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Effectiveness of fitness training and psychosocial education intervention programs in wildland firefighting: a cluster randomised control trial

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ABSTRACT

Critical to effective fire management is the protection and preparedness of highly trained wildland firefighters who routinely face extreme physical and psychological demands. To date, there is limited scientific evidence of psychosocial education intervention effectiveness in this context. The objective of the current study is to utilise a cluster randomised control trial study design to evaluate fitness training and psychosocial education intervention programs across a wildland fire season. Wildland firefighters ($n = 230$) were randomly assigned by their work location to one of four experimental conditions. Pre- and post-season assessments of primary (e.g. psychosocial risk factors, physical fitness and psychological capital) and secondary (e.g. work engagement, job stress and incidence of injury) outcomes facilitated comprehensive evaluation. The psychosocial education intervention program was effective at buffering participant appraisals of 12 of 13 psychosocial risk factors, namely: organisational culture, civility, psychological demands, balance, psychological support, leadership expectations, growth and development, influence, workload management, engagement, protection and safety. Participants in the psychosocial education intervention also reported lower stress relating to organisational support compared with those who not receiving the intervention program. Wildland firefighters receiving either or both intervention programs reported a significantly lower incidence rate of injury (9.9%) compared with the organisation's 5-year average (16.0%).

Keywords: cluster randomised control trial, firefighting, health, human dimensions, injury, job demands-resources theory, job stress, mental health, physical fitness, psychological capital, psychosocial intervention, psychosocial work environment, wildland fire, work engagement.

Introduction

Workplaces have been identified as a priority setting for promoting physical and psychological health and wellbeing and work performance (Ford *et al.* 2011; Malik *et al.* 2014; Commissaris *et al.* 2016). Intervention programs designed, delivered and evaluated by and within organisations are a critical component in the promotion of employee health and wellbeing and in reducing the risk of occupational injury (Rivara and Thompson 2000; Cartwright and Cooper 2009; Cooper 2013; Karanika-Murray and Biron 2015; Van Eerd *et al.* 2015). Wildland firefighting presents employees with many arduous physical and psychological demands, including rough terrain, heavy equipment, long working hours, personal risk, poor sleep and a variety of unpredictable environmental factors (e.g. weather, heat, wildlife) (Aisbett *et al.* 2007, 2012; Cuddy and Ruby 2011; Gordon and Larivière 2014; Cuddy *et al.* 2015; Bulmer *et al.* 2017; Carballo-Leyenda *et al.* 2019). In addition to these demands, wildland firefighters (WFFs) are often challenged in attempting to contain and suppress wildland fires raging across hectares of densely forested regions in extreme heat (Cuddy and Ruby 2011; Carballo-Leyenda *et al.* 2019). Research over the past 15 years has consistently estimated the daily energy demands while fighting wildland fires to exceed 4500 kcal (1 kcal = 4.186 kJ), a result of navigating rough terrain while

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carrying or pulling heavy equipment such as pumps and hoses (Heil 2002; Ruby *et al.* 2002; Cuddy *et al.* 2015; Robertson *et al.* 2017). This level of energy expenditure has been found to be comparable with military personnel during combat training and professional athletes during a competitive season (Ebine *et al.* 2002; Tharion *et al.* 2005). To work effectively and safely, WFFs must maintain a high level of personal resources including above-average fitness levels (Domitrovich 2011), with many additional factors to consider including: hydration (Raines *et al.* 2012, 2013, 2015), nutrition (Ruby *et al.* 2002; Robertson *et al.* 2015) and thermoregulation across variable and extreme thermal environments (Budd 2001; Lui *et al.* 2014; Carballo-Leyenda *et al.* 2019, 2021).

Wildland firefighters irrespective of role within crews across Canada are required to complete the Canadian Physical Performance Exchange Standard for Type 1 Wildland Firefighters (abbreviated: WFX-FIT), a four-component timed circuit, within 14 min and 30 s to qualify for national exchange (Tobias 2012; Gumieniak *et al.* 2018*a*, 2018*b*). Following screening, the four components completed in succession are: (1) carry pump on back; (2) hand carry pump; (3) hose pack life and carry on back; and, (4) charged hose advance. The WFX-FIT test must be completed prior to each wildland fire season. There have been limited in-season assessments of WFF physical fitness to date, creating a gap in our understanding with regard to the change in physical capabilities across a wildland fire season. Gaskill *et al.* (2003) evaluated one component of fitness, aerobic capacity, and found a slight decrease from pre-season to mid- and post-season measures, positing that individuals adapted to the specific demands of the occupation and particular fire season. These findings are consistent with the principle of detraining, where significant reductions in fitness can occur after a few weeks of reduced training, in this context after a period of intense training to meet the WFX-FIT standard to qualify for employment (Bickel *et al.* 2011). However, given the physical demands of wildland firefighting do not diminish over the course of a fire season, it is imperative that WFFs maintain a high level of fitness to complete their tasks safely. To date, research has yet to be conducted to comprehensively evaluate the other components of fitness (including anaerobic capacity or flexibility) of WFFs and the impact of in-season training activity on fitness levels over the course of a fire season. Moreover, there remains no validated in-season fitness training program to support WFFs' capacity to physically meet the demands of their occupation. Injury rates are high among WFFs, with fitness levels and physical fatigue often identified as contributing factors, highlighting the need for in-season fitness training and continuous monitoring (Palmer 2005; Britton *et al.* 2013; Gordon and Larivière 2014; Leduc *et al.* 2018).

Despite the regular occurrence of occupational and environmental stressors, limited research has been conducted on the psychological demands and subsequent psychological wellbeing of WFFs (Barton *et al.* 2015). Gordon and Larivière (2014) found that nearly half of surveyed WFFs in Ontario, Canada, reported high levels of job stress over the course of a fire season. In a smaller sample of Ontario WFFs, experiences of overall job stress were shown to have increased from mid- to post-season, though scores remained within normal limits, indicating perceived work stress is comparable with the average range in normative data for workers employed in the skilled-maintenance sector (Spielberger and Vagg 1994; McGillis *et al.* 2015, 2017). More specifically, WFFs in Ontario identified that their perceived level of organisational support was the primary driver of overall job stress, which increased significantly over the course of the fire season (McGillis *et al.* 2015).

To this point, no comprehensive evaluation of psychosocial risk factors has been completed in the context of wildland fire, nor do organisations typically possess complete data on the impact of psychosocial climate on organisation-level outcomes or lost-time claims within its workforce. Repeated challenges to physical fitness and health-promoting interventions include a lack of theoretical grounding to connect and link findings across contexts or organisations and poor methodological rigour (Conn *et al.* 2009; Ford *et al.* 2011; Abdin *et al.* 2018). Moreover, research addressing job demands and resources has often focused on documenting, developing or understanding a single aspect of either physical or psychological wellbeing rather than attempting to influence and measure both simultaneously.

A central framework for understanding the relationship between job characteristics and employee wellbeing over the past 20 years is the Job Demands–Resources (JD-R) Theory (Bakker and Demerouti 2014). Widely accepted owing to its inherent flexibility in classifying work characteristics as either a demand or resource, the JD-R Theory incorporates both positive and negative antecedents of employee strain and wellbeing within a single model (Demerouti *et al.* 2001; Bakker and Demerouti 2007; Schaufeli and Taris 2014). As a result, and since its inception, the JD-R Theory has been applied in a vast amount of empirical research and utilised across a diverse range of organisations around the world (Schaufeli and Taris 2014; Bakker and Demerouti 2017), evolving into a mature theory expounding on the relationships between job characteristics and employee wellbeing (Crawford *et al.* 2010; Nahrgang *et al.* 2011; Bakker *et al.* 2014; Bakker and Demerouti 2017; Lesener *et al.* 2019). Explaining the relationship between demands and resources through two independent processes influencing psychological state and subsequently employee wellbeing, the JD-R Theory can also be used to understand a diverse range of organisational outcomes (Bakker and Demerouti 2014, 2017). Applied to a highly demanding work context such as wildland firefighting, the JD-R Theory can be used to understand the importance and influence of fostering the development and maintenance of resources to meet the demands of the job. Moreover, and more recently, unified

calls have persisted for the JD-R Theory to guide the development, implementation and evaluation of applied intervention research in the workplace; however, to our knowledge, the JD-R Theory has yet to be applied in the context of wildland firefighting (Schaufeli and Taris 2014; Bakker and Demerouti 2017; Schaufeli 2017).

Purpose

Given interventions designed to promote health and well-being in addition to reducing the risk of injury are needed within wildland firefighting, the aim of this study was to utilise a cluster randomised control trial to evaluate two resource-building human dimension intervention programs, delivered independently in two separate experimental conditions, simultaneously and compared with a control group. Based off the established relationships between constructs within the JD-R Theory, the interconnectedness between the physical and psychological demands of wildland firefighting, and knowledge of declining physical and psychological states of WFFs across a fire season, the following are hypothesised with regard to the primary outcomes (e.g. job demands and resources, personal resources) of the two intervention programs:

Hypothesis 1 (H1): WFFs who participated in any intervention program will maintain (i) levels of psychosocial risk; (ii) physical fitness; and (iii) psychological capital across a wildland fire season as compared with those who did not.

With regard to secondary outcomes, including work engagement, job stress and incidence of injury across a wildland fire season, the following is hypothesised:

Hypothesis 2 (H2): WFFs participating in any intervention program will demonstrate (i) significant increases in work engagement; (ii) significantly lower job stress over the course of the fire season as compared with WFFs in a control group; and (iii) significantly lower incidence rate of reported injuries over the course of the fire season as compared with those in a control group, and compared with the preceding 5-year average within the organisation.

Methods

Study design and procedure

The current study utilised a cluster randomised control trial design to evaluate the impact of two interventions before (T1) and after (T2) program delivery as: standalone programs; in combination; and compared with a control group. Random assignment of experimental condition was completed by location within the two geographic regions of the province. This procedure was followed to avoid contamination effects, as WFFs work in close proximity to each other within each location. This study was approved by both Laurentian University's Research Ethics Board (Sudbury, Ontario, Canada) and Lancaster University's Faculty of Health and Medicine Research Ethics Committee (Lancaster, UK).

Selection of locations and randomisation

Selection of participating locations began in the spring immediately preceding the fire season under study. Each of the locations within the two regions of the province was entered into a random generator (Random.org 2016) as a list and randomly assigned to one of four conditions: (1) Fitness Training (FT) Intervention; (2) Psychosocial Education (PE) Intervention; (3) Both (FT/PE) Interventions; or (4) Control Group. This was repeated for both regions to ensure that there would be representation from both geographic regions across all experimental conditions. Additional detail surrounding the selection and randomisation procedures is reported in greater detail elsewhere (Leduc 2020; Leduc *et al.* 2021).

Recruitment of participants

All individuals 18 years of age or older and employed as full-time seasonal wildland firefighters at each of the eight participating locations were eligible to take part in the research. Participants were recruited at their respective location within the first month of the 2016 wildland fire season in late April to early May. Subsequent to informed consent, participants were required to complete the Physical Activity Readiness Questionnaire (PAR-Q) as a screening tool to determine their ability to engage in physical fitness testing. Following clearance, participants completed all pre-intervention baseline measures (T1). Participants at locations assigned to intervention conditions also took part in the corresponding introduction to the program on that same day. Interventions were then delivered over the course of the wildland fire season, a minimum of 13 weeks. As the wildland fire season within the organisation begins to draw to a conclusion from September through to October, the post-intervention follow-up measures occurred between 14 and 16 weeks after baseline testing and a minimum of 1 week after completion of the delivery of the intervention programs (T2) or in late August 2016.

Measures

Assessment of intervention effectiveness was completed via assessments of primary outcome and secondary outcome measures, and selected based on: (1) alignment with JD-R Theory components (see Fig. 1); (2) the availability of equipment, space, time and resources for testing; and (3) the reality of conducting research during a wildland fire season, wherein the participants could have been interrupted at any moment to respond to a fire and were not to be placed in a compromised position, physically or psychologically. This precluded engagement in any maximal level of aerobic or extensive muscular endurance testing. Additional details surrounding the selection process of both primary and secondary outcomes measures are outlined in greater detail in Leduc *et al.* (2021).

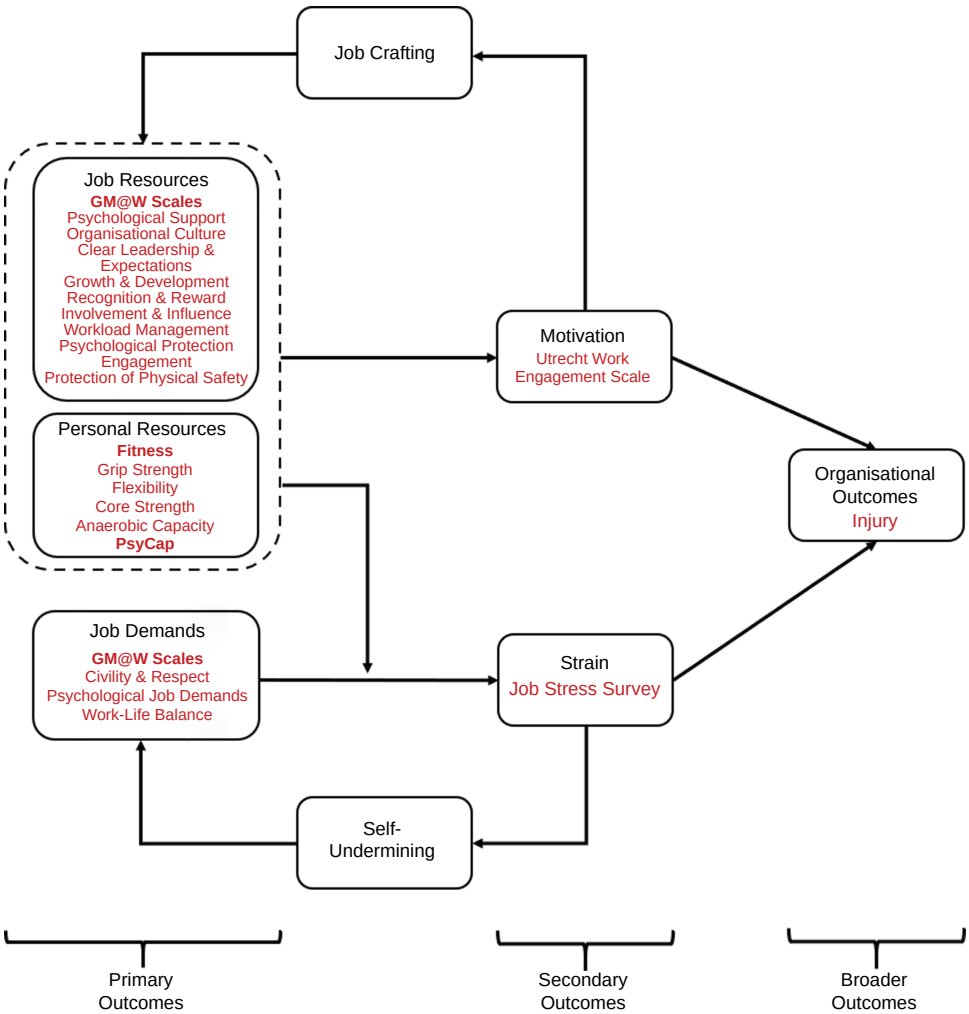

Fig. 1. Primary and secondary measures mapped onto the JD-R Theory.

Measures of primary outcomes

Psychosocial risk factors. Three psychosocial risk factors classified as job demands and 10 psychosocial risk factors classified as job resources were measured using the Guarding Minds at Work (GM@W) survey to evaluate psychosocial factors in the workplace (Samra *et al.* 2012*a*). The three job demands factors were civility and respect, psychological job demands and work–life balance. Job resources were assessed through 10 risk factor scores, including: organisational culture, psychological support, clear leadership and expectations, growth and development, recognition and reward, involvement and influence, workload management, psychological protection, engagement and protection of physical safety (Samra *et al.* 2012*a*).

Physical fitness. Physical fitness measures were selected in an effort to complement existing knowledge and testing procedures within the partnering organisation. Given all participants would have successfully completed the WFX-FIT test, a solid aerobic baseline fitness level was assumed. As a result, an emphasis was placed on identifying complementary measures of global physical fitness.

- **Anthropometrics.** Participant height was measured using a Seca 213 portable stadiometer. Weight was measured using a digital scale. Body Mass Index (BMI) was subsequently calculated.
- **Grip strength.** Grip strength is a measure of hand and forearm strength, evaluating the total force applied during a maximal isometric contraction (Klavora 2015). Maximum grip strength was measured for both dominant and non-dominant hands using a Smedley digital grip tester and following standardised procedures (Roberts *et al.* 2011).
- **Flexibility.** Flexibility was assessed using the sit and reach test, evaluating the flexibility of the hamstring muscles and, indirectly, the lower back (Wells and Dillon 1952; ACSM 2021). Using a Baseline 12-1085 Sit and Reach Trunk Flexibility Box, participants followed standard protocol and scores were recorded to the nearest half centimetre.

- **Core strength.** Core strength was evaluated using the Core Muscle Strength and Stability Test, which is designed and commonly used to evaluate abdominal and lower back muscle strength and stability (Mackenzie 2002; Quinn 2019). The test guided participants through a maximum of nine stages of varying lengths and plank positions. Participants continued through the stages until they were unable to hold the position with the correct form, and both the time and end stage were recorded.
- **Anaerobic capacity.** Anaerobic capacity refers to the ability of an individual to meet significant short-term demands for high-energy production without oxygen and is reflective of their immediate alactic and short-term lactic energy systems (Klavora 2015). Anaerobic performance was evaluated using the Running-based Anaerobic Sprint Test (RAST), a test developed at the University of Wolverhampton (Draper and Whyte 1997) that has demonstrated test validity and reliability (Zagatto *et al.* 2009; Bongers *et al.* 2015). The RAST requires each participant to undertake six consecutive 35-m sprints on a flat surface with 10 s allotted for recovery between each sprint. Each sprint time was measured using the Brower Timing TC System to the nearest hundredth of a second. Subsequently, the following output variables were calculated for each participant: power output (body mass × distance^2/time^3) for each sprint, allowing identification of maximum, minimum and average power outputs (in watts), a Fatigue Index (FI) representing the decline in power output every second (FI = [maximum power − minimum power]/total time for six sprints), and a relative peak power output (maximum power/body weight, in watts produced per kilogram).

Psychological capital. Participants completed the 24-item Psychological Capital Questionnaire (PsyCap) developed by Luthans *et al.* (2007). Psychological capital is characterised by four main characteristics and subscale scores: hope, self-efficacy, resilience and optimism (Luthans *et al.* 2007).

Measures of secondary outcomes

Work engagement. The Utrecht Work Engagement Scale is a 17-item questionnaire to measure work engagement that prompts participants to respond on a seven-point Likert scale to a series of statements about how they feel at work (Schaufeli and Bakker 2003).

Strain. Job stress was evaluated as a part of the post-season questionnaires via the Job Stress Survey (JSS) (Spielberger and Vagg 1994). The JSS is a 30-item questionnaire assessing the perceived severity and frequency of events experienced as stressful within the workplace. The JSS prompts participants to consider the 6 months prior to survey completion and, as such, for the current research it was only appropriate for it to be administered once at the end of the fire season (T2).

Incidence of injury. Wildland firefighters are required to log all incidents requiring any form of first aid or medical attention at the time of occurrence. All participants consented to provide access to year-end injury reports, which would indicate whether they had, over the course of the fire season, completed a first aid injury report or suffered a lost-time injury. This approach was used in an effort to reduce recall bias. In order to facilitate a comparison between the incidence rate of reported injuries observed in the current study with that of previous fire seasons', the organisation provided all injury statistics from all WFFs within their organisation for the 5-year period (2011–2015) immediately preceding the study period.

Intervention programs

Both intervention programs were designed to maintain personal resources, mitigate job demands, foster work engagement and psychological capital, and decrease job stress and incidence of injury. The development of both intervention programs and a description of their content are documented elsewhere (Leduc *et al.* 2021).

Fitness Training (FT) intervention program

The FT intervention program contained five elements: (1) an educational workshop; (2) a formalised training schedule; (3) a training log system; (4) access to a wearable fitness tracker; and (5) provision of personalised fitness test results feedback. Each of the components was designed to align strategically with the organisation's existing 'Commit to be Fit' program to address its limitations: a lack of structure, provide tailored feedback, offer in-season training support and evaluate participation.

Psychosocial Education (PE) intervention program

The PE intervention program was designed to educate WFFs about the influence of psychosocial risk factors, including job demands and resources, on their physical and psychological wellbeing. The PE intervention had two primary components: (1) a 45-min workshop providing an overview of psychosocial risk factors in general, and describing 13 factors in greater detail and as they relate to the context of wildland firefighting and the organisation at large; and (2) the provision of a one-page fact sheet on each of the 13 factors, delivered weekly to participants throughout the fire season (Samra *et al.* 2012*b*).

Statistical analyses

Several sample-size calculations and power analyses were conducted using G*Power 3.1.9.2 for Mac (Faul *et al.* 2007, 2009) using an average effect size of 0.4–0.5 and based on a significance level of $\alpha = 0.05$ and a desired power of $\beta = 0.80$

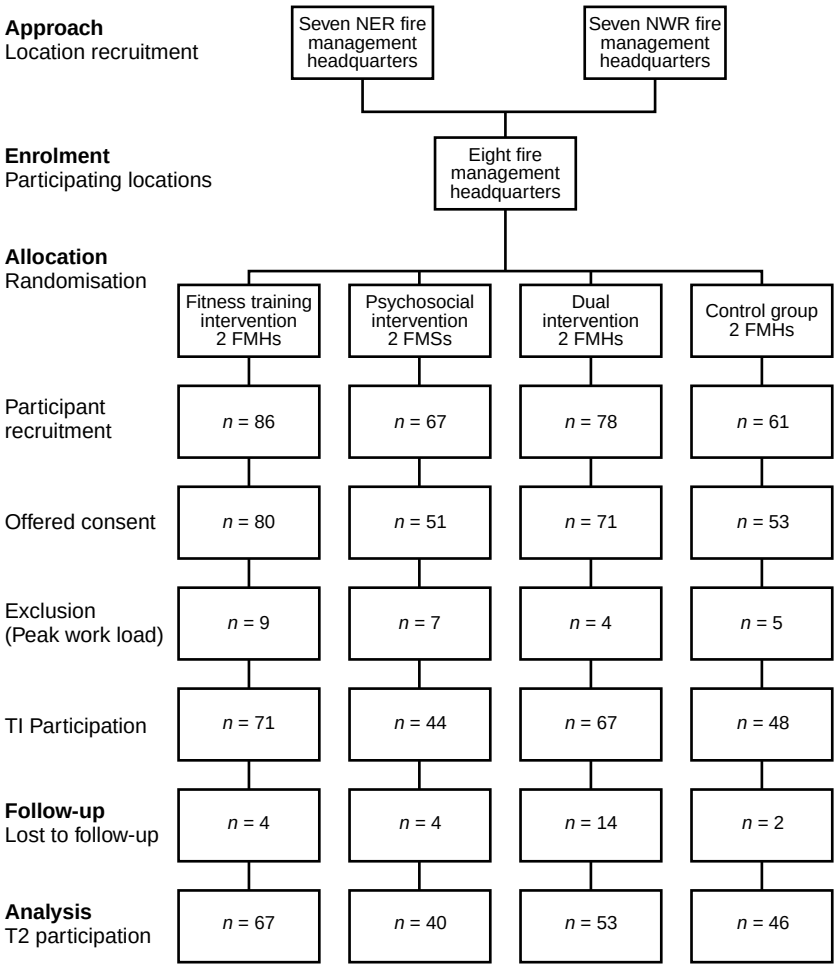

Fig. 2. CONSORT flow diagram detailing study participation.

as observed in previous wildland firefighter research (Budd *et al.* 1997; Vincent *et al.* 2015). It was determined that 51 participants per experimental condition would be required, or approximately 25 for each of the eight participating locations for a total sample size of 200 (Leduc 2020).

A single score was calculated taking the difference between the baseline (T1) and follow-up (T2) measurement points for all variables to represent the change in each measure across the wildland fire season for all participants. Statistically, this approach has demonstrated efficacy and a close relationship to traditional average-based change statistics (Estrada *et al.* 2019, 2020). The single score representing deviation from baseline measurements accounts for the fairly high starting point on many of the baseline measures and reflects the change that occurs on each of these measures across the fire season. Assessing differences between experimental conditions for the primary (e.g. resources and demands) and secondary (e.g. work engagement, strain) outcomes was completed using a two-way multivariate analysis of variance (MANOVA) to test Hypotheses 1 through 2ii. As participants were allocated to experimental condition by location and region, multilevel modelling was used to compare differences in experimental condition while accounting for the variability and level of correlation between scores at individual bases and regions of the province within each group. Significant models of the combined groupings of dependent variables resulted in the subsequent evaluation of each measure within the category using a linear multilevel model analysis. Finally, with regard to evaluating effectiveness of the intervention on incidence of injury, binomial tests of proportion were used to compare incidence rate of injury across the wildland fire season observed within intervention groups with the organisation's 5-year average rate to test Hypothesis 2iii.

Results

Participation

Following the recruitment sessions at the two regional management group meetings, 8 of the 14 (57.1%) locations agreed to participate in the current research project, four in each region of the province. Each location was at least 100 km from the next closest participating location, with the greatest distance spanning more than 1500 km.

Table 1. Descriptive statistics across T1 and T2 measurement points and by experimental condition.

Characteristic	Total sample		Experimental condition							
			Control		Psychosocial		Fitness		Fitness + psychosocial	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
N	230	206	48	46	44	40	71	67	67	53
Sex										
Female	51 (22.2)	43 (20.9)	8 (16.7)	7 (15.2)	13 (29.5)	10 (25.0)	15 (21.1)	13 (19.4)	15 (22.4)	13 (24.5)
Male	179 (77.8)	163 (79.1)	40 (83.3)	39 (84.8)	31 (70.5)	30 (75.0)	56 (78.9)	54 (80.6)	52 (77.6)	40 (75.5)
Age (years)										
Under 21	4 (1.7)	46 (22.3)	14 (29.2)	14 (30.4)	14 (31.8)	12 (30.0)	10 (14.9)	11 (15.5)	12 (17.9)	10 (18.9)
21–24	77 (33.5)	92 (44.7)	23 (47.9)	22 (47.8)	16 (36.4)	16 (40.0)	27 (40.3)	28 (39.4)	31 (46.3)	27 (50.9)
25 and over	98 (42.6)	66 (32.0)	11 (22.9)	10 (21.7)	14 (31.8)	12 (30.0)	29 (43.3)	31 (43.7)	21 (31.3)	15 (28.3)
Unknown	51 (22.2)	2 (1.0)	–	–	–	–	1 (1.5)	1 (1.4)	3 (4.5)	1 (1.9)
Years of experience										
1	60 (26.1)	55 (26.7)	11 (22.9)	10 (21.7)	17 (38.6)	16 (40.0)	15 (22.4)	18 (25.4)	14 (20.9)	14 (26.4)
2–4	101 (43.9)	90 (43.7)	24 (50.0)	24 (52.2)	18 (40.9)	16 (40.0)	29 (43.3)	30 (42.3)	29 (43.3)	21 (39.6)
5 or more	69 (30.0)	61 (29.6)	13 (27.1)	12 (26.1)	9 (20.5)	8 (20.0)	23 (34.3)	23 (32.4)	24 (35.8)	18 (34.0)
Role on crew										
Crew member	153 (66.5)	137 (66.5)	34 (70.8)	33 (71.7)	30 (68.2)	27 (67.5)	43 (64.2)	46 (64.8)	43 (64.2)	34 (64.2)
Crew boss	41 (17.8)	36 (17.5)	6 (12.5)	5 (10.9)	8 (18.2)	7 (17.5)	15 (22.4)	15 (21.1)	12 (17.9)	9 (17.0)
Crew leader	36 (15.7)	33 (16.0)	8 (16.7)	8 (17.4)	6 (13.6)	6 (15.0)	9 (13.4)	10 (14.1)	12 (17.9)	10 (18.9)

At the outset of the fire season, 292 wildland firefighters attended information sessions about participation across the eight locations. Of the 292 wildland firefighters, 255 (87.3%) consented to participate in baseline testing (T1). See the CONSORT flow diagram detailing the enrolment of locations, their allocation to experimental condition, and subsequent recruitment and retention of participants in Fig. 2.

Demographic variables

Descriptive statistics on participants' demographic information for the complete sample and by intervention condition can be found in Table 1. Reflective of the overall workforce, the sample was predominantly male (n = 179, or 77.8%) (Gordon 2014). The average age of participating WFFs at T1 was 24.0 years (s.d. 5.08), with ages ranging from 18 to 50 years. With respect to experience, 26.1% were first-year WFFs. The average experience in wildland firefighting was 3.9 fire seasons (s.d. 3.30).

Evaluating intervention effectiveness: primary outcomes

Psychosocial risk factors: job demands

A two-way MANOVA with the two intervention programs as independent variables was run with three psychosocial risk factors (civility and respect, psychological job demands, and work–life balance) as dependent variables simultaneously. There was a statistically significant interaction effect between those receiving the FT intervention and the PE intervention on the dependent variables, $F(3,183) = 2.754$, $P = 0.044$, Wilks' $\Lambda = 0.957$; partial $\eta^2 = 0.056$. Further examination of the between-subjects effects revealed no statistically significant interaction effect on any of the three subjective measures individually. The simple main effect for participants receiving the PE intervention and those who did not was statistically significant, $F(3,183) = 3.647$, $P = 0.014$, Wilks' $\Lambda = 0.376$; partial $\eta^2 = 0.043$. As such, multilevel modelling was completed for each of the three subjective measures of job demands over the course of the fire season while controlling for base and region. Statistically significant differences for those receiving the PE intervention compared with those who did not were found for all three measures of subjective job demands, namely civility and respect, psychological job demands and work–life balance (see Table 2).

Psychosocial risk factors: job resources

A two-way MANOVA with the two intervention programs as independent variables was run with 10 psychosocial risk factors (psychological support, organisational culture, leadership and expectations, growth and development, recognition and reward, involvement and influence, workload management, engagement, psychological protection and physical safety) as dependent variables. There was a statistically significant main effect for the PE intervention on the

Table 2. Change in psychosocial risk factors classified as job demands from T1 to T2 by experimental condition: MANOVA results.

Variable			Fitness training intervention					
					Yes		No	
Civility and respect (n = 190)		Overall			−1.03 (2.455)	n = 113	−1.27 (2.573)	n = 77
	Psychosocial education intervention[A]	Yes	−0.58 (2.457)	n = 86	−0.75 (2.244)	n = 51	−0.34 (2.754)	n = 35
		No	−1.58 (2.456)	n = 104	−1.26 (2.611)	n = 62	−2.05 (2.152)	n = 42
Psychological job demands (n = 194)		Overall			−0.89 (1.999)	n = 114	−1.48 (2.397)[B]	n = 80
	Psychosocial education intervention[C]	Yes	−0.61 (2.157)	n = 88	−0.43 (1.972)	n = 51	−0.86 (2.394)	n = 37
		No	−1.56 (2.125)	n = 106	−1.25 (1.959)	n = 63	−2.00 (2.299)	n = 43
Work-Life balance (n = 195)		Overall			−0.50 (2.798)	n = 115	−0.84 (3.021)	n = 80
	Psychosocial education intervention[D]	Yes	−0.11 (2.814)	n = 89	0.21 (2.452)	n = 52	−0.57 (3.236)	n = 37
		No	−1.08 (2.891)	n = 106	−1.08 (2.947)	n = 63	−1.07 (2.840)	n = 43

[A]$z = -2.84$, $P = 0.005$; [B]$z = 1.99$, $P = 0.046$; [C]$z = -3.22$, $P = 0.001$; [D]$z = -2.14$, $P = 0.032$.

grouping of 10 psychosocial risk factors as dependent variables, $F(10,169) = 3.363$, $P = 0.001$, Wilks' $\Lambda = 0.834$; partial $\eta^2 = 0.166$. As such, multilevel modelling was completed for the each of the 10 job resource factors individually while controlling for base and geographic region. The effect of the PE intervention was statistically significant as compared with those who did not receive it for all but one measure of job resources (recognition and reward); mean scores and standard deviations can be found in Table 3. The effect for both FT and PE intervention programs was significant as compared with those who did not receive those programs for one resource score, organisational culture.

Personal resources

Physical fitness. A two-way MANOVA conducted for all six difference measures of physical fitness with the two intervention conditions as independent variables revealed statistical significance for the PE intervention for all measures, $F(6,149) = 2.528$, $P = 0.023$, Wilks' $\Lambda = 0.908$; partial $\eta^2 = 0.092$. Multilevel modelling was completed for each of the change in scores across the fire season of all physical fitness measures to determine which measure influenced the significant result, while controlling for both work location and geographic region. Both age and sex were added to the multilevel modelling evaluations; however, they did not yield any significant effects across all six measures. Table 4 displays the mean and standard deviations for the change in scores from pre- to post-season measures by experimental condition. Only the change in maximum power yielded a significant result, with participants receiving the PE intervention (mean [M] = −28.59, s.d. 72.365) demonstrating a significantly greater decline as compared with those who did not (M = −2.32, s.d. 83.001).

Psychological capital. Two-way MANOVA results considering the change in the four PsyCap measures by the two intervention programs as independent variables yielded a significant interaction effect, $F(4,163) = 2.741$, $P = 0.030$, Wilks' $\Lambda = 0.937$; partial $\eta^2 = 0.063$. Results for each of the four scales can be found in Table 4. Multilevel modelling controlling for base and geographic region revealed a significant effect for participation in the FT intervention on the hope scale (M = 0.22, s.d. 3.531) compared with those who did not (M = −1.16, s.d. 4.832). Participation in the PE intervention approached significance on the hope scale as well.

Evaluation of secondary outcomes

Motivation: work engagement

With regard to testing Hypothesis 2, multilevel modelling controlling for base and geographic location of participants did not reveal a statistically significant effect for participation in either intervention condition on the change in work engagement scores over the course of the fire season.

Job stress

Completion of the Job Stress Survey at T2 allowed the calculation of several composite index and subscale scores, as presented in Table 5. Controlling for base and geographic region, multilevel modelling was conducted for participation in either intervention program for all composite and subscale scores. Participants in the FT intervention (M = 47.37, s.d. 7.633) reported statistically significantly higher scores on the Job Pressure Index as compared with those who did not participate in the FT intervention (M = 45.12, s.d. 7.109). Participants in the PE intervention (M = 48.48, s.d. 8.558) reported statistically significant lower scores on the level of organisational support frequency subscale than those who did not (M = 51.91, s.d. 10.736).

Incidence of injury

Over the course of the wildland fire season, 20 participants reported experiencing a workplace injury. Given an

Table 3. Change in psychosocial risk factors classified as job resources from T1 to T2 by experimental condition: MANOVA results.

Variable					Fitness training intervention			
					Yes		No	
Psychological support ($n = 189$)			Overall		−0.51 (2.190)	$n = 111$	−1.06 (2.684)	$n = 78$
	Psychosocial education intervention[A]	Yes	−0.21 (2.257)	$n = 87$	−0.31 (2.293)	$n = 51$	−0.06 (2.229)	$n = 36$
		No	−1.20 (2.462)	$n = 102$	−0.68 (2.103)	$n = 60$	−1.93 (2.762)	$n = 42$
Organisational culture ($n = 195$)			Overall[C]		−1.30 (2.410)	$n = 115$	−2.00 (2.917)	$n = 80$
	Psychosocial education intervention[B]	Yes	−0.61 (2.299)	$n = 89$	−0.56 (2.071)	$n = 52$	−0.68 (2.615)	$n = 37$
		No	−2.42 (2.643)	$n = 106$	−1.92 (2.510)	$n = 63$	−3.14 (2.696)	$n = 43$
Leadership and expectations ($n = 194$)			Overall		−1.02 (2.551)	$n = 115$	−1.22 (2.702)	$n = 79$
	Psychosocial education intervention[D]	Yes	−0.56 (2.309)	$n = 88$	−0.69 (2.183)	$n = 52$	−0.36 (2.497)	$n = 36$
		No	−1.55 (2.764)	$n = 106$	−1.29 (2.808)	$n = 63$	−1.93 (2.685)	$n = 43$
Growth and development ($n = 195$)			Overall		−0.97 (2.419)	$n = 115$	−0.94 (2.425)	$n = 80$
	Psychosocial education intervention[E]	Yes	−0.48 (2.237)	$n = 89$	−0.60 (2.251)	$n = 52$	−0.32 (2.237)	$n = 37$
		No	−1.36 (2.496)	$n = 106$	−1.29 (2.524)	$n = 63$	−1.47 (2.482)	$n = 43$
Recognition and reward ($n = 193$)			Overall		−0.83 (2.308)	$n = 114$	−1.14 (2.659)	$n = 79$
	Psychosocial education intervention[F]	Yes	−0.61 (2.409)	$n = 88$	−0.61 (2.410)	$n = 52$	−0.61 (2.441)	$n = 36$
		No	−1.25 (2.468)	$n = 105$	−1.02 (2.221)	$n = 62$	−1.58 (2.779)	$n = 43$
Involvement and influence			Overall		−0.95 (2.540)	$n = 115$	−1.28 (2.796)	$n = 79$
	Psychosocial education intervention[G]	Yes	−0.58 (2.472)	$n = 88$	−0.83 (2.455)	$n = 52$	−0.22 (2.486)	$n = 36$
		No	−1.50 (2.723)	$n = 106$	−1.05 (2.624)	$n = 63$	−2.16 (2.760)	$n = 43$
Workload management ($n = 193$)			Overall		−0.96 (2.451)	$n = 114$	−0.73 (2.505)	$n = 79$
	Psychosocial education intervention[H]	Yes	−0.25 (2.268)	$n = 87$	−0.39 (2.173)	$n = 51$	−0.06 (2.414)	$n = 36$
		No	−1.37 (2.524)	$n = 106$	−1.41 (2.582)	$n = 63$	−1.30 (2.464)	$n = 43$
Engagement ($n = 195$)			Overall		−0.92 (1.728)	$n = 115$	−1.05 (1.614)	$n = 80$
	Psychosocial education intervention[I]	Yes	−0.71 (1.597)	$n = 89$	−0.71 (1.730)	$n = 52$	−0.70 (1.412)	$n = 37$
		No	−1.20 (1.721)	$n = 106$	−1.10 (1.720)	$n = 63$	−1.35 (1.730)	$n = 43$
Psychological protection ($n = 193$)			Overall		−0.67 (2.256)	$n = 114$	−1.01 (2.889)	$n = 79$
	Psychosocial education intervention[J]	Yes	−0.01 (1.909)	$n = 88$	0.02 (1.679)	$n = 51$	−0.05 (2.210)	$n = 37$
		No	−1.48 (2.795)	$n = 105$	−1.22 (2.511)	$n = 63$	−1.86 (3.167)	$n = 42$
Physical safety ($n = 195$)			Overall		−0.43 (1.644)	$n = 115$	−0.36 (2.388)	$n = 80$
	Psychosocial education intervention[K]	Yes	−0.01 (1.862)	$n = 89$	−0.33 (1.543)	$n = 52$	0.43 (2.180)	$n = 37$
		No	−0.74 (2.020)	$n = 106$	−0.52 (1.731)	$n = 63$	−1.05 (2.370)	$n = 43$

[A] $z = -2.29$, $P = 0.022$; [B] $z = -1.96$, $P = 0.049$; [C] $z = -5.15$, $P < 0.001$; [D] $z = -2.75$, $P = 0.006$; [E] $z = -2.62$, $P = 0.009$; [F] $z = -1.74$, $P = 0.082$; [G] $z = -2.56$, $P = 0.011$; [H] $z = -3.21$, $P = 0.001$; [I] $z = -2.09$, $P = 0.037$; [J] $z = -4.25$, $P < 0.001$; [K] $z = -4.25$, $P < 0.001$.

average of 121.6 injuries per 760 WFFs across the 5-year period preceding the intervention period, an average proportion of 16.0% was used (Leduc *et al.* 2018). The binomial test of proportion indicated a significant result for the observed incidence rate of 9.9% as lower for participation in any intervention group compared with the 5-year average of 16%. The observed incidence rate for the FT/PE intervention group (1.5%) was also statistically significantly different from the 5-year incidence rate ($P < 0.001$); see Table 6.

Discussion

The current study is the first to comprehensively document the baseline and changes over the course of a wildland fire season of psychosocial risk factors classified as either job resources or job demands, and physical fitness and psychological capital, classified as personal resources. Moreover, evaluations of secondary outcomes also included assessments of intervention impact on work engagement, job stress and incidence of injury.

Table 4. Change in personal resources including physical fitness and psychological capital from T1 to T2 by experimental condition: MANOVA results.

Variable			Fitness training intervention					
					Yes		No	
Total grip strength in kilograms ($n = 196$)		Overall			1.88 (10.217)	$n = 115$	1.25 (7.730)	$n = 81$
	Psychosocial education intervention	Yes	2.34 (8.728)	$n = 90$	3.83 (9.700)	$n = 51$	0.39 (6.964)	$n = 39$
		No	1.01 (9.678)	$n = 106$	0.33 (10.448)	$n = 64$	2.05 (8.384)	$n = 42$
Flexibility in centimetres ($n = 195$)		Overall			1.23 (4.684)	$n = 114$	1.59 (4.393)	$n = 81$
	Psychosocial education intervention	Yes	1.54 (3.986)	$n = 89$	2.24 (4.158)	$n = 50$	0.64 (3.609)	$n = 39$
		No	1.24 (4.428)	$n = 106$	0.44 (4.945)	$n = 64$	2.46 (3.177)	$n = 42$
Core strength in minutes ($n = 189$)		Overall			0.11 (0.556)	$n = 109$	0.13 (0.487)	$n = 80$
	Psychosocial education intervention	Yes	0.15 (0.511)	$n = 84$	0.16 (0.537)	$n = 45$	0.13 (0.487)	$n = 39$
		No	0.10 (0.540)	$n = 105$	0.08 (0.571)	$n = 64$	0.14 (0.493)	$n = 41$
Maximum power in watts ($n = 173$)		Overall			−18.27 (87.643)	$n = 99$	−6.53 (67.351)	$n = 74$
	Psychosocial education intervention[A]	Yes	−28.59 (72.365)	$n = 72$	−34.66 (80.928)	$n = 38$	−21.80 (61.917)	$n = 34$
		No	−2.32 (83.001)	$n = 101$	−8.06 (90.726)	$n = 61$	6.45 (69.791)	$n = 40$
Fatigue index in watts per second ($n = 159$)		Overall			−0.82 (2.475)	$n = 97$	0.33 (2.349)	$n = 62$
	Psychosocial education intervention	Yes	−1.02 (2.593)	$n = 65$	−1.14 (2.381)	$n = 38$	−0.85 (2.905)	$n = 27$
		No	−35 (2.286)	$n = 94$	−0.61 (2.531)	$n = 59$	.08 (1.749)	$n = 35$
Relative peak power output in watts per kilogram ($n = 173$)		Overall			−0.33 (0.959)	$n = 99$	−0.24 (0.878)	$n = 74$
	Psychosocial education intervention	Yes	−0.45 (0.898)	$n = 72$	−0.47 (0.900)	$n = 38$	−0.42 (0.910)	$n = 34$
		No	−0.18 (0.930)	$n = 101$	−0.24 (0.991)	$n = 61$	−0.09 (0.831)	$n = 40$
PsyCap efficacy ($n = 190$)		Overall			0.04 (4.616)	$n = 111$	−0.87 (4.762)	$n = 79$
	Psychosocial education intervention	Yes	0.36 (4.730)	$n = 84$	1.21 (4.736)	$n = 47$	−0.73 (4.556)	$n = 37$
		No	−0.90 (4.598)	$n = 106$	−0.83 (4.363)	$n = 64$	−1.00 (4.988)	$n = 42$
PsyCap resilience ($n = 196$)		Overall			1.02 (3.570)	$n = 114$	0.06 (3.811)	$n = 82$
	Psychosocial education intervention	Yes	0.72 (4.017)	$n = 88$	1.18 (3.657)	$n = 50$	0.11 (4.422)	$n = 38$
		No	0.54 (3.424)	$n = 108$	0.89 (3.524)	$n = 64$	0.02 (3.246)	$n = 44$
PsyCap hope ($n = 196$)		Overall			0.22 (3.531)	$n = 116$	−1.16 (4.832)	$n = 80$
	Psychosocial education intervention[B]	Yes	0.26 (4.030)	$n = 88$	0.75 (3.515)	$n = 51$	−0.41 (4.616)	$n = 37$
		No	−0.84 (4.210)	$n = 108$	−0.20 (3.514)	$n = 65$	−1.81 (4.973)	$n = 43$
PsyCap optimism ($n = 188$)		Overall			−2.14 (4.257)	$n = 111$	−1.95 (3.947)	$n = 77$
	Psychosocial education intervention	Yes	−1.69 (4.072)	$n = 83$	−1.04 (4.015)	$n = 49$	−2.62 (4.030)	$n = 34$
		No	−2.35 (4.158)	$n = 105$	−3.00 (4.273)	$n = 62$	−1.42 (3.844)	$n = 43$

[A] $z = 2.26$, $P = 0.024$; [B] $z = -2.37$, $P = 0.018$.

The results of the cluster randomised control trial indicate support for the PE intervention program, as the change in scores on 12 of the 13 measured psychosocial risk factors over the course of a wildland fire season was better than for those who did not participate in the program. Limited evidence was found for the effectiveness of the FT intervention program for improving or maintaining aspects of physical fitness, psychosocial risk or psychological capital as compared with wildland firefighters who were not assigned to the program. Importantly, fewer injuries were observed for participants assigned to any intervention condition as compared with the average incidence rate over the 5-year period preceding the study.

Primary outcomes

Psychosocial risk factors

For participating WFFs, assessments of psychosocial risk associated with all three measures of job demands increased

Table 5. Job stress survey results at T2 by experimental condition.

Job stress survey scale	Total sample			Intervention condition											
				Control			Psychosocial			Fitness			Fitness + psychosocial		
	n	*M*	s.d.	*n*	*M*	s.d.	*n*	*M*	s.d.	*n*	*M*	s.d.	*n*	*M*	s.d.
Job stress index	202	47.04	7.843	45	46.96	7.946	38	46.08	7.441	65	48.14	8.006	54	46.48	7.895
Job stress severity	207	43.27	9.416	46	41.35	8.784	40	43.30	9.332	67	43.52	9.473	54	44.57	9.910
Job stress frequency	204	51.27	8.908	45	52.51	10.257	38	49.18	8.696	65	52.77	8.448	56	49.95	8.132
Job pressure index[A]	203	46.44	7.486	45	44.51	5.911	39	45.82	8.306	65	47.75	7.327	54	46.91	8.031
Job pressure severity	207	43.63	9.653	46	40.80	8.783	40	43.73	9.745	67	43.85	9.251	54	45.70	10.432
Job pressure frequency	205	50.01	8.070	45	49.04	8.276	39	48.41	8.729	65	52.00	7.435	56	49.59	7.897
Level of organisational support index	202	48.04	8.523	45	49.93	9.804	39	46.67	7.965	64	48.33	8.549	54	47.11	7.610
Level of organisational support severity	207	44.69	9.557	46	44.57	9.333	40	44.15	9.929	67	44.75	9.836	54	45.13	9.361
Level of organisational support frequency[B]	205	50.32	9.913	45	53.40	11.458	39	48.31	9.526	65	50.88	10.168	56	48.61	7.901

[A]Fitness Training Intervention: $z = -2.07$, $P = 0.039$.
[B]Psychosocial Education Intervention: $z = 1.90$, $P = 0.057$.

Table 6. Frequency of reported injuries by experimental condition across a wildland firefighting season.

Experimental condition	Injury reported during fire season (%)		Total
	No	Yes	
Control	46 (95.8)	2 (4.2)	48
Psychosocial	38 (86.4)	6 (13.6)	44
Fitness	60 (84.5)	11 (15.5)	71
Fitness + psychosocial[A]	66 (98.5)	1 (1.5)	67
Total, any intervention group[B]	164 (90.1)	18 (9.9)	182

[A]$P = 0.0002$ (two-sided test) as compared with 5-year organisation-wide incidence rate of 16%.
[B]$P = 0.0255$ (two-sided test) as compared with 5-year organisation-wide incidence rate of 16%.

over the course of the wildland fire season. This is evidenced by the negative scores across all experimental groups representing a decline in scores from T1 to T2; however, there were differences in the scores between them. There was a significant interaction effect between both intervention programs as compared with the control group on the combination of all three measures of job demands and all 10 measures of job resources. A further examination revealed that the simple main effect for participants in the PE intervention was also significant, and subsequent multilevel modelling revealed that the significant difference held when considering each of the three measures of job demands independently. Therefore, the change in civility and respect, psychological job demands and work–life balance was significantly less for those participating in the PE intervention program as compared with those who did not. Likewise, the change in scores across 9 of 10 job resource scores was significantly less for participants receiving the PE intervention as compared with those who did not. The effect was significant for both FT and PE intervention programs on one job resource score: organisational culture, with the greatest discrepancy across scores between those receiving both intervention programs as compared with those in the control group.

Taking the aforementioned outcomes together and considering the intervention effectiveness across both job demands and resources, participants receiving the PE intervention revealed statistically significant differences on 12 of 13 psychosocial risk factor scores across the wildland fire season. The PE intervention program contained two components: an educational workshop at the outset of the fire season and the weekly provision of a fact sheet throughout the season on each of 13 psychosocial risk factors classified either as a job demand or resource. As a result, the evidence for the effectiveness of the PE intervention is strong for the mitigation of the psychosocial risk factors across the wildland fire season. The findings are in line with another resource-building intervention conducted with firefighters

targeting psychological health through education sessions where particular increases in job resources including social support were observed (Ângelo and Chambel 2013).

One strength of the PE intervention was the process through which the content of the educational material took into account the demands and resources experienced by the participating WFFs across a wildland fire season and integrated them with the measurement tool for assessing psychosocial risk, GM@W (Leduc *et al.* 2021). Guided by the suite of GM@W resources, the current research project was able to leverage the structure and information of the program to the context of wildland fire through a collaborative process between the research team, management and staff within the partnering organisation. Through this process, an emphasis was placed on the format in which the material was delivered and received. Tailoring of the material with examples and visual aids from the field enhanced the relevance and facilitated the applicability of the topics to the working life of the participating WFFs. Moreover, having considered the high-demand occupation group, the provision of the material in small portions staggered across the wildland fire season allowed workers to pick up material to suit their own availability (e.g. via email, or posted around their work location). This consideration has also been substantiated in other intervention research conducted in high-demand hospital contexts (Estabrook *et al.* 2012).

A second consideration for the effectiveness of the PE intervention is the unique blend of group and individual delivery methods. The initial workshop was delivered in a group setting, which previous research has established as having a positive effect on improving desirable work outcomes (Knight *et al.* 2017; Donaldson *et al.* 2019). An explanation of the mechanism at play with regard to the group setting delivery relates particularly to fostering positive interactions between colleagues and the development of social support (Knight *et al.* 2017). Subsequently, the PE intervention material was delivered individually via email, a modality that has also proved particularly successful at decreasing undesirable work outcomes (Donaldson *et al.* 2019). As such, it is posited that delivering the material by group setting initially and reinforcing it individually throughout the intervention period was one of the keys to the PE intervention program demonstrating effectiveness measures of job demands and resources. Indeed, many other resource-building intervention programs scaffold opportunity for individual application and coaching following an initial group delivery or workshop (Ângelo and Chambel 2013; Biggs *et al.* 2014; van Wingerden *et al.* 2016).

Physical fitness

When considering all six measures of physical fitness simultaneously, there was a statistically significant effect for participation in the PE intervention group as compared with no participation. Subsequent multilevel modelling revealed a significant effect for only one measure of physical fitness: maximum power. Participants receiving both PE and FT interventions demonstrated the greatest decline in maximum power, whereas those in the control group increased their power across the wildland fire season.

Psychological capital

Across all participants, assessments of psychological capital across the wildland fire season remained relatively constant, with slight declines overall on levels of optimism, hope and efficacy and a slight increase on the hope scale. A significant interaction effect between experimental conditions on all four measures of PsyCap indicated that participation in any intervention program had an effect on the change in scores across the wildland fire season. Subsequent multilevel modelling revealed a significant effect for participation in the FT intervention on the hope scale, while participation in the PE intervention approached significance. The greatest difference within the four experimental groups on the hope scale lies between the group receiving both intervention programs, which increased their score from T1 to T2, and the control group, which saw the greatest decline. These findings are in line with other resource-building intervention programs, which were able to demonstrate increases in PsyCap over a 4-week intervention period through the utilisation of exercises to support personal resource development (van Wingerden *et al.* 2016).

Taken together, the results with respect to personal resources are not consistent: participation in either intervention program had a negative impact on maximum power produced whereas participation in fitness training program had a positive impact on psychological capital's hope scale. The contextual influences that may have impacted the lack of desired measurable effects of the FT intervention require further exploration.

Secondary outcomes

Work engagement and job stress

Multilevel modelling did not reveal a statistically significant effect on work engagement across experimental groups. Further, there was no statistically significant effect for the overall score; however, there were two differences that emerged when considering the subscales. First, participants in the FT intervention reported significantly higher levels of stress associated with the job itself (Job Pressure Index). Although statistically significant, the scores for the Job Pressure Index for those participating in the FT intervention program still fall well within the moderate range of normative data and do not present an excessive risk. Second, participants receiving the PE intervention reported lower scores on the stress emerging from the organisational support frequency subscale as compared with those who did not. It is worth noting that the scores across all scales of the JSS were in line with previously measured cross-sectional

studies with WFFs in the same jurisdiction (Gordon and Larivière 2014; McGillis *et al.* 2017).

Incidence of injury

WFFs participating in any intervention program experienced a lower reported incidence of injury across the wildland fire season (9.9%) as compared with the yearly average within the organisation over the 5 years previous to the study period (16.0%). More specifically, the reported injury incidence rates of WFFs receiving both intervention programs (1.5%) demonstrated the greatest difference from the 5-year average.

Although the examination of effectiveness across primary and secondary outcomes provides an evaluation of the overall impact of two intervention programs, it does little to provide insight into the contextual and procedural influences. Owing to the unpredictable nature of a wildland fire season, consideration must be given to the associated contextual factors that may have influenced intervention delivery and effectiveness. Moreover, there remains an opportunity to consider the influence of personal and contextual characteristics (e.g. who was reached and adopted the intervention programs) and aspects of the implementation process. The current project is unique in its extension of previous literature on WFFs to assess the change in characteristics across a wildland fire season as opposed to cross-sectional research with a single measurement point in time, often mid or post season (Sell and Livingston 2012; Gordon and Larivière 2014). An exploration of the contextual demands of a particular fire season and monitoring hours of work over the season could add to our understanding of the dynamic changes that occur to subjective evaluations of job demands and resources, personal resources, work engagement and job stress across a wildland fire season.

Study strengths and limitations

First, using a cluster-randomised control trial methodology, the current study possessed the methodological rigour to evaluate the effectiveness of two intervention programs on primary, secondary and organisational outcomes. Second, the study benefited from its participatory approach (Leduc *et al.* 2021). As input was sought from members across all levels of the organisation, the research received meaningful organisational support from both senior and local levels of management and was advocated for within the WFFs' population. A testament to this is the nearly 90% participation and adoption rate of participants across measurements points in the wildland fire season, nearly double the response and retention rates of intervention research conducted with high demand or emergency response occupation groups (Tuckey *et al.* 2012; Biggs *et al.* 2014). The positive response rate, influenced by the participatory efforts ahead of the intervention period to allow for input from WFFs, staff and management also facilitated hitting the desired target sample size, an aspect of intervention rarely reported. (Nielsen and Randall 2012; van Wingerden *et al.* 2017). Further, support mechanisms for participants across the intervention period were engaged, leveraging advances in technology, by also providing intervention material (content and feedback) via email in addition to in-person within their workplace as recommended by van den Heuvel *et al.* (2015).

Further, the current study provides evidence for the flexibility of the JD-R Theory to adapt to and be applied in novel and dynamic workplace settings and support the development of intervention programs. Indeed, this project represents the first application of the JD-R Theory as the basis for intervention program development in wildland firefighting. Several aspects of the JD-R Theory contributed in this regard. For example, the current project took an expanded view of personal resources to include both physical and psychological capacities as they related to the context of wildland firefighting. The JD-R Theory's ability to comprehensively classify work characteristics, psychosocial factors and desired outcomes into its individual components and corresponding processes facilitates dialogue between researchers and members of partnering organisations in a way that is easily understood. Moreover, the current research also highlights that it is possible to target interventions with specific constructs within the JD-R Theory (e.g. personal resources), and achieve desired outcomes while operating within highly dynamic and heavily context-driven workplaces. Future research should be well positioned to explore the mechanisms of action in this regard, supplementing the current work by including additional measures of job crafting or self-undermining and allowing more complete testing of the JD-R Theory as a whole.

Several limitations require mentioning. The first relates primarily to the measures utilised across the study. Although objective measures were used where feasible (e.g. objective job demands, anthropometric data), the current methodological approach employed a number of self-report measures pertaining to certain constructs (e.g. job stress and incidence of injury) where more invasive, physiological or direct observation measurements were not practical. As a result, the reliance on self-report measures can yield common method biases (Podsakoff *et al.* 2012). Moreover, although the FT intervention sought to maintain all aspects of physical fitness required to perform core wildland firefighting tasks, the assessments of fitness in the current study were not comprehensive (e.g. no measurement of aerobic fitness). Indeed, the measures selected were governed largely by the practicalities of recruiting participants in season without compromising their ability to return immediately to their duties as WFFs.

Second, the cluster-randomised control trial design and subsequent analyses are not without their shortcomings. Random assignment of participants to experimental conditions was completed at the work-location level as opposed to the individual level in an effort to avoid contamination effects. Had the allocation been completed at the individual level, ensuring the integrity of a control group without

knowledge or influence of the intervention programs under evaluation would not have been possible given the high level of interconnectedness of staff in a given work location (e.g. one shared fitness facility for training as in the FT intervention, or one shared common room for displaying posters as in the PE intervention). However, although we were successful in selecting eight locations from two geographic regions of the province to match one location from each region to each experimental condition, the possibility remains that the differences in city or town characteristics may have also influenced any differences or predispositions among participants at the outset of the study. Indeed the potential for disparate groups at T1 or across the length of the study is acknowledged (Lipsey and Cordray 2000); however, given the potential for extraneous factors to influence groups in the unpredictable occupational context of wildland firefighting and conducting applied organisational intervention research, the choice is justified (Adkins and Weiss 2003).

Finally, the current study was limited by the time constraints of a wildland fire season, which runs annually from April to October in Ontario, Canada, with the majority of WFFs employed from April through September annually. In order to allow a 2-week window for participants to complete baseline and post-intervention measurements, the opportunity for intervention implementation lasted 13 weeks. As a result of this practical restriction based on the seasonality of wildland firefighting, there was limited opportunity to measure the lasting influence of the intervention programs. Indeed, it is indeterminable whether the effects observed would be enduring or short-lived and whether participants returning the following fire season would continue to benefit from their participation in the intervention programs. Future studies could take this into account in an effort to determine the viability of the program at influencing retention, and whether a cumulative benefit exists for improving fitness and psychosocial climate across fire seasons or whether the programs are investments that need to be made annually to positively impact outcomes during each fire season.

Conclusion

In summary, participation in the PE intervention program demonstrated a statistically significant difference in the change in scores on 12 of 13 psychosocial risk factors across a wildland fire season as compared with those in the FT program alone or those in a control group receiving no intervention. Furthermore, there was limited evidence for the effectiveness of the FT intervention program as compared with not receiving it on aspects of psychosocial risk, physical fitness or psychological capital. However, consideration of effectiveness outcomes alone does not provide adequate context and understanding of the impact of the interventions (Nielsen and Miraglia 2017). As a result, a detailed examination of additional process aspects of the intervention program is required to further contextualise effectiveness findings and consolidate learning for both intervention research and the organisation at large (Leduc 2020). Participation in any intervention program resulted in fewer observed injuries as compared with the average incidence rate over the 5-year period preceding the current study. This first application of the JD-R Theory within wildland firefighting to document characteristics of the occupation, measure change over time and attempt to mitigate impact through applied participatory action intervention research serves as a positive foundation and example for subsequent research across this high-demand occupation group.

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Data availability. Data that support the findings of this study are available from the corresponding author, CL, on reasonable request. Owing to the nature of this research, participants of this study did not agree for their raw data to be shared to be shared publicly.

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