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RESEARCH ARTICLE
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Assessment of Performance between Different Wildland Firefighter Crews for a Modified Pack Hike Test

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Abstract:

Introduction: Fitness levels for wildland firefighters are assessed based on the Pack Hike Test (PHT), a submaximal work capacity test. There are three different levels of hand crew members who are exposed to different working conditions, and previous literature has suggested that the current test may not accurately reflect the occupational abilities of the different crew levels.

Purpose: The purpose of this study was to test the feasibility of an altered PHT in order to maximize the effort level as a means of illustrating differences between crew tiers. This was performed with the goal of creating an improved assessment to determine which individuals had the fitness capacity to perform the job tasks for a given crew type.

Methods: According to professional standards, the wildland firefighters into two hand crew categories: Type 1 (T1C; *n=12*) and Type 2 (T2C; *n=7*, Type 2 and Type 2IA were grouped together). All participants performed one pack hike test simulated to elicit maximal effort in realistic working conditions. The test covered 1.3 miles of hiking at a 16.5% grade while carrying a 20 kg load carriage system, designed to simulate the potential weight load that would be carried during normal working conditions. Participants performed a 1-minute lying-supine recovery period following immediately following completion of the test. All participants were fitted with Polar H10 monitors in order to collect the performance variables: Pace (min/mile), HR recovery (bpm), HR average (bpm) and HR max (bpm).

Results: No statistically significant differences were shown for any performance variables (p>.05). There were mean differences that approached significance. Increased Pace (-2.07 min/mile, Cohen's d = -0.633) and HR recovery (+3.00 bpm, Cohen's d = 0.043) were evident for T1C. Additionally, T1C showed increased HR average (+8.18%, Cohen's d = 0.718) and HR maximum (+8.51%, Cohen's d = 0.861) compared to those of T2C.

Discussion: While not statistically significant, T1C tended to display an increased duration of mean maximal work rates as evidenced by HRmax and HRave levels coupled with improved pace, potentially suggesting the ability to operate at higher fitness levels compared to T2C. While the differences are not statistically significant, the small differences could prove beneficial in the rugged working conditions where every second counts.

Conclusion: No statistically significant differences were present between the two crew types. However, there is evidence to support minor increases in fitness levels among more elite levels.

Keywords: Wildland firefighter, Occupational fitness, Pack hike test, Crew members, Hand crew member.

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1. INTRODUCTION

Interagency Hotshot Crews are classified broadly as a hand crew. Hand crews (HCM), unlike engine or helitack crews, must hike up rugged mountainside terrain to reach their assignment areas and only operate with equipment they can carry such as hand tools, chainsaws and drip torches [1]. These crews consist of 18-20 members and can be classified within three categories: 1, 2IA and 2. Type 1 crews are assumed to possess the highest levels of performance amongst all crews in terms of physical capacities and job-related skills [2]. Although the responsibilities of type 1 crews are similar to type 2IA and type 2, these members are required to perform in the most physically demanding circumstances [2, 3]. These crews can be described as "the elite" of all Wildland Firefighters (WLFF) and this distinction between the types of crews lies in IHC's physical capabilities relating to their fitness levels, self-reliance and expertise that are needed to fight fires more aggressively in the arduous terrain of the West [2, 3]. The Forest Service currently obtains no means of quantifying the physical differences between crews within their pre-season testing parameters. This leaves captains and superintendents with the responsibility to subjectively determine which individuals possess the requisite physical capabilities to safely perform the workloads associated with a given crew type.

The current fitness standard that all WLFF must adhere to is known as the Pack Hike Test (PHT). The PHT is the standardized fitness assessment protocol to determine adequate fitness for all wildland firefighters to perform occupational tasks. It entails a 3-mile hike over flat terrain (often conducted on a track surface) while carrying a 20kg pack. The test must be completed in under 45 minutes to be considered a pass. The PHT was originally administered to wildland firefighters to assess occupational performance through aerobic fitness. The Forest Service initially hypothesized that HCM should be able to exert themselves at 50% of their VO_2max to sustain daily operations; therefore, the PHT was designed to elicit a similar demand and assess individuals' ability to endure this work rate for moderate durations defined as 45 minutes [4]. Individuals who could endure this were deemed occupationally capable of performing the job base [5]. Although this test does account for minimum aerobic fitness, it lacks the ability to discern whether individuals, such as type 1 HCM, obtain the fitness levels required to safely perform job-related tasks at higher workloads in more difficult circumstances compared to type 2 HCM [6]. Sol and colleagues collected field data during the fire seasons between 2013 and 2015 and reported that type 1 crews, compared to type 2, carried significantly greater loads during shifts as well as training [6]. There is substantial data to support the understanding that increased load carriage results in a proportional increase in metabolic and physiological demand [7-9]. Although previous work has pointed to the unique demands placed upon type 1 crews, and there is a unanimous theoretical distinction between the fitness expectations seen between type 1 and type 2 crews, there are currently no means of quantifying these differences based on the current protocols of the PHT [4, 6, 10]. This could potentially lead to the recruitment of HCM members being placed with the wrong type of crew.

1.1. Problem Statement

The current PHT is a baseline work capacity test that does not account for the daily physical demands placed on hand crews, especially type 1, who often work in terrain with elevation changes. Therefore, the aim of this study was to assess whether a modified PHT (a more arduous and situational-specific (presence of inclined terrain) work capacity test) should be utilized to determine occupational fitness amongst hand crews.

1.2. Research Hypothesis

It was hypothesized that there would be larger differences in performance test outcomes amongst type 1 and type 2 hand crews when looking at the modified PHT. In regards to these performance differences, the following outcomes were assumed: type 1 crew would achieve faster completion time (as indicated by faster pace) scores, increased heart rate max (HRmax) and average (HRave) values, and larger heart rate recovery (HRrec) values than type 2 crew during the modified PHT, thus indicating increased fitness levels of the T1C.

2. MATERIALS AND METHODS

2.1. Experimental Approach to the Problem

This study utilized a cross-sectional design to compare performance outcome measures amongst two classes of hand crews (type 1 and type 2). All participants engaged in one maximal effort test: one modified PHT (mPHT) that was performed on incline terrain and required the carrying of 20 kg packs. The comparisons between crew types allowed the determination of performance differences or indifferences between the hand crew members.

2.2. Participants

This population that completed the experiment consists of type 1 and type 2 HCM. Nineteen participants (one female in T1C, all the rest were males) from the California hand crews employed by the U.S. Forest Service agreed to participate in the experimental protocol and descriptive statistics such as crew type, age (years), height (meters), weight (kg) and job experience (years) were obtained prior to testing (Table **1**). The number of subjects was obtained based on firefighter availability and the willingness of the captains in the region to have their crews be asked to participate, which did limit the number of participants available. In order to be included in the current study, all hand crew members must have been employed during at least one fire season at their current rank (type 1 or type 2). Participants between the two groups were not matched for any anthropometric characteristics as there was a desire to take an adequate cross-sectional sample of the groups as they existed. Furthermore, participants must have had no history of musculoskeletal injury to the lower

Table 1. Anthropometric data of participant description.

-	Hand Crew Categories					
	Type 1 *(n=12)*			Type 2 *(n=7)*		
	Mean +/- SD	Min	Max	Mean +/- SD	Min	Max
Age (years)	28.1 +/- 5.5	22.0	40.0	21.3 +/- 0.8	20.0	22.0
Height (m)	1.8 +/- 0.1	1.7	1.9	1.8 +/- 0.1	1.7	2.0
Weight (kg)	82.5 +/- 7.4	71.8	96.8	74.9 +/- 5.2	67.3	84.1
Experience (years)	3.95 +/- 4.1	1.0	16.0	1.9 +/- 0.4	1.0	2.0

Note: Type 1 hand crews are considered the "elite" crew working in the most arduous conditions. Type 2 crews perform similar work but in circumstances considered less physically demanding. SD = standard deviation.

extremities or torso that resulted in lost work time during the past fire season. For the current study, musculoskeletal injury can be defined as any injury to the musculoskeletal system, such as muscles, tendons, ligaments and bones; lost work time can be defined as any alteration to tactical activities such as physical training or fire suppression activities [11]. Lastly, at the time of testing, participants must have been free of any condition that could have affected hiking performance with load carriage. Common conditions that might have affected hiking performance included, but were not limited to, acute illnesses such as cold, flu, and COVID-19. Participants were recruited to perform this test at the beginning of their training season as testing could not occur during the fire season due to the potential impact on the working availability of the firefighters (to minimize any impact on job performance due to the emergency nature of the work).

2.3. Procedures

All procedures were approved by the California State University Long Beach Institutional Review Board. Prior to beginning any data collection, all participants signed an informed consent document. Secondly, participants were asked to sign the medical health and history form as well as a physical activity readiness questionnaire. Finally, by using the ACSM preparticipation screening algorithm, all participants were confirmed safe to perform the maximal effort exercise test [12].

2.3.1. Experimental Design

All participants who met inclusion criteria were asked to refrain from consuming alcohol or participating in any strenuous activities unrelated to their job within the 24-hour period prior to testing [11]. All descriptive statistics were recorded at the respective fire stations each participant worked for. Descriptive statistics included height (m), mass (kg), age (years), crew type (1 or 2) and experience level (years). During the execution of the test, all participants were instructed to wear the standard training equipment assigned by their captains during the execution of the PHT in previous years; these crews wore their standard cargo pants, a cotton t-shirt and leather boots. Aside from the participants' clothing and backpacks, lightweight HR monitors were placed at each individual's xiphoid process. Before the work capacity test was performed, all participants underwent a warm-up protocol. The author chose to leave the protocol subjective to the participants as tampering with their usual routine could alter their performance. The suggested guidelines for the warm-up protocol went as follows: 5 minutes of free stretching followed by 10-15 minutes of light aerobic activity such as walking or jogging to safely prepare the body to undergo a maximal effort energy bout and prevent subsequent injury [13]. After the execution of the participant's warm-up, they were fitted with a Polar HR monitor (H10, Polar Electro Inc, New York, USA). The participant then proceeded to the starting line to begin the test. The mPHT was performed on a hiking trail located in the Los Padres National Forest. The hike was chosen based upon convenience for both crews as it fell in accordance with the crews existing training regimen. The participants were administered a 20 kg pack, filled and weighed by the PI to ensure standardized load carriage values across the sample. Individuals began the hike in a staggered order to avoid crowding on the trail. The separation in starting times was minimized to allow for all testing to occur within the same 2-hour period and reduce the possible effects of temperature on performance [14]. Each hand crew member was instructed to hike to the top of the hill, where they would cross a finish line constructed by the PI. The distance covered during the test was 1.3 miles and averaged a 16.5% grade. Participants were instructed to perform the trial with maximum effort, and no pacing feedback was administered at any point as it could have influenced their pacing strategies [13]. All dependent variables were collected *via* their phones, conducting a hiking activity session with the Polar Beat app. Participants were instructed to start the activity once they crossed the starting line and end the activity when they passed the finish line. Following the completion of the mPHT, all participants were instructed to perform inactive recovery in a supine position on the floor. HR recovery values, measured in bpm, were taken during the first minute of recovery.

2.4. Instrumentation

In order to confirm the accuracy of all distances and incline levels, Garmin GPS technology was used for three hiking trials performed by the researcher on the trail participants were expected to perform on [15]. Prior to the execution of the mPHT, all participants were required to attach Polar H10 (Polar, USA) heart rate monitors to their Xiphoid process and download the Polar Beat app on their phones. In the app, participants recorded a hiking session during the test in order to collect HRave (average heart rate), HRmax (maximum heart rate) and TTC (time to completion).

2.5. Data Extraction

After the execution of the mPHT, each participant had two activities recorded in their Polar Beat app: the mPHT and the recovery period. The app automatically gives a session analysis with the maximum HR, average HR and Time to Completion (TTC) of the trial. All participants were logged into the PI's Polar Beat account to allow for direct collection of the data. In order to indirectly assess the HR recovery of each participant, the author utilized the HRave and HRmax variables to mathematically solve for the minimum HR; HR recovery was computed by subtracting the HRmin from the HRmax during the 1-minute recovery session.

2.6. Statistical Analysis

Data were analyzed using SPSS 28.0 software (SPSS Inc, Chicago, Illinois, USA). Normality of the sample was conducted with the Shapiro-Wilk test. HRave measurements were represented as a percentage of the individuals' age-predicted maximum HR. Age-predicted HRmax was collected *via* the following equation: $HRmax = 208-(.7(age))$ [16]. TTC measurements were converted into 'pace' values to allow for universal comparison amongst future studies executing hikes with different parameters. Pacing was computed as follows: $Pace = TTC/1.3$, where 1.3 was the mileage covered over the hike. Between-group differences of the dependent variables were compared using an independent samples T-test. The level of significance was set to $p < .05$. Effect sizes were assessed using Cohen's d values calculated within SPSS.

3. RESULTS

The mPHT resulted in no significant differences between crew types for the variables of pace (p = .22, Cohen's d = -0.633), HRrec (p = .62, Cohen's d = 0.043), HRave (p = .14, Cohen's d = 0.718) or HRmax (p = .09, Cohen's d = 0.861) (Table 2). Although independent t-tests revealed no significant differences, there are several findings worth mentioning as they relate to fitness levels between type 1 and type 2 crews. Type 1 crews obtained slightly better pacing scores than type 2 crews (-2.07 minutes/mile) (Table 2). It must be noted that one type 2 HCM was determined to be a statistical outlier and was excluded from the pacing analysis, and if otherwise included, would have resulted in a larger mean difference between the crews (p = .08). Three participants were excluded from the HRrec analysis due to inadequate data being obtained for this specific variable as the protocol for the recovery test was not correctly followed. Similarly with overall pace, type 1 crew members elicited slightly better HRrec values than type 2 crews (+3.0 bmp, or <1% of age-calculated maximum heart rate) (Table 2). Additionally, type 1 HCM obtained greater HRave values than type 2 HCM (+8.2%) as well as higher HRmax values (+8.5%).

Table 2. Performance outcome measures amongst both hand crews.

-	Crew Type	n	Mean + SD	Sig *p*-value
Pace (min/mile)	1	12	24.6 + 3.1	0.22
-	2	6	26.7 + 3.6	-
HRmax (%)	1	11	100.8 + 5.7	0.09
-	2	6	92.3 + 5.7	-
HRave (%)	1	11	92.9 + 7.2	0.14
-	2	6	84.7 + 14.6	-
HRrec (bpm)	1	9	57.7 + 7.8	0.62
-	2	6	54.7 + 14.8	-

Note: Type 1 hand crews are considered the "elite" crew working in the most arduous conditions. Type 2 crews perform similar work but in circumstances considered less physically demanding. min = minute; bpm = beats per minute. SD = standard deviation. HRmax = heart rate maximum. HRave = heart rate average. HRrec = heart rate recovery. HRmax and HRave are reported as a percentage of the age-calculated maximum value.

4. DISCUSSION

The main objective of this study was to conduct a maximal effort exercise test to assess the possible differences in cardiovascular fitness amongst different tiers of hand crews. The traditional PHT was modified to include an inclined terrain with the 20 kg pack as a means of simulating the working conditions the wildland firefighter crews experience. It was hypothesized that type 1 HCM would complete the PHT at a faster pace, exhibit increased HRmax and HRave, and demonstrate greater HRrec than type 2 HCM based on their "elite" categorization and the assumption members must obtain exceptional fitness levels to be capable of successfully executing the most difficult workloads of all WLFF [2]. However, no significant differences between pace or any HR measure (maximum, average, or recovery) between hand crews were observed, and therefore, the hypothesis was rejected. This may suggest the current mPHT may not elicit a sufficient physical challenge to discern fitness discrepancies between type 1 and type 2 HCMs; a current concern of the traditional PHT [6]. While none of the statistics showed significant differences, there is still merit in the data as it does show important information relevant to the different crew levels.

4.1. Relative Intensity as an Indicator of Fitness

To the best of the author's knowledge, this was the first study that attempted to alter the parameters of the PHT and identify fitness discrepancies in performance between type 1 and type 2 HCM. The authors aimed to differentiate the fitness tiers of the two crews by instructing all individuals to execute the test at a maximal pace, thus altering the traditional 45-minute cut-off window of the PHT. Additionally, the PHT is typically executed on a track with no elevation gain [4], and the author included the variable of incline to increase the intensity and energetic demands of the test in order to facilitate maximal exertion from the participants. This addition of incline allowed for increased specificity within the occupational tasks associated with wildland fire suppression, which typically take place on rugged mountainside terrain [4] while simultaneously carrying a heavy load of equipment, simulated by the 20 kg pack.

After execution of the modified PHT, it was observed that none of the performance or heart rate response variables between crews achieved statistical significance ($p > .05$). These findings suggest the mPHT protocols were not sufficient enough to differentiate hiking performance between the crews; this was possibly due to the fact that participants executed the hike at a self-selected pace and temperature was not controlled for. Tucker and Noakes noted that exercise bouts executed at high ambient temperatures provoke large variations in exertion levels when athletes are allowed to regulate their work rate at a self-selected pace [17]. Although the temperature was not controlled, the author did note that all tests were conducted above 33.3 degrees Celsius, which could have resulted in participants deviating from the 'maximal effort pace' cued by the researcher, in order to respond to their rising core temperatures, and consequent increased ratings of perceived exertion in conjunction with decreased arousal levels [18, 19]. The T1C group achieved a mean HRmax of 100.8%, suggesting this group achieved maximum effort, while T2C achieved a mean HRmax of 92.3%. While this is not a statistically significant difference, it could signify the ability of the T1C to perform at a higher physiologic threshold, potentially indicating a higher level of fitness. This goes in conjunction with the T1C group's ability to execute the test at a faster pace therefore sustaining higher HR levels for a longer duration of time.

This variation in exertion level opposes the traditional models of fatigue and decrements in performance one might expect during a controlled maximal effort exercise test [20]. In agreement with Galloway and Maughan, a 2015 study observed potential differences between self-selected pace *versus* standardized RAMP protocols amongst aerobically trained females during an incremental running test to volitional fatigue. Augustine *et al*. noted that the self-selected pace protocols elicited lower measurements of relative intensities and time to exhaustion by the participants, thus reducing performance outcome measures [21]. Future studies looking to assess cardiovascular fitness between type 1 and type 2 HCM should employ RAMP protocols during an incremental exercise test in a controlled setting to minimize the influence of strategy and temperature fluctuations.

4.2. Anaerobic Influence on Maximal Effort Testing

The measurements of HRmax and HRave were utilized to assess the intensity of the test relative to each HCM [22]. All HR values were expressed as a percentage of the individual age-predicted HRmax; The Tanaka equation, $HRmax = 208-(.7*age)$, was employed in order to avoid underestimating the maximal heart rates of older individuals [16]. The positive linear relationship between HR and VO2 has been well-established in previous work [23]. For anaerobic efforts, heart rate is not an accurate index of the metabolic or cardiovascular stress experienced [24]. In the current study, type 1 and type 2 crews obtained HRave values, indicated as %HRmax, of 92.9% and 84.7%, respectively. Age and body weight could have potentially impacted these results. Anthropometric characteristics were not matched between groups for this study. The T1C had a mean age of more than 6.8 years and a mean body weight of 7.6kg greater compared to the T2C. This could have potentially altered HRmax and HRave variables, even though an attempt was made to account for age using the Tanaka equation. The effect of additional body weight is unclear as the composition of the weight (*i.e.*, tissue type) is unknown. The overall tendency towards a faster pace of the T1C crews suggests that age and body weight did not hinder performance. The additional experience of the T1C crews may have led to the development of additional muscle tissue over time that makes them better suited to an increased performance (in terms of pace) and the ability to operate at a higher HR level for a longer period of time.

Previous authors have illustrated that high-level endurance athletes typically reach their lactate deflection point (LaT), a clear indicator of a switch between aerobic and anaerobic metabolism, between 84% and 86% of the relative HRmax [25, 26]. The current mPHT protocols were not sufficient in differentiating fitness levels between crews based on HR response and levels of relative intensity. It is possible that HR in isolation may not be an adequate variable to assess metabolic efficiency during activities that do not primarily rely upon aerobic metabolism, and therefore, variables such as LaT or blood lactate accumulation post-exercise, may allow for a deeper understanding of the underlying differences between type 1 and type 2 crews [24].

4.3. Recovery Capabilities as an Indicator of Fitness

Lastly, type 1 HCM saw 5.3% higher (non-statistically significant) HRrec values than type 2 HCM. Although these results were not significant ($P = .62$), it is worth mentioning the slight positive trend in cardiovascular fitness towards type 1 compared to type 2 crews. Aside from the differences between the two crews, it must be noted that the HRrec values obtained were particularly high based on previous studies performed on elite athletes [27]. Additionally, there are compelling data to show a positive correlation between VO_{2max} and HRrec measurements in well-trained endurance athletes ($r = .51$) [28]. It is plausible that both crews assessed in the current study exhibit above-average fitness levels and may not fully represent the broad spectrum of hand crews across the entire country. This assumption was further supported when this particular type 2 crew served as a "feeder system" for HCM to improve their fitness and expertise to eventually earn a spot in the IHC.

4.4. Future Studies and Limitations

This study is not without its limitations. A lack of consistency within the testing environment and protocols can be seen as a primary limitation of the study. Temperatures could not be strictly controlled and could have resulted in greater physiological strain, subsequently altering performance and HR variables. Along with temperature, food intake was not monitored and could have affected the participants' ability to supply the energetic demand of the maximal effort bout. Additionally, each individual likely experienced deviations in their hike due to the following ecological variables: rocks, potholes, and alternating surfaces. Furthermore, the horizontal displacement covered by each participant was not taken into account and could have affected their time to completion scores. It must be noted that the PI did not account for the current fitness level at the time of testing. All HCM were tested prior to their first mandatory period of physical training with their crews, however, the researchers were not granted access to this testing and therefore, could not incorporate it into the analysis presented here. Therefore, the fitness variables achieved for each participant may have been a result of the residual effects of training adaptations from the prior year, along with their personal training regimen in preparation for the new season.

Although no significant differences were observed between crews for any performance and HR variables assessed, these values may be more pronounced in a controlled environment such as an indoor graded exercise test, where temperatures can be controlled, and the "strategy" component of the test is diminished as a result of all individuals executing the test at the same work rate. In addition, both crews appeared to approach or reach maximal exertion during the test. However, measuring relative intensity by means of HR response was not successful in differentiating fitness levels between crew types. It is likely that this maximal effort exercise in high ambient temperatures did not rely primarily on aerobic means and therefore challenged the classic model of HR response indicating fitness level based upon exertion. Analyzing variables such as lactate deflection points as well as overall lactate accumulation may illustrate differences in fitness levels between crews to a higher magnitude and should be utilized as a marker in further studies. Lastly, the sample size for this study consisted of two hand crews from Central California; the type 2 crew observed has been said to serve as a "feeder" system for hand crew members to improve their fitness, skill and field knowledge to eventually earn a spot on the type 1 crew observed. Regional limitations were a problem as was the willingness of fire captains to solicit their crews to undergo this test. Additional crews up to 160 kilometers away from the location of the PI were approached, but a willingness to participate was limited prior to the start of the working season. As such, the attainable sample size was quite limited. An a-priori analysis for sample size was not conducted due to the limited ability to attain participants. The researchers approached all available wildland firefighters within a reasonable geographic radius (approximately 160 km) and were only able to attain nineteen total participants. In spite of that, the researchers still believed that while small in size, the available sample size would still serve as a solid starting point for a novel test. As significance was approached for HRmax, it stands to reason that a larger sample size would help further delineate whether or not that statistical significance exists as the power is ultimately limited. Future studies should recruit a larger sample size of crews from different geographical locations to better represent possible fitness discrepancies between crew types across the entire Forest Service.

CONCLUSION

To the best of the author's knowledge, this was the first study that attempted to modify the physical parameters surrounding the PHT in order to assess possible differences between the tiered classes of WLFF. It was originally hypothesized that type 1 HCM would naturally obtain superior physical fitness levels compared to type 2 HCM. This hypothesis fell in line with the previously existing notion that type 1 HCM are placed under the most arduous circumstances and require the highest capacity systems to safely perform their occupational tasks. After examination of the modified PHT implemented in the current study, there were no significant differences between type 1 and type 2 HCM for any of the fitness variables assessed. Although the difference between the means was not statistically significant, the tendency was for the type 1 crew to complete the hike with a slightly faster pace and recovery heart rates post-exercise. T1C were able to achieve a maximum effort level as indicated by HRmax while having a tendency towards a faster pace, although not at a statistically significant level. This still may be indicative of an increased fitness level for the T1C group. While none of these variables have statistical significance, in a situation such as wildland firefighting, small improvements can potentially be life-saving in the field. Therefore, it is critical to mention the potential differences that can come with the added years of experience and abilities of the T1C group.

AUTHORS' CONTRIBUTIONS

It is hereby acknowledged that all authors have accepted responsibility for the manuscript's content and consented to its submission. They have meticulously reviewed all results and unanimously approved the final version of the manuscript.

LIST OF ABBREVIATIONS

PHT	=	Pack hike test
WLFF	=	wildland firefighter
HCM	=	Hand crew member
T1C	=	Type 1 Crew
T2C	=	Type 2 Crew
HR	=	Heart Rate
TTC	=	Time to completion
mPHT	=	modified Pack hike test
HRave	=	Heart rate average
HRmax	=	Heart rate maximum
HRrec	=	Heart rate recovery
LaT	=	Lactate deflection point

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The project was approved by the California State University Long Beach Institutional Review Board for project number 1887311-4.

HUMAN AND ANIMAL RIGHTS

All procedures performed in studies involving human participants were in accordance with the ethical standards of institutional and/or research committee and with the 1975 Declaration of Helsinki, as revised in 2013.

CONSENT FOR PUBLICATION

All participants signed an informed consent for this study.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article will be available from the corresponding author [K.A.V] upon reasonable request.

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None.

CONFLICT OF INTEREST

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