*
If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you have High Blood Pressure?
If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes*
If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

2014 PAR-Q+

6.	**Do you have any Mental Health Problems or Learning Difficulties?** *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome*	
	If the above condition(s) is/are present, answer questions 6a-6b	If **NO** ☐ go to question 7
6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
6b.	Do you **ALSO** have back problems affecting nerves or muscles?	**YES** ☐ **NO** ☐
7.	**Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*	
	If the above condition(s) is/are present, answer questions 7a-7d	If **NO** ☐ go to question 8
7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	**YES** ☐ **NO** ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	**YES** ☐ **NO** ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	**YES** ☐ **NO** ☐
8.	**Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia*	
	If the above condition(s) is/are present, answer questions 8a-8c	If **NO** ☐ go to question 9
8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	**YES** ☐ **NO** ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	**YES** ☐ **NO** ☐
9.	**Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*	
	If the above condition(s) is/are present, answer questions 9a-9c	If **NO** ☐ go to question 10
9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
9b.	Do you have any impairment in walking or mobility?	**YES** ☐ **NO** ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	**YES** ☐ **NO** ☐
10.	**Do you have any other medical condition not listed above or do you have two or more medical conditions?**	
	If you have other medical conditions, answer questions 10a-10c	If **NO** ☐ read the Page 4 recommendations
10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	**YES** ☐ **NO** ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	**YES** ☐ **NO** ☐
10c.	Do you currently live with two or more medical conditions?	**YES** ☐ **NO** ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

____

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

2014 PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that the Trustee maintains the privacy of the information and does not misuse or wrongfully disclose such information.

NAME ______________________________ DATE ______________________________

SIGNATURE ______________________________ WITNESS ______________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

For more information, please contact

www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

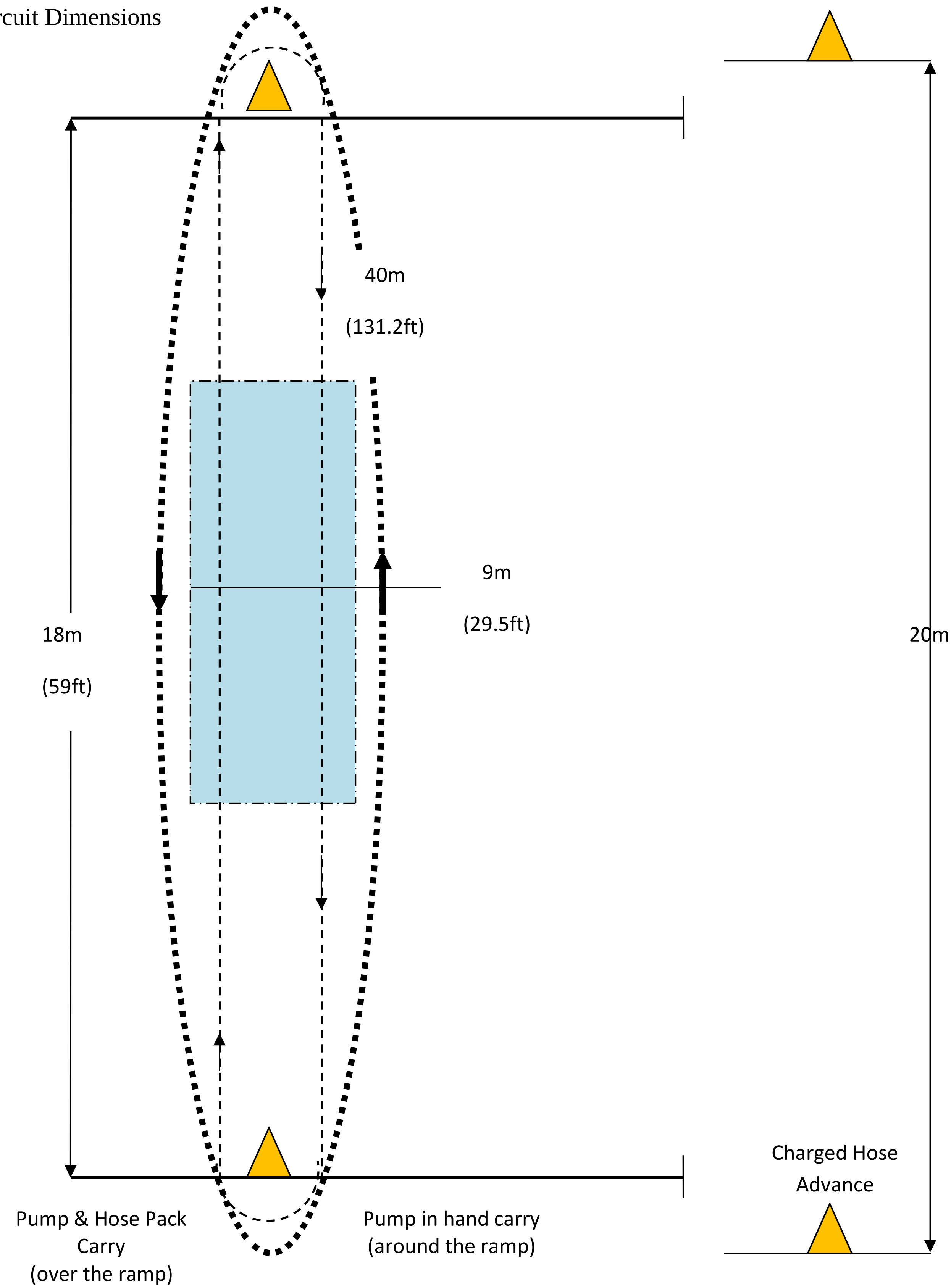
The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References
1. Jamnik VK, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.

08-01-2014

APPENDIX D

Circuit Dimensions



APPENDIX E

Ontario Standard ≤ 17:15 min:sec **Photo ID ___________**

Participant WFX-FIT Results Recording and Reporting Form

Name		**Test Location**		**Date**
Address		**Age**	**Male**	**Female**
		Type 1 Years experience	**Height (cm)**	**Weight (kg)**
Postal Code	**Phone #**	**email**		

SCREENING & BLOOD PRESSURE		
Signed PAR-Q+ clearance OR cleared by ePARmed-X+	□ Yes	□ No
Signed Informed Consent & Release submitted	□ Yes	□ No
Resting Blood Pressure ≤ 144/90 mmHg	□ Yes	□ No

WFX-FIT CIRCUIT

Carry Medium Pump On Back 4 laps (160 m; 524.9 ft)	1	2	3	4		
	:29	**:58**	**1:27**	**1:56**	**Completed**	**Not completed**
	:24	*:48*	*1:12*	*1:36*		

Hand Carry Medium Pump 2 laps (80 m; 262.4 ft)	1	2		
	2:35	**3:14**	**Completed**	**Not Completed**
	2:10	*2:44*		

WFX-FIT Hose Pack Lift & Carry on Back 25 laps (1 km; 3,281 ft)										
	1	2	3	4	5	6	7	8	9	10
	3:53	**4:22**	**4:51**	**5:20**	**5:49**	**6:18**	**6:47**	**7:16**	**7:45**	**8:14**
	3:18	*3:42*	*4:06*	*4:30*	*4:54*	*5:18*	*5:42*	*6:06*	*6:30*	*6:54*
	11	12	13	14	15	16	17	18	19	20
	8:43	**9:12**	**9:42**	**10:10**	**10:39**	**11:08**	**11:37**	**12:06**	**12:35**	**13:04**
	7:18	*7:42*	*8:06*	*8:30*	*8:54*	*9:18*	*9:42*	*10:06*	*10:30*	*10:54*
	21	22	23	24	25					
	13:33	**14:02**	**14:31**	**15:00**	**15:29**	**Completed**		**Not Completed**		
	11:18	*11:42*	*12:06*	*12:30*	*13:00*					

Advance Charged Hose 2 laps (80 m; 262.4 ft)	1	2		
	16:23	**17:15**	**Completed**	**Not Completed**
	13:45	*14:30*		

Time to complete the WFX-FIT Circuit: ____________min:sec
☐ Meets **Agency** Performance Standard ≤ **17:15** min:sec
☐ Does Not Meet **Agency** Performance Standard > **17:15** min:sec
☐ Meets **National Exchange** Performance Standard ≤*14:30* min:sec
☐ Does Not Meet **National Exchange** Performance Standard > *14:30* min:sec
☐ Does Not Meet Standard due to failure to complete **one or more** components of the circuit (see details above)

I, ____ acknowledge that I have received a copy of my WFX-FIT results. I also acknowledge that CIFFC and its' Member Agencies are required to adhere to Canadian guidelines regarding the storage of personal health information ensuring that they maintain the secrecy of the information and not misuse or wrongfully disclose such information.

Signature of Candidate: ____

Printed Name & Signature of Trainer/Appraiser: ____

APPENDIX F

WFX-Fit Circuit Instructions to be Read to the Participants

Throughout the WFX-FIT circuit you will wear a 9 lb weighted belt which encumbers you with the weight of normal wildland fire line work wear. You are not permitted to wear a hat, watch or bracelets throughout the test. Also, please make sure your shoe laces are double knotted. Should you have to stop to reposition the waist belt or retie your shoes the time will continue.

The circuit involves 4 separate tasks performed in a continuous sequence over 40 m. From pylon to pylon it is 18 m and you must travel around the cones to cover 20 m.

Timing of the circuit begins when you cross the start line while carrying the simulation medium pump on your back. The pump weights 62.7 lbs (28.5 kg). For safety purposes, the appraiser assists with the lifting and lowering of the medium pump onto and off your back. Once the starting line is crossed, the timing begins. You will then proceed over the ramp – around the opposite cone and return back over the ramp 4 times (8 lengths). The simulation medium pump is then assisted off the participant's back and onto the platform.

Next, pick up the simulation medium pump from the platform in your hands and carry it along the side of the ramp ramp, around the same pylons and back 2 times (4 lengths). For safety purposes, while carrying the pump in your hands you will not go over the ramp.

Next, place the simulation medium pump on the platform and pick up the WFX-FIT hose bag containing 4 sections of dry rolled/folded hose. The hose bag weighs 55 lb (25 kg). Due to the demands of the job, the hose pack cannot be assisted onto your back; however any lifting technique may be used, additionally the platform may **not** be used to assist with lifting the hose pack. The pack is then carried over the ramp – around the cone opposite the starting cone and returned back over the ramp 25 times (50 lengths, or 1 km).

After the 25th lap, place the hose pack down next to the table (do not throw it) and proceed to the simulated charged hose advance. Grasp the hose over your shoulder and advance the sled beyond the end line to the turning line or until the appraiser says "stop". Turn the sled around and return in the opposite direction. This will be repeated a second time after which, the timing of the circuit ends.

You now have 5 minutes to warm up and stretch. Please double knot your shoes.

WFX-FIT Pre-Test Circuit Considerations for the Appraiser

Over the course of a testing day there are several considerations for the appraiser before the participant begins the test. These are in addition to the standard calibrations and maintenance performed before the test.

1. Has the participant been provided a warm up before the test ?
2. Has the participant been provided a walk-through of the circuit so they are familiar with the ramp and where the cones are ?
3. Has the participant double knotted their shoes ?
4. Has the participant removed hats, watches and bracelets ?
5. Is the participant wearing a weighted waist belt ?
6. Do you, have two stop watches in case one fails ?
7. Have the caps which secure the weights on the pump pack and sled been tightened ?
8. Is the sled facing in the proper direction ?
9. Have the straps on the pump pack and hose bag been adjusted so the participant has enough slack to pull down on the straps ?
10. If any cones were knocked over or moved, have they been replaced ?

WFX-FIT Circuit Feedback and Coaching

Throughout the WFX-FIT Circuit it is imperative that the appraiser provide the participant with constant feedback and coaching. Below is an example of what can be said to the participant during the WFX-FIT Circuit.

"Once you cross the start line, timing of the circuit begins. Are you ready ?"
"GO!"

"Go over the ramp, use the hand rails both up and down"
"Go around the cone" – *point to the cone*
"Go back over the ramp", "Around the start cone", "That's one, three more to go"
"Go back over the ramp", "Around the same cone"
"Go back over the ramp", "Around the start cone", "That's two, two more to go", "You are __ seconds under/above the time standard, keep up/pick up the pace"

Transition to Pump Pack in Hands

"When you get back to the table, I will help take the pump pack off"
"Stop, turn around, slide your arms out the sides, I've got it"
"Pick up the pump pack from the table"
"Go to the side of the ramp, do not go over" – *Appraiser should stand in front of the ramp, blocking the path over the ramp*
"Around the same cone" – *point to the cone*
"Back down the side of the ramp"
"Around the start cone", "That's one, one more to go", "You are __ seconds under/above the time standard, keep up/pick up the pace"

Transition to Hose Pack

"Place the pump pack down on the table"
"Pick up the hose bag", "Pull down on the straps to adjust the height"
"Go back over the ramp", "Around the same cone"
"Go back over the ramp", "Around the start cone", "That's one, twenty four more to go", "You are __ seconds under/above the time standard, keep up/pick up the pace"
The participant may wish to have every lap counted down or at intervals (ie. Lap 5, 10, 15 etc.) However, it is critical that the participant is constantly aware of their pacing and timing.

Transition to Hose Advance

"Place the hose bag down next to the platform, do not throw it"
"Take the end of the hose over your shoulder and pull it to the far cone, do not go around the cone"
"Keep going … STOP! … Turn around", "Same thing on the way back"
"Keep going … STOP! … Turn around", "That's one, one more to go", "You are __ seconds under/above the time standard, keep up/pick up the pace"

APPENDIX G

FITNESS TRAINING GUIDELINES

FOR THE

CANADIAN PHYSICAL PERFORMANCE EXCHANGE STANDARD FOR TYPE 1 WILDLAND FIRE FIGHTERS (WFX-FIT)

Robert Gumieniak MSc, Norman Gledhill PhD & Veronica Jamnik PhD

August, 2011

School of Kinesiology and Health Science,

Faculty of Health,

York University

FITNESS TRAINING GUIDELINES

FOR THE

CANADIAN PHYSICAL PERFORMANCE EXCHANGE STANDARD FOR TYPE 1 WILDLAND FIRE FIGHTERS (WFX-FIT)

Following is a physical fitness training program to prepare candidates for performing the WFX-FIT. It begins with a 6 week generic plan to improve all areas of physical fitness, then, for candidates who do not have access to specific resistance training equipment, 4 different detailed programs are provided utilizing different training modalities;

A) Contemporary Fitness Training Equipment
B) Free Weights (dumbbells) Only
C) Body Weight/Callisthenic Only
D) A Replication of the WFX-FIT Circuit

Six Week Generic Training Program for the WFX-FIT

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Week 1	Muscular Strength & Endurance; Stretch	Aerobic training 25 minutes; Stretch	Muscular Strength & Endurance; Stretch	WFX-FIT (x1)	(Make-up day)	Rest	Rest
Week 2	Circuit Training	Aerobic training 25 minutes; Stretch	Muscular Strength and Endurance	WFX-FIT (x1)	(Make-up day)	Rest	Rest
Week 3	Aerobic training 30 minutes; Stretch	Muscular Strength & Endurance; Stretch	Circuit Training	WFX-FIT (x1)	(Make-up day)	Rest	Rest
Week 4	Muscular Strength and Endurance	Circuit Training	Aerobic training 35 minutes; Stretch	WFX-FIT (x1)	(Make-up day)	Rest	Rest
Week 5	Circuit Training	Aerobic training 40 minutes; Stretch	Muscular Strength and Endurance	WFX-FIT (x1)	(Make-up day)	Rest	Rest
Week 6	Aerobic training 45 minutes; Stretch	Muscular Strength and Endurance	Circuit Training	WFX-FIT (x1)	(Make-up day)	Rest	Rest

Note: Any missed training sessions can be made up on the “make-up” day.

Detailed Aerobic Fitness Training

I) Aerobic Training on a Treadmill:

a) The following sample training session consists of 2 minute work intervals performed continuously until volitional fatigue. Continue repeating the cycles until the weekly requirement is accomplished or until the number of cycles that can be tolerated is achieved.

One Cycle: 2 min walk at 3 mph – 2 % elevation
2 min jog at 5 or 6 mph – 4 % elevation
2 min run at 7 or 8 mph – 6 % elevation *****
2 min run at 7 or 8 mph – 8 % elevation *****

Following the loading sequence above, a walking pace is required initially, then subsequent workloads require jogging followed by running at a comfortable pace. Once a comfortable running pace has been established, keep the speed constant and achieve subsequent workloads by increasing the elevation to make the exercise progressively more demanding.

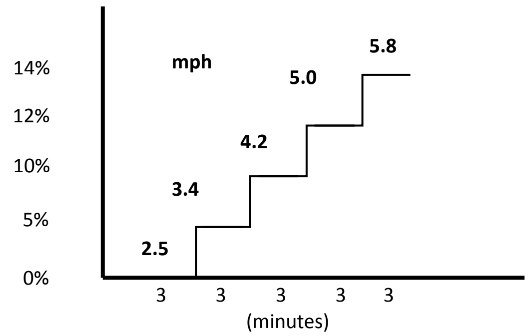
During the first two weeks, you may only be able to complete the first two workloads in the cycle after which you should repeat these workloads until the desired duration has been completed. During the third week, add another workload to the cycle and then repeat the cycle until the desired duration has been achieved. By the fourth week (and the remainder of the training program), you should be able to complete the four workloads in the cycle and then repeat the cycle until the desired duration has been completed.

b) As an alternative, should you wish to use a different treadmill protocol; the 20m shuttle run protocol can be replicated on the treadmill. Below are the speed equivalents for 10 stages of the shuttle run. Each stage is two min in duration. In your exercise sessions you should increase the speed of the treadmill continuously following the speed equivalents listed for each stage of the shuttle run. Keep the treadmill elevation at 1-2%. If you are only able to run continuously for 4 stages, then walk for 2 min and repeat the process again until your total time is completed for that session.

Speed km/hr	Speed mph	20m shuttle on stage	METS	Predicted VO_2 max
8.5	5.3	1	6.7	23.5
9.0	5.6	2	7.6	26.6
9.5	5.9	3	8.5	29.8
10.0	6.2	4	9.3	32.6
10.5	6.5	5	10.2	35.7
11.0	6.8	6	11.0	38.5
11.5	7.1	7	11.9	41.7
12.0	7.5	8	12.7	44.5
12.5	7.8	9	13.6	47.6
13.0	8.0	10	14.5	50.8

c) A third treadmill protocol alternative which simulates the inclination in the WFX-FIT circuit can be performed as follows.

Speed (mph)	Elevation (%)	Duration (min)
2.5	0	3
3.4	5	3
4.2	10	3
5.0	12	3
5.8	14	3



II) Outdoor Aerobic Training: If you do not have access to a treadmill, aerobic training may be performed on a high school track or another surface of known distance (using a car odometer). An outdoor track generally measures 400 metres so that covering approximately one mile requires 4 laps and covering 2 kilometres requires 5 laps. Record your distance covered for the training session (i.e. number of laps and distance). Your goal for the following week should be to increase both time, as per the schedule, and the pace at which you are running.

Detailed Musculoskeletal Fitness Program

I) Muscular Strength, Endurance and Power Exercises: This program consists of 9 exercises, each of which is chosen to replicate the motions and forces required to complete the WFX-FIT protocol. These exercises can be performed one at a time with adequate rest between each, or in a circuit format. The circuit format means that one set of each exercise is completed with minimal rest in between, followed by a repetition of the entire circuit with the prescribed number of reps and sets. The goal is to reach the target number of repetitions listed in the chart below, with the last repetition performed being the most difficult. The circuit training format is recommended because while performing the WFX-FIT protocol there are no scheduled breaks and a variety of different muscle groups are used immediately following one another.

II) Sets, Reps, Weight & Rest: Weeks 1-4 are targeted as the strength development stage. Perform 3 sets for each exercise, incrementally increasing the weight by 5-10 lb depending on the exercise for each set. The number of reps should decrease from 12 to 10 to 8 as the number of sets and the weight increase progressively. Rest: 45 to maximum 60 sec between sets.

Weeks 5 & 6 are targeted as the strength and muscular endurance stage. Perform 4 sets of 10 repetitions. Keep the weight constant – it is usually the same weight used to perform the first set (12 RM) of the initial strength development stage. Rest: 30 sec maximum between sets.

III) <u>Warm-Up</u>: Should be dynamic and reflect those exercises included in the WFX-FIT training program (for example; push-ups, pull-ups, travelling lunges). The total warm-up routine, including an aerobic component, should last 3-5 min.

IV) <u>Cool-Down</u>: Each strength training session should conclude with a brief cool-down of 5 min of easy aerobic activity followed by the stretching program described below.

V) <u>Intensity and Volume:</u>

	Target Number of Repetitions	Sets	Resistance
Week 1	12, 10, 8	3	A light weight that can be easily lifted. Proper technique should be emphasized.
Week 2	12, 10, 8	3	Weight increased to a point where the last rep is difficult to perform.
Week 3	12, 10, 8	3	Weight increased to a point where the last rep of each set is difficult to perform.
Week 4	12, 10, 8	3	Weight maintained from the previous week.
Week 5	10	4	Weight maintained to a point where the last rep of sets 3-4 is difficult to perform.
Week 6	10	4	Weight maintained from the previous week.

Note that determining the initial weights is essential. Learning proper form and technique is another important goal of the first training week and therefore lighter weights should be selected.

Following are <u>four detailed training modality alternatives</u> for preparing for the WFX-FIT.

A) Contemporary Fitness Training Equipment

Muscular strength, endurance and power exercises using contemporary (sophisticated) fitness training equipment such as Nautilus, Cybex, and Life Fitness in a gym setting.

Lower Body Exercises:

1. Leg Press using plate loaded or stack machine

Rationale: *to strengthen the anterior muscles of the leg. Throughout the WFX-FIT circuit quadriceps strength and endurance is important for negotiating the ramps, meant to simulate traversing hills, mountains, and burms.*

Execution: Sitting with your feet shoulder width apart on the deck/foot hold in front of you. Adjust the seat position so that your knees are at 90 degrees. Keep the weight on your heels, and push forward. Do not lock your knees. Return to the starting position.

2. Quadriceps Extensions using dedicated machine

Rationale: *to strengthen the anterior muscles of the leg and gluteals.*

Execution: Sitting with your feet under the support pad, raise your feet by extending your legs, parallel to the floor. Slowly lower the weight back to the starting position. The support pad should be resting just above the ankle. Most machines will permit changing the height of the support pad or seat position to ensure the correct execution.

3. Stiff-Legged Dead Lifts using Olympic bar or Universal cables

Rationale: *to strengthen the posterior muscles of the leg and gluteals. The inclusion of this exercise provides symmetry to an anterior dominant program.*

Execution: Stand with feet shoulder width apart in front of the bar as it rests on the floor. Grasp the bar with an overhand grip and stand straight up. Bend forward at the waist, keeping the knees slightly bent and rigid. Keep the chest forward and lower back arched. Reach forward until a stretch is felt in the lower back, hamstrings and gluteals and return to the upright position. If using Universal cables, lower the pulleys to the lowest setting and attach a straight bar to the clips.

4. Hamstring Curl using a dedicated curl machine

Rationale: *to strengthen the anterior muscles of the leg while simulating the repetitive ramp climbing performed in the WFX-FIT circuit.*

Execution: Sitting with your legs extended and feet under the support pad, pull your heels towards the seat. Slowly raise the weight back to the starting position. The support pad should be resting just above the ankle on the posterior side of the leg. Most machines will permit changing the height of the support pad or seat position to ensure the correct execution. Alternatively, some machines have the person lying face-down and raising the weight by bending at the knees.

Upper Body Exercises:

5. Seated Row using dedicated machine or Universal cables

Rationale: *to strengthen the posterior muscles of the upper body. This motion will assist strengthening the posterior musculature needed to support the pump and hose pack.*

Execution: Sit facing the machine, feet braced against the foot holds. Grasp the bar/handles and pull the weight towards the chest by straightening the back and pulling the elbows back along the side of your body. Alternatively, lower the pulley to the bottom position and affix a straight bar or handles to the cable.

6. Bent Row (underhand grip) using dedicated machine or Universal cables

Rationale: *to strengthen the posterior muscles of the upper body. This motion will assist strengthening the posterior musculature needed to support the pump and hose pack.*

Execution: Stand facing the machine, with feet shoulder width apart. Grasp the handles and, with the back straight, and knees slightly bent, lean forward approximately 45 degrees - bending at the hips. Pull the weight up to the chest and return to the starting position. Alternatively, lower the pulleys to the bottom position and affix a straight bar to the cable. Using an underhand grip perform the same movement execution.

7. Lateral Arm Raises using dedicated machine or Universal cables

Rationale: *to strengthen the musculature forming the shoulder (Deltoids, Trapezius, Pec Major). This motion will also assist lifting and lowering the hose pack.*

Execution: Stand with feet shoulder width apart, arms at 90 degrees resting against the pads. Raise the arms to the sides of the body by pressing out against the pads then lower them back to the starting position under control. Alternatively, lower the pulleys to the bottom position and affix a handle to the cable. Using an overhand grip and an outstretched arm by your side, raise the weight by bringing the hand to shoulder height.

6. Incline Press using dedicated machine or Universal cables

Rationale: *to strengthen the musculature forming the shoulder girdle (Deltoids, Pec Major, Triceps). This motion will help improve general upper body strength and provide symmetry to a pull dominant program.*

Execution: Sitting on the machine, feet braced against the foot holds, grasp the bar/handles and push the weight up by extending the arms trying to avoid locking the elbows. Lower the weight under control to the starting position. Alternatively, lower the pulley to the bottom position and affix a straight bar or handles to the cable. Sit on a bench with a 45 degree angle. Hold the handles so they are in line with the shoulders and elbows bent. Extend the arms vertically, bringing the weights together at the top of the motion.

7. Core Strengthening using dedicated machine or Universal cables

Rationale: *to strengthen the musculature forming the abdomen. There are a wide variety of exercises which can be performed. Based on familiarity and comfort with performing more* *complex exercises 'Lumber-Jacks', 'overhead medicine ball slams', and 'lateral medicine ball slams' are recommended. However, novice exercisers should begin with crunches or sit-ups.*

Execution: Sitting on the machine, grasp the handles next to the head. Raise the weight by contracting the abdomen and curling forward; do not use the arms to pull the weight. Return the weight to the starting position under control. Alternatively, raise the pulley to the top position and affix a rope-like handle. Kneel down facing away from the machine. Grasp the handles behind the head. Raise the weight by contracting the abdomen and curling forward; do not use the arms to pull the weight. Return the weight to the starting position under control.

Stretching Program:

Stretch #1: Knee Flexion (Hamstrings: Raised Leg Knee Flexor Stretch)

Stretch #2: Knee Extension (Quadriceps: Kneeling Knee Extensor Stretch)

Stretch #3: Gastrocnemius / Soleus (Plantar Flexor Stretch)

Stretch#4: Back Flexion (Seated Lower-Trunk Extensor Stretch)

Stretch #5: Shoulder Extension (Extensor, Adductor and Retractor Stretch)

Stretch #6: Chest (Shoulder Flexor Stretch)

Note: Each stretch is static in nature and should be held for 20-30 seconds considering any local muscle discomfort post exercise.

<u>Summary Table</u> for muscular strength, endurance and power exercises using contemporary fitness training equipment.

	Lower Body Exercises				Upper Body Exercises				
	1. Leg Press	2. Quadriceps Extensions	3. Dead Lifts	4. Hamstring Curls	5. Seated Row	6. Bent Over Row	7. Lateral Raises	8. Incline Press	9. Core Exercises
Week 1	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 3 x 20-25 RM or as tolerated
Week 2	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 3 x 20-25 RM or as tolerated
Week 3	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk
Week 4	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk
Week 5	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	Same as Previous Wk
Week 6	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk
	Abbreviations: Wk - week RM - repetitions S - seconds Wt - weight								

B) Free Weights (dumbbells) Only

Muscular strength, endurance and power training exercises using free weights (dumbbells) only

Lower Body Exercises:

1. Dumbbell Squats

Rationale: *to strengthen the anterior muscles of the leg. Throughout the WFX-FIT circuit quadriceps strength and endurance is important for negotiating the ramps which are meant to simulate traversing hills, mountains, and burms.*

Execution: Stand with feet shoulder width apart with your feet, knees and hips in a straight line facing forward. Slowly lower your body, as though you are sitting in a chair. If you can, go down until knees are at 90 degrees. Make sure your knees are BEHIND your toes. Keeping the weight in your heels, slowly push your body back to starting upright position. At the top of the movement, do NOT lock your knees.

2. Dumbbell Lunges (walking / traveling)

Rationale: *to strengthen the anterior muscles of the leg and gluteals.*

Execution*:* Stand with feet together. Take a large step forward, and slowly lower your body into a lunge position. Make sure your knee is above your ankle, keeping it at a 90 degree angle. Slowly push back up to starting position, pushing from your heel. Do not lean/hunch forward or position your knee past your front foot.

3. Stiff-Legged Dead Lifts

Rationale: *to strengthen the posterior muscles of the leg and gluteals. The inclusion of this exercise provides symmetry to an anterior dominant program.*

Execution*:* Stand with feet shoulder width apart. Grasp the weights with an overhand grip and stand straight up. Bend forward at the waist, keeping the knees slightly bent and rigid. Keep the chest forward and lower back arched. Reach forward until a stretch is felt in the lower back, hamstrings and gluteals and return to the upright position.

4. Step Ups

Rationale: *to strengthen the anterior muscles of the leg while simulating the repetitive ramp climbing performed in the WFX-FIT circuit.*

Execution: With free weights held in hands, stand facing a box or bench. Place one foot on the platform, using it to push off the floor and onto the platform. The focus should be on using the front foot to push upward, avoid using the back foot to assist pushing off the floor.

Upper Body Exercises:

5. One Arm Row

Rationale: *to strengthen the posterior muscles of the upper body. This motion will assist strengthening the posterior musculature needed to support the pump and hose pack.*

Execution: Grasp a free weight with the palm facing in. Use the opposite hand and knee to support the body on a bench. Raise the upper arm and elbow as high as possible, inline with the body. Keep the back straight, the elbow should end at a 90 degree angle. Lower the weight under control.

6. Bent Row (underhand grip)

Rationale: *to strengthen the posterior muscles of the upper body. This motion will assist strengthening the posterior musculature needed to support the pump and hose pack.*

Execution: Stand with feet shoulder width apart. Grasp the bar with an underhand grip, with the hands wider than shoulder width. With the back straight, and knees slightly bent, lean forward approximately 45 degrees - bending at the hips. Pull the bar up to the chest and return to the starting position.

7. Front Raises

Rationale: *to strengthen the musculature forming the shoulder (Deltoids, Trapezius, Pec Major). This motion will also assist lifting and lowering the hose pack.*

Execution: Stand with feet shoulder width apart. Grasp the free weights with an overhand grip so they rest against the thighs. Raise the arms in front of your body to eye level and lower them back to the starting position under control.

8. Incline Dumbbell Press

Rationale: *to strengthen the musculature forming the shoulder girdle (Deltoids, Pec Major, Triceps). This motion will help improve general upper body strength and provide symmetry to a pull dominant program.*

Execution: Sit on a bench with a 45 degree angle. Hold the weights so they are in line with the shoulders and elbows bent. Extend the arms vertically, bringing the weights together at the top of the motion.

9. Core Strengthening

Rationale: *to strengthen the musculature forming the abdomen. There are a wide variety of exercises which can be performed. Based on familiarity and comfort with performing more complex exercises; 'Lumber-Jacks', 'overhead medicine ball slams', and 'lateral medicine ball slams' are recommended. However, novice exercisers should begin with crunches or sit-ups.*

Execution: Lie on the back, with hands behind the head. Knees bent and feet flat on the floor. Raise the shoulders off the ground bringing the chest towards the knees.

Stretching Program:

Stretch #1: Knee Flexion (Hamstrings: Raised Leg Knee Flexor Stretch)

Stretch #2: Knee Extension (Quadriceps: Kneeling Knee Extensor Stretch)

Stretch #3: Gastrocnemius / Soleus (Plantar Flexor Stretch)

Stretch#4: Back Flexion (Seated Lower-Trunk Extensor Stretch)

Stretch #5: Shoulder Extension (Extensor, Adductor and Retractor Stretch)

Stretch #6: Chest (Shoulder Flexor Stretch)

Note: Each stretch is static in nature and should be held for 20-30 sec considering any local muscle discomfort post exercise.

<u>Summary Table</u> of muscular strength, endurance and power exercises limited to free weights (dumbbells) only.

	Lower Body Exercises				Upper Body Exercises				
	1. Db Squats	2. Db Lunges	3. Dead Lifts	4. Step Ups	5. One Arm Row	6. Bent Over Row	7. Front Raises	8. Incline Db Press	9. Core Exercises
Week 1	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 3 x 20-25 RM or as tolerated
Week 2	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 3 x 20-25 RM or as tolerated
Week 3	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk
Week 4	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk
Week 5	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	4 Sets: 4 x 10 RM Rest: 30 s Maintain Wt each Set	Same as Previous Wk
Week 6	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk
	Abbreviations: Db - dumbbells (free weights) Wk - week RM - repetitions S - seconds Wt - weight								

C) Body Weight/Callisthenic Only

Muscular strength, endurance and power exercises using body weight (calisthenics) only.

Lower Body Exercises:

1. Step Ups

Rationale: *to strengthen the anterior muscles of the leg while simulating the repetitive ramp climbing performed in the WFX-FIT circuit.*

Execution: The following may be performed using body weight only or while wearing a hose pack on the back. Weight can be added or removed by increasing or decreasing the number of sections of hose in the bag. Stand facing a box or bench. Place one foot on the platform, using it to push off the floor and onto the platform. The focus should be on using the front foot to push upward, avoid using the back foot to assist pushing off the floor.

2. Lunges (walking / traveling)

Rationale: *to strengthen the anterior muscles of the leg and gluteals.*

Execution: The following may be performed using body weight only or while wearing a hose pack on the back. Weight can be added or removed by increasing or decreasing the number of sections of hose in the bag. Stand with feet together. Take a large step forward, and slowly lower your body into a lunge position. Make sure your knee is above your ankle, keeping it at a 90 degree angle. Slowly push back up to starting position, pushing from your heel. Do not lean/hunch forward or position your knee past your front foot.

3. One-Legged Hamstring Bridges

Rationale: *to strengthen the posterior muscles of the leg and gluteals. The inclusion of this exercise provides symmetry to an anterior dominant program.*

Execution: Lie on the back, with hands flat on the floor and knees bent to 90 degrees. Raise the pelvis and lower back off the floor by pushing down through the heels. Squeeze the hamstrings during the contraction.

4. Side Facing Step Ups

Rationale: *to strengthen the anterior muscles of the leg while simulating the repetitive ramp climbing performed in the JSC.*

Execution: The following may be performed using body weight only or while wearing a hose pack on the back. Weight can be added or removed by increasing or decreasing the number of sections of hose in the bag. Stand next to a box or a bench. The outside foot comes across the inside foot and is positioned on the box/bench. Use this lead foot to raise and lower off the platform in a similar motion to that of the step ups.

Upper Body Exercises:

5. Pull Ups (Chin Ups)

Rationale: *to strengthen the latissimus, deltoids and anterior shoulder. This motion will assist strengthening the musculature needed to lift and lower the pump and hose pack.*

Execution: The following may be performed using body weight only or while wearing a hose pack on the back. Weight can be added or removed by increasing or decreasing the number of sections of hose in the bag. Stand facing a horizontal bar, at arms reach above the head. Using an underhand grip on the bar, raise your body by curling your arms until the bar meets chin-level. Lower in a controlled manner, try to avoid swinging.

6. Supine Pull Ups (Inverted Row)

Rationale: *to strengthen the posterior muscles of the upper body. This motion will assist strengthening the posterior musculature needed to support the pump and hose pack.*

Execution: Lying on your back with a horizontal bar or nylon straps with handles secured to a structure, grasp the bar/handles using an overhand grip. Form a bridge with your torso by keeping your heels firmly in place, tightening your core and raising your hips. Pull up on the bar/handles until they contact the chest. Lower in a controlled manner.

7. Back (Hyper) Extensions

Rationale: *to strengthen the musculature forming the lower back (erectors). This motion will also assist bending and lifting as well as supporting the weight of the pump/hose pack against the lower back.*

Execution: Lay on your front with your arms and legs extended in front and behind your body. Keeping your arms and legs straight, raise them both 6-8 inches off the floor by contracting the muscles of your lower back.

8. Push Ups

Rationale: *to strengthen the musculature forming the shoulder girdle (Deltoids, Pec Major, Triceps). This motion will help improve general upper body strength and provide symmetry to a pull dominant program.*

Execution: Lay on your front with your arms slightly wider than shoulder-width and legs extended in front and behind your body. Press down on your palms raising your body off the floor and keeping your legs straight. Extend upward until full extension at the elbows and lower yourself until the chin contacts the floor. Maintain a horizontal posture throughout by keeping the core muscles tight and raising the hips slightly.

9. Core Strengthening

Rationale: *to strengthen the musculature forming the abdomen. There are a wide variety of exercises which can be performed. Based on familiarity and comfort with performing more complex exercises 'Lumber-Jacks', 'overhead medicine ball slams', and 'lateral medicine* *ball slams' are recommended. However, novice exercisers should begin with crunches or situps.*

Execution: Lie on the back, with hands behind the head, knees bent and feet flat on the floor. Raise the shoulders off the ground bringing the chest toward the knees.

Stretching Program:

Stretch #1: Knee Flexion (Hamstrings: Raised Leg Knee Flexor Stretch)

Stretch #2: Knee Extension (Quadriceps: Kneeling Knee Extensor Stretch)

Stretch #3: Gastrocnemius / Soleus (Plantar Flexor Stretch)

Stretch#4: Back Flexion (Seated Lower-Trunk Extensor Stretch)

Stretch #5: Shoulder Extension (Extensor, Adductor and Retractor Stretch)

Stretch #6: Chest (Shoulder Flexor Stretch)

Note: Each stretch is static in nature and should be held for 20-30 sec considering any local muscle discomfort post exercise.

Summary Table of muscular strength, endurance and power exercises limited to body weight (calisthenics) only.

	Lower Body Exercises				Upper Body Exercises				
	1. Step Ups	2. Lunges	3. One Leg Hamstring Bridge	4. Side Facing Step Up	5. Pull Ups	6. Supine Pull Ups	7. Back Extensions	8. Push Ups	9. Core Exercises
Week 1	3 Sets: 1 x 25 RM 1 x 20 RM 1 x 15 RM Rest: 45-60 s Increasing step height each set	3 Sets: 1 x 15 RM 1 x 12 RM 1 x 10 RM Rest: 45-60 s	3 Sets: 3 x 12 RM Rest: 45-60 s	3 Sets: 1 x 25 RM 1 x 20 RM 1 x 15 RM Rest: 45-60 s Increasing step height each set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s or as tolerated	3 Sets: 1 x 15 RM 1 x 12 RM 1 x 10 RM Rest: 45-60 s Decreasing angle each set	3 Sets: 3 x 15 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 3 x to fatigue Rest: 45-60 s	3 Sets: 3 x 20-25 RM or as tolerated
Week 2	3 Sets: 1 x 25 RM 1 x 20 RM 1 x 15 RM Rest: 45-60 s Increasing step height each set	3 Sets: 1 x 15 RM 1 x 12 RM 1 x 10 RM Rest: 45-60 s	3 Sets: 3 x 12 RM Rest: 45-60 s	3 Sets: 1 x 25 RM 1 x 20 RM 1 x 15 RM Rest: 45-60 s Increasing step height each set	3 Sets: 1 x 12 RM 1 x 10 RM 1 x 8 RM Rest: 45-60 s or as tolerated	3 Sets: 1 x 15 RM 1 x 12 RM 1 x 10 RM Rest: 45-60 s Decreasing angle each set	3 Sets: 3 x 15 RM Rest: 45-60 s Increasing Wt each Set	3 Sets: 3 x to fatigue Rest: 45-60 s	3 Sets: 3 x 20-25 RM or as tolerated
Week 3	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk
Week 4	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk
Week 5	4 Sets: 4 x 15-20 RM Rest: 30 s Maintain step height	4 Sets: 4 x 10-12 RM Rest: 30 s	4 Sets: 4 x 10 RM Rest: 30 s	4 Sets: 4 x 15-20 RM Rest: 30 s Maintain step height	4 Sets: 4 x to fatigue Rest: 30 s	4 Sets: 4 x 10-12 RM Rest: 30 s Maintain angle each set	4 Sets: 4 x to fatigue Rest: 30 s	4 Sets: 4 x to fatigue Rest: 30 s	Same as Previous Wk
Week 6	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk	Same as Previous Wk

Abbreviations:
Wk - week
RM - repetitions
S - seconds
Wt - weight

D) A Replication of the WFX-FIT Circuit

The following exercises can be performed to simulate the demands of the WFX-FIT circuit. Using minimal equipment and available landscape or facilities, each component of the circuit can be recreated. This requires accessing a set of stairs, or a portion of a hill or a burm and the space available must be adequate to perform length of the as course described below.

WFX-FIT Circuit components:

1. **Carry a Medium Pump on Back**
2. **Hand Carry a Medium Pump**
3. **Hose Pack Lift and Carry on Back**
4. **Advanced Charged Hose**

Replicated WFX-FIX course:

1. The Carry a Medium Pump on Back over the ramp can be simulated using a standard issue medium decommissioned pump or object of similar weight and dimensions and substituting stairs, or a portion of a hill, or a burm for the ramp. If using stairs, a minimum of 5 steps up followed by 5 steps down is required. If using a portion of a hill or burm, a 35° slope best simulates the incline of the ramp. The total distance travelled should be 160 m (525 ft) with a total of 8 trips over or up and down the simulated “ramp”.

2. The Hand Carry a Medium Pump can be simulated using a standard issue medium decommissioned pump or object of similar weight and dimensions, carried on any flat unobstructed surface. The total distance travelled is 80 m (263 ft).

3. The Hose Pack Lift and Carry on Back over the ramp can be simulated using a standard issue hose pack a weighted back pack or object of similar weight and dimensions and substituting stairs, or a portion of a hill or a burm for the ramp. If using stairs, a minimum of 5 steps up followed by 5 steps down is required. If using a portion of a hill or burm, a 35° slope best simulates the incline of the ramp. The total distance travelled should be 1000 m (3281 ft) with a total of 50 trips over the simulated “ramp”.

4. The Advanced Charged Hose can be replicated by dragging an object of similar weight and friction along the ground a distance of 80 m (263 ft). Some creativity may be required in assembling a simulation sled, but a tire affixed with weights requiring a drag force 18.5 kg (40.8 lb) would be ideal.

Stretching Program:

Stretch #1: Knee Flexion (Hamstrings: Raised Leg Knee Flexor Stretch)

Stretch #2: Knee Extension (Quadriceps: Kneeling Knee Extensor Stretch)

Stretch #3: Gastrocnemius / Soleus (Plantar Flexor Stretch)

Stretch#4: Back Flexion (Seated Lower-Trunk Extensor Stretch)

Stretch #5: Shoulder Extension (Extensor, Adductor and Retractor Stretch)

Stretch #6: Chest (Shoulder Flexor Stretch)

Note: Each stretch is static in nature and should be held for 20-30 sec considering any local muscle discomfort post exercise.

Summary Table of the training on a Replicated WFX-FIT Circuit.

	1. Carry a Medium Pump on Back	2. Hand Carry a Medium Pump	3. Hose Pack Lift and Carry on Back	4. Advanced Charged Hose
Week 1	Performed once to establish a baseline time.	Performed once to establish a baseline time.	Performed once to establish a baseline time.	Performed once to establish a baseline time.
Week 2	Performed once improving on established time.	Performed once improving on established time.	Performed once improving on established time.	Performed once improving on established time.
Week 3	Same as Previous Week	Same as Previous Week	Same as Previous Week	Same as Previous Week
Week 4	Same as Previous Week	Same as Previous Week	Same as Previous Week	Same as Previous Week
Week 5	Same as Previous Week	Same as Previous Week	Same as Previous Week	Same as Previous Week
Week 6	Same as Previous Week	Same as Previous Week	Same as Previous Week	Same as Previous Week

References:

Delavier, Frederic, 2010. Strength Training Anatomy. Human Kinetics, www.Human.Kinetics.com

Nelson, A. G. and J. Kokkonen, 2007. Stretching Anatomy. Human Kinetics, www.Human.Kinetics.com

APPENDIX H

Seeking students to participate in a
Forest Fire Fighter Testing & Training Study

Professors Gledhill and Jamnik are seeking participants for a **6** week study to begin late January/early February and end early March/April.

Primary Objective: to determine the pass/fail rate of non forest fire fighters (York university students) on a newly developed forest fire fighter fitness test.
Secondary Objective: to determine the degree to which familiarization improves performance on the fitness test.
Study participants will be RANDOMIZED into '*Control*' and '*CIRCUIT ONLY*' Groups.

What will be asked of you if you are selected?

- **Extensive *pre* and *post* fitness assessments in York's Human Performance Laboratory.**
- **1 day/wk of completing the forest fire fighter fitness test ~20 minutes**

Participants cannot be already engaged in a structured exercise program (eg. not a varisity athlete or outside competitive athlete) and must have the appropriate ID access to use Tait Mckenzie Fitness Centre and/or Toronto Track and Field Centre

To learn more, please contact Robbie at robbie5@yorku.ca

Seeking students to participate in a
Forest Fire Fighter Circuit Study

Seeking participants for a **6** week study to begin in January and end in February/March.

Primary Objective: to determine the pass/fail rate of non-forest fire fighters (York university students) on a newly developed forest fire fighter fitness test.

Secondary Objective: to determine the degree to which familiarization improves performance on the fitness test.

Study participants will be RANDOMIZED into '*Control*' and '*CIRCUIT ONLY*' Groups

What will be asked of you if you are selected?
- **Extensive *pre* and *post* fitness assessments in York's Human Performance Laboratory.**
- **1 day/wk of completing the forest fire fighter fitness test ~20 minutes**

To learn more, please contact Robbie at robbie5@yorku.ca

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APPENDIX I

Training Study
DATA COLLECTION FORM

Name of Tester: ________________________________ Date: ________________________________
Subject Name: _________________________________ Age: ______________ Sex: ____________

Body Composition Assessment:

Variable	Measurement		Score
Height (cm)			Omit
Weight (kg)			Omit
BMI (kg/m^2)			
Waist Circumference (cm)		Triceps: ________________	
Sum of Five Skinfolds (mm)	∑	Biceps: ________________ Iliac: ________________ Subscap: _______________ Medial Calf: ____________	
% Body Fat (Tanita)	___________________________ %		Omit

Musculoskeletal Fitness Measures:

Variable	Measurement	Score
Grip Strength	R: __________ / ____________ kg L: __________ / ____________ kg	
Push –Ups (#) **(Male or Female circle one)**		
Vertical Jump **Standing reach:** **______________in**	1:__________________________in 2:__________________________in 3:__________________________in	

Additional Measures:

Variable	Measurement	
Push-Pull (lb)	Push: ______ / _______ / _______ Maximum x __530__ = _______lb	Pull: ______ / _______ / _______ Maximum x __530__ = _______lb

Directly Measured VO_2Max:

$mL \cdot kg^{-1} \cdot min^{-1}$	$L \cdot min^{-1}$

APPENDIX J

DETERMINATION OF LEG POWER

The *Sayers equation* (below) determines peak leg power which is essential for the functional requirements of mobility, task performance and personal safety actions such as avoiding collisions or catching one's balance. (This equation takes into account body mass; whereas, the simple vertical jump height does not).

Insert body mass and vertical jump height measures as documented on the recording into the following equation to calculate peak leg power in watts:

Peak leg power (W) = [60.7 x jump height (cm)] + [45.3 x body mass (kg)] – 2055

REFERENCES

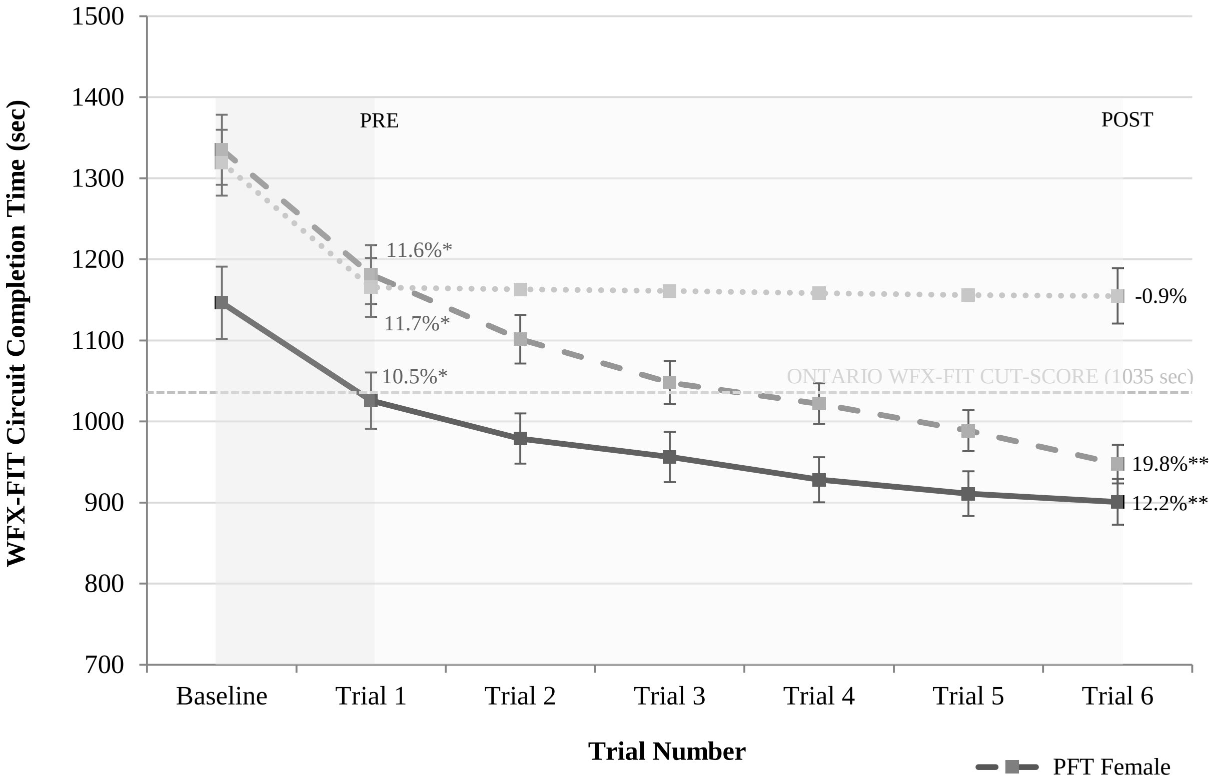
Keir, PJ., Jamnik, VK., and Gledhill, N. Technical-Methodological Report: A Nomogram for Peak Leg Power Output in the Vertical Jump. Journal of Strength and Conditioning Research. 2003, 17(4), 701–703.

Jamnik, VK., and Gledhill, N. Physical Activity and Lifestyle "*R*" Medicine. A Health-Related Physical Activity, Fitness and Lifestyle *Rx*. York University, Faculty of Health, School of Kinesiology and Health Science. Copyright 2015-2016. ISBN 978-1-895971-18-7. pp 209.

APPENDIX K

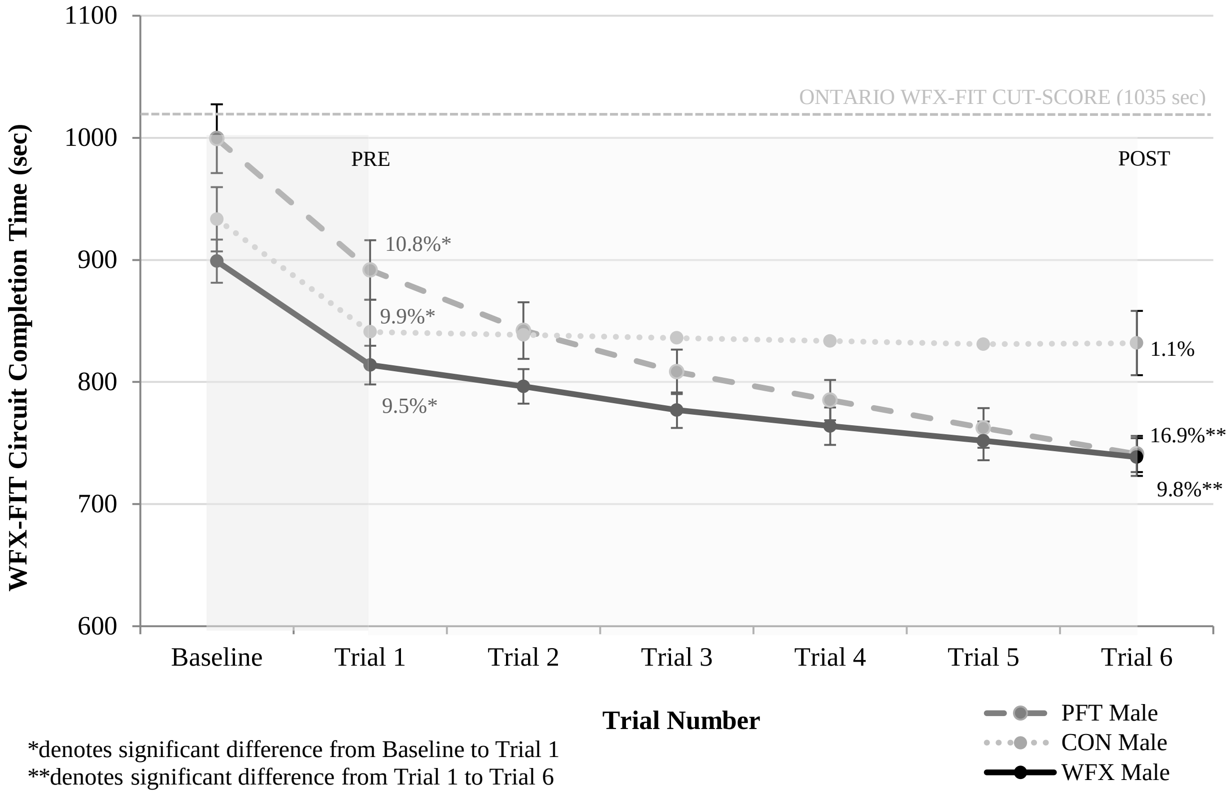
Alternative Figure 3 from Manuscript IV; *Familiarization and Training*, illustrating female and male participant stratification.

Figure 3b. Mean±SE WFX-FIT circuit completion times (sec) over 7 trials for FEMALES only in the physical fitness training group (PFT), weekly circuit performance only group (WFX) and control group (CON) along with percent (%) improvement in circuit completion time from Baseline to Trial 1 (familiarization) and Trial 1 to Trial 6 (training period).



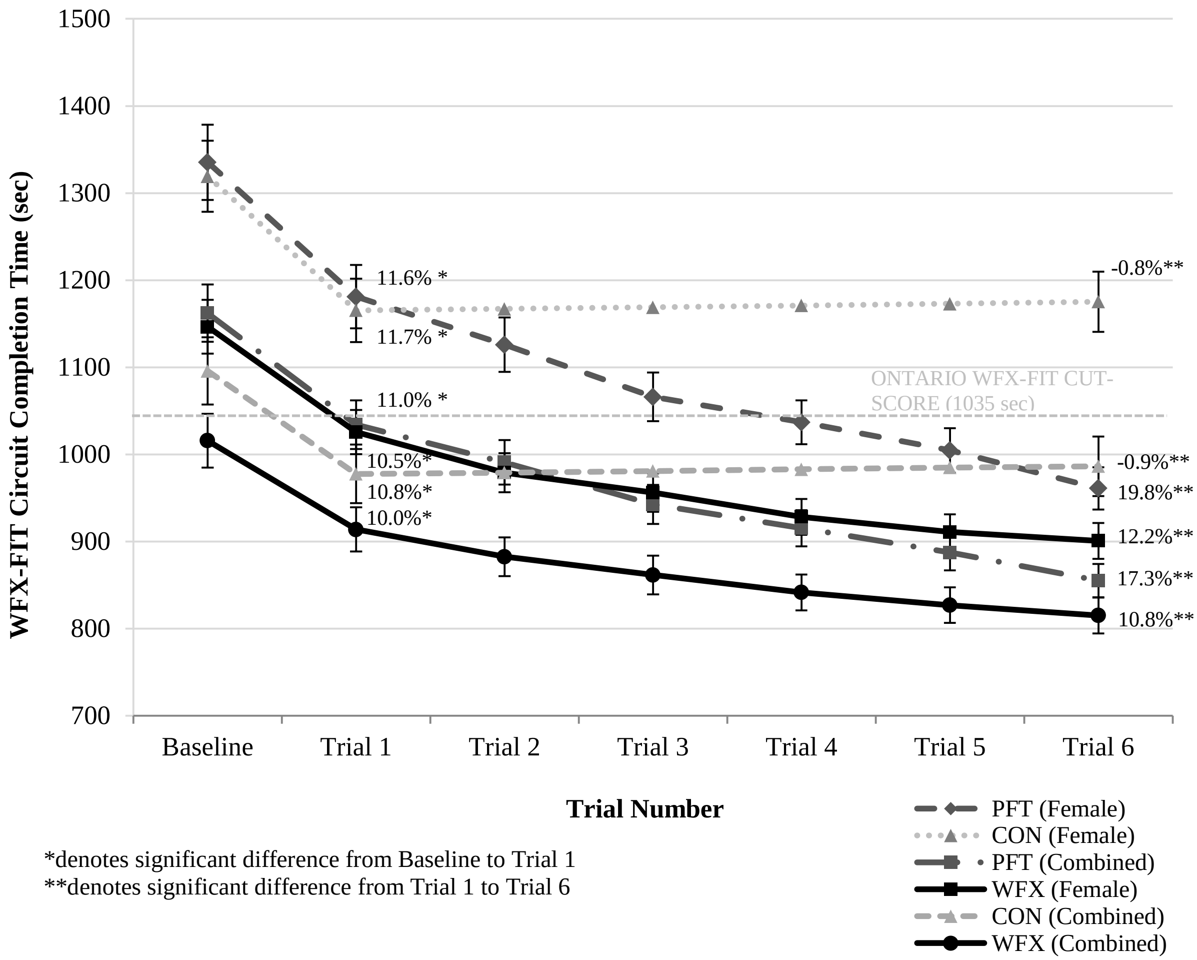
*denotes significant difference from Baseline to Trial 1
**denotes significant difference from Trial 1 to Trial 6

Figure 3c. Mean±SE WFX-FIT circuit completion times (sec) over 7 trials for MALES only in the physical fitness training group (PFT), weekly circuit performance only group (WFX) and control group (CON) along with percent (%) improvement in circuit completion time) from Baseline to Trial 1 (familiarization) and Trial 1 to Trial 6 (training period).



*denotes significant difference from Baseline to Trial 1
**denotes significant difference from Trial 1 to Trial 6

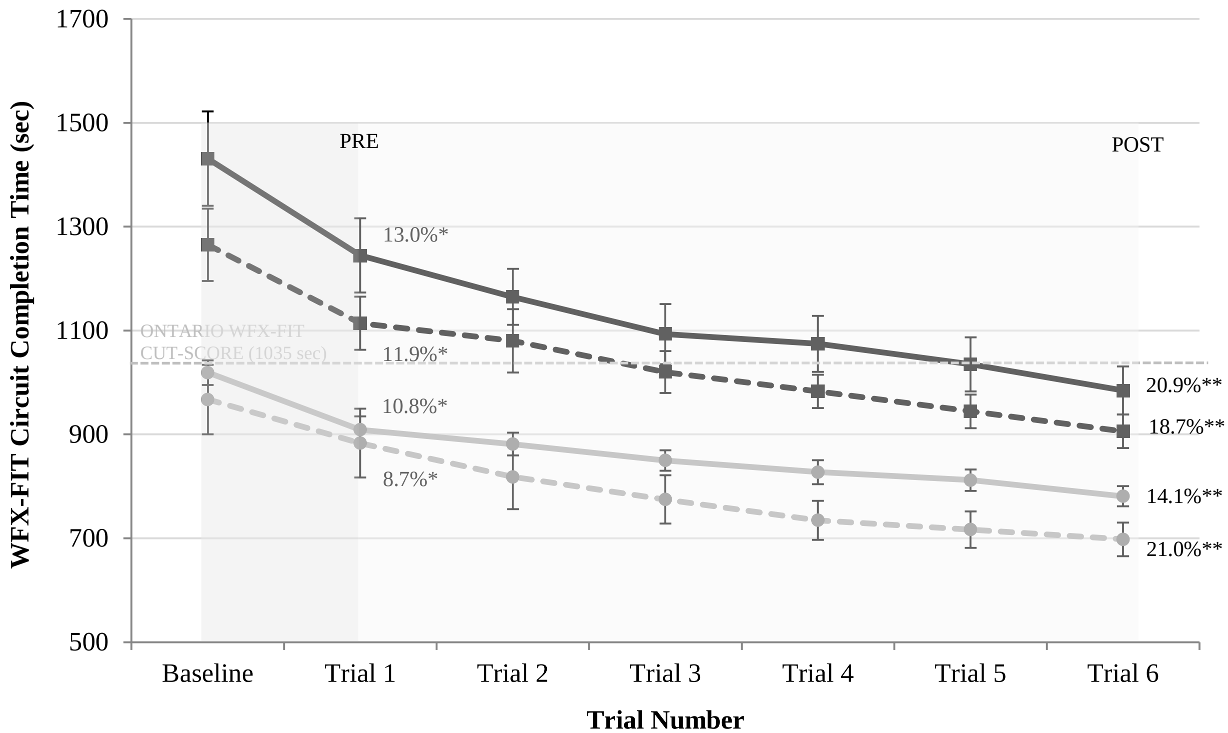
Figure 3d. Mean±SE WFX-FIT circuit completion times (sec) over 7 trials for Combined FEMALES and MALES, and FEMALES only in physical fitness training group (PFT), weekly circuit performance only group (WFX) and control group (CON) along with percent (%) improvement in circuit completion time from Baseline to Trial 1 (familiarization) and Trial 1 to Trial 6 (training period).



*denotes significant difference from Baseline to Trial 1
**denotes significant difference from Trial 1 to Trial 6

APPENDIX L

Figure 5. Mean±SE WFX-FIT circuit completion time (sec) over 7 trials for MALES only and FEMALES only in the physical fitness training group (PFT) stratified by LO/HI VO_2max, along with percent (%) improvement in circuit completion time from Baseline to Trial 1 (familiarization) and Trial 1 to Trial 6 (training period).



*denotes significant difference from Baseline to Trial 1
**denotes significant difference from Trial 1 to Trial 6