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Body Composition Changes of United States Smokejumpers during the 2017 Fire Season

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Abstract: Wildland firefighting is arduous work with extreme physical and nutritional demands that often exceeds those of athletes competing in sports. The intensity and duration of job demands, impacts the amount of calories burned, which can influence body composition. The purpose of this study was to determine if the body composition of nine wildland firefighters working as smokejumpers changed throughout the 2017 fire season. Subjects (n = 9) for the study ranged in age from 24–49 (age 30.1 ± 8.3 y). Height (177 ± 18.8 cm) and weight (81.32 ± 6.39 kg) was recorded during initial body composition testing and body fat percentage was determined pre and post-season using Lange skinfold calipers. Outcomes were evaluated using a paired t-test. Body fat percentage was significantly different between pre and post-season (average body fat percentage increase = 1.31%; t = 2.31, p = 0.04, alpha = 0.05). Body weight increased slightly from pre to post-season (average increase in body weight: 0.17 kg), although the differences were not significant (t = 2.31, p = 0.78). Change in body fat percentage without change in body weight suggest that monitoring of WLFF body composition and fitness may be needed help inform dietary and fitness interventions to insure that nutritional demands of this population are sufficient to support physical work on the fireline.

Keywords: wildland firefighters; body composition; body fat percentage; nutrition; body weight; lean mass; fat mass

1. Introduction

Health and performance can be affected by body composition (BC) [1]. In light of this, studying BC has received considerable research attention when examining physical performance [2–6]. Body fat percentage (BF%) and lean body mass are of interest to coaches and athletes because of their importance in athletic performance [1,7]. The relationship between nutrition and performance is well established in the literature and optimal nutrition is thus widely accepted as a means to enhance performance and recovery [8]. The intensity and duration of certain sports, impacts the number of calories burned and research shows that sports with higher physical activity influence BC [7,9–11].

Wildland firefighters (WLFFs) are considered tactical athletes [12], a term used to describe those in service professions that require significant physical fitness and performance [13]. While wildland firefighting may not be considered a sport, the physical and nutritional demands of the occupational activities [14,15] can be comparable to or exceed those of athletes [16,17]. In the Western United

States, WLFF duties often require fighting fires in steep terrain, in high temperatures, and with smoke-degraded air quality.

Wildland firefighting includes a wide range of line-based positions including hand crews, fuels crews, engine crews, hotshot crews, and aviation crews such as Helitack and smoke jumpers. All agency line-based WLFFs are required to pass a Work Capacity Test at the light, moderate, or arduous level [18]. These requirements vary depending on the position of the WLFF. The light walk test requires a 1.6 km walk test in a 16 min period with no pack. The moderate field test requires a 3.2 km hike with a 11.3 kg pack in 30 min. The arduous past test requires a 4.8 km hike with a 20.4 kg pack in 45 min [18].

Smokejumpers, the focus of this research, must pass the arduous pack test and in addition must be able to do, at the minimum, seven pull-ups, 45 sit-ups, 25 push-ups, and a 2.4 km run in less than 11 min. They must be able to perform a gear pack-out with a 50 kg pack over 4.8 km in 90 min or less [19].

Smokejumpers are WLFF who parachute from planes, often in remote areas, to combat wildfires [20]. They are typically dispatched at the national level, including Alaska and Canada [21]. They must be in excellent physical condition and possess a high degree of emotional well-being and mental alertness [21]. Employment for a typical fire season can be May to October [22], however, research shows that the fire season has grown by 30 days in the last 20+ years with wildfires starting earlier in the spring and continuing later in the fall [23]. This may increase a WLFFs commitment of continuous physical job demands in duration and might ultimately test the physical and nutritional components that are essential for optimal health and performance.

Many factors such as body size and composition contribute to performance [24]. BF% that is either too high or too low may have negative impacts on health and fitness [25]. Having a higher BF% lowers the endurance of individuals, which allows fatigue to set in quicker than those with lower BF% [1]. Therefore, many athletes and athletic teams have their BC assessed on a regular basis [26,27]. Monitoring and evaluation of WLFF BC throughout the fire season may be of interest for both the individual and members of a team. For example, mean BC levels for a crew might be integrated into a general overall health assessment throughout the fire season, in order to inform individuals when nutritional requirements are insufficient and/or where deficiencies may be occurring.

Monitoring BC may also provide firefighting agencies with beneficial feedback in regard to conditioning programs and nutritional guidelines to achieve and maintain optimal BC for WLFFs. Additionally, with cardiac events being the leading cause of WLFF deaths [28], BC could also be a useful tool to predict underlying health issues before a WLFF is placed in less than ideal situations. To evaluate WLFF BC changes associated with work over the course of a fire season, a pilot study with a United States smokejumper crew was initiated in 2017. One aim of this study was to evaluate changes in body fat percentage and body weight immediately before and after the fire season. Due to the reported physical job demands, long work days, lack of reported sleep and recovery between shifts, and the reported nutritional habits that were documented from an earlier survey [29], it was hypothesized that smokejumpers would undergo BC changes over the course of the season.

2. Materials and Methods

2.1. Participants

A convenience sample of United States smokejumpers was used for this study. Nine WLFFs ranging in age from 24–49 volunteered to participate in this study after being informed of the research project. Approval was obtained from the University of Idaho's Institutional Review Board (project 17-131) prior to conducting research. As this was part of a larger research project, each participant was provided a folder containing study directions and rationale, researcher's contact information, a consent waiver to sign prior to participation, as well as a revocation of consent form. Any participant unable to meet all the requirements for the study (pre-season and post-season BC testing) was excluded.

2.2. Protocol

Body composition measurements were taken pre-season (11 June 2017) and post-season (21 September 2017) using Lange Skinfold Calipers (Beta Technologies, Cambridge, MD). Lange Skinfold Calipers are factory calibrated to ±1 mm with no further calibration needed. Body weights were recorded at the same time on a weighing scale with a precision of 0.01 kg (Salter Brecknell PS1000, Fairmont, MN, USA) that was calibrated each time and height was recorded using a standard stadiometer. BC equations obtain body fat percentage by first determining body density. The Jackson and Pollock body density equation [30] and the Siri equation [31] were chosen as they are the best fit for this athletic male population. The Jackson and Pollock three-site skinfold testing was utilized (triceps, abdomen, and thigh) to measure body density (Equation (1)) [30]. Body density was then factored into the Siri equation (Equation (2)) [31] to provide BF% for each participant. The Siri body density to body fat equation is a two-compartment model that only measures fat mass and fat free mass [30]. Lean body mass was calculated by subtracting body fat weight from total body weight.

Jackson and Pollock 3 Site Skinfold Body Density Equation =

$$\begin{aligned}\text{(Male)} =& 1.10938\text{-}(0.0008267 \times (\text{sum of three skin folds}) + (0.0000016 \times \\ & (\text{sum of three skinfolds}^2)) - (0.0002574 \times \text{age in years})\end{aligned} \tag{1}$$

Siri Body Density to Body Fat Equation:

$$\% = (4.95/\text{Body Density}) - 4.5 \tag{2}$$

Skinfolds were measured in a rotational manner to allow testing sites to regain normal texture and thickness before testing the site again. This was repeated until a total of three caliper readings per site were collected. Measurements started with the triceps and were followed by the abdomen and thigh, respectively. All measurements were taken on the right side of the body, which was marked on the skin for consistency and adherence for site specific guidelines. All repeated measurements were required to be within 2 mm of each other or re-measured [32]. Skinfold calipers have a ±3.5% error largely due to participant's hydration status, whether or not their body is inflamed (i.e., after a workout or other physical activity), and the researcher's level of experience completing skinfold testing [32].

The best use of skinfold thickness data is as raw values, where they act as reliable indices of regional fat mass and can be converted into standard deviation score (SDS) formatted for longitudinal evaluations [32]. Lange skinfold calipers are a "precision instrument" specifically designed for simple and accurate measurements of subcutaneous fat [33]. Unlike other methods of BC measurements (i.e., Dual energy X-ray absorptiometry (DXA) or hydrostatic weighing), skinfold caliper measurements can be conducted in the field at a reduced cost requiring less time, equipment, and manpower to provide estimations of BC [1]. Lange skinfold calipers are widely used by medical and physical health care professionals and allows for efficient and practical measurements for valid testing [30] and well trained testers can provide estimations of BC within the acceptable range of ±3.5% BF [1]. The popularity of skin-fold assessment is derived from its quickness and portability as the procedure usually takes less than 10 min and can be performed in most settings [1].

2.3. Statistical Analyses

The outcomes are described as means and standard deviation (mean ± standard deviation) (Table 1). A paired t-test was performed to evaluate the change in mean pre-season and post-season weight and BF% among the WLFFs 2017 fire season. Normal distribution probabilities from the t-tests were appropriate. An alpha level of $p < 0.05$ was used for all statistical tests.

Table 1. Descriptive statistics for participants.

Dependent Variables	Mean	Std. Deviation	Range
Age (years)	30.1	8.28	24–49
Height (cm)	177	10.83	152.4–190.5
Pre Weight (kg)	81.32	6.39	69.85–89.36
Post Weight (kg)	81.50	6.98	69.85–91.17
Change Pre- Post weight (kg)	0.17 *	6.36	−3.4–2.9
Pre BF%	7.63	1.89	4.83–11.11
Post BF%	8.94	2.90	5.25–14.29
Change Pre- Post%	1.31 **	1.64	−1.5–3.18

Note: * non-significant at p = 0.78 with set alpha level of 0.05 (2-tailed); ** significant at p = 0.04 with set alpha level of 0.05 (2-tailed)

3. Results

3.1. Body Fat

The study consisted of nine WLFF smokejumpers from the same base. Descriptive statistics from the participants are summarized in Table 1. All subjects were Caucasian males, healthy, and eligible for the job of wildland firefighting, thus making them eligible for the study. The average age was 30.1 years, average height was 177.0 cm, and average pre-season body weights were 81.32 kg while BF% was 7.63% (Table 1). Post-season body weights increased slightly to 81.5 kg while BF% increased to 8.94% (Table 1).

BF% calculated using the Jackson and Pollock and Siri equations differed pre-season and post-season (average increase BF%: 1.31%), which was a significant increase (t = 2.31, p = 0.04) (Table 1).

The mean pre-season BF% was 7.63 ± 1.89 and the mean post-season BF% was 8.94 ± 2.90 (Table 1). When fat mass (anything that is not muscle, bone, or ligaments) was compared between pre-season to post season, seven out of the nine smokejumpers gained body fat (Figure 1).

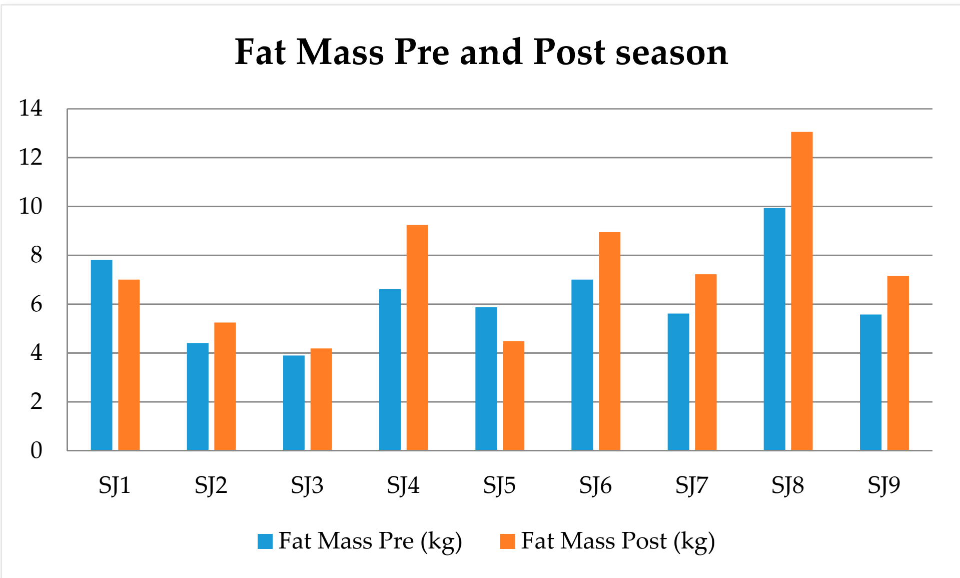

Figure 1. Pre and post season fat mass. Each set of paired bars represents an individual smokejumper.

3.2. Body Weight

There was no significant change in body weight pre and post-season (Table 1) (t = 2.31, p = 0.78). The mean pre-season body weight was 81.32 ± 6.39 kg and the mean post-season body weight was

81.50 ± 6.98 kg (Table 1). When body weight was observed pre-season and post-season, 44.4% (SJ1, SJ2, SJ3, &SJ7) did not have a significant change in bodyweight, 33.3% (SJ4, SJ6, & SJ8) gained weight, and only 22.2% (SJ5 & SJ9) lost body weight (Figure 2). Participants SJ1 and SJ5 had a decrease in BF% (Figure 1) and slightly fluctuating body weights (Figure 2).

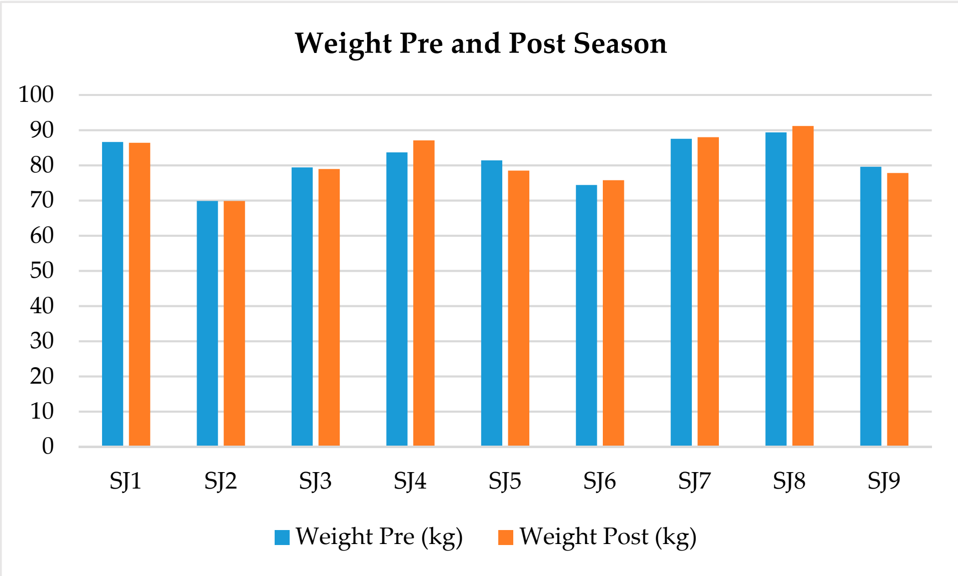

Figure 2. Pre and post season weight (kg). Each set of paired bars represents and individual smokejumper.

4. Discussion

Research on changes in body composition of smokejumpers throughout the fire season is limited. Understanding BC changes can provide firefighting agencies with beneficial feedback in regard to conditioning and nutritional guidelines given BC can determine performance [24]. It was anticipated that smokejumpers would undergo BC changes during the season due to the arduous and physical demands of the job. The data indicates 78% of participants underwent what could be construed as an unfavorable BC change—meaning body weight remained constant or increased while body fat increased—indicating a loss of lean mass.

Although objective or subjective nutritional data were not collected in this initial phase of the study, one possible explanation could be that the nutritional requirements of these participants were not being met. For example, observations in the data that participants maintained body weight, increased fat mass, and lost lean mass from the beginning of the season to the end of the season may suggest that inadequate protein and carbohydrate consumption is occurring during the fire season. However, a follow-up study that includes monitoring detailed dietary intake would be needed to evaluate this hypothesis.

One explanation for the changes in BC may be that pre-season BF% was measured immediately after a two week refresher course when the smokejumpers were all training together on a daily basis. This two week period includes extensive physical training and jumping and individuals are expected to be in peak condition prior to the refresher course. Many WLFFs may also conduct pre-fire season conditioning, especially cardiovascular training. Once fire season begins, periods of inactivity during in between fires coupled with dietary habits can potentially lead to accumulation of body fat which can also affect performance and fitness levels [34]. This possible occurrence could be useful to study in future research. Additionally, objective data on diet on and off the fireline, including quantifying time spent in different levels of exertion along with a larger sample size will help further explain underlying trends.

Other studies examining BC of tactical athletes provides contrasting results. Sell and Livingston [35] found BF% of interagency hotshots (n = 20) to be 12.9% ± 2.3% at mid-season but did not elaborate further. Their research is incomplete as a baseline of BF% was not measured prior to the fire season and further BF% data was not collected. Cuddy et al. [36] measured WLFF (n = 16) body weight before and after a single day shift but this information was only measured for water turnover and there was no bodyweight difference among the groups studied. Ruby et al. [15] found that total body mass of 14 WLFFs over a five day period decreased but attributed the results to total body water loss.

The relationship between simulated job performance tasks, body fat percent, and lean body mass on firefighters has also been reported [4]. Williford et al. [4] examined 100 individuals to determine their body fat percent and ability to perform a simulated job task. Results showed a statistically significant relationship between BF% and the time to perform the simulated fire line job tasks. As BF% increased, time to perform the simulated job tasks increased. They also found a negative relationship between lean mass and job-related performance. As the amount of muscle mass increased, the time to perform the job tasks decreased. The study concluded that percent of body fat and lean body mass were important predictors of job performance. Firefighters with greater fat-free weight and less fat mass tended to perform the simulated job tasks in less time [4]. With a lengthening fire season [23], what remains to be seen is if BC changes are significant enough to decrease job performance in the WLFF population.

Possible limitations of this study are the participant group and limited sample size (n = 9) which limits our ability to generalize results. Additionally, participants were from the same base, all male, and with an occupational weight limit of 90.7 kg, both of which may have had an impact on possible weight changes throughout the study. Having all-male study participants limits further implications/suggestions for female WLFFs. Future research will include assessing hydration while monitoring BC during the fire season and during the off-season (January) to track longitudinal changes in a larger population in order to address limitations.

Another limitation of our research may be the use of skinfold calipers, which have a ±3.5% error associated with BF% readings [32]. While skinfold calipers are widely recognized and used for field testing [1], discrepancies exist between skinfold caliper results and the reference laboratory method of DXA, which may provide a more accurate measure of BC [37–39]. Therefore, to ensure consistency throughout the study, body fat caliper testing was performed by a single observer who is a trained ACE certified trainer with prior experience. The measurements were conducted at the same time of day and the participants were instructed to follow the same guidelines each time to ensure adequate hydration. Although hydration status was not assessed, this may be another possible limitation in the study and should be included in future research.

In conclusion, these results indicate that WLFFs underwent BC changes across the 2017 fire season. It should be mentioned that changes in fat mass may be associated with other physiological changes as the body adapts. The depth of physiological changes that WLFFs undergo longitudinally over the course of the year is an area that merits further research due to the high number of cardiovascular related deaths [25] that have occurred in a seemingly "physically fit" and "healthy" population. Monitoring variables such as sleep, training, nutrition, hydration, and recovery, both on and off fire assignments, is needed in order to determine which variable(s) are contributing factors affecting BC changes. Such information will allow for creation of interventions for WLFFs to better maintain BC during the fire season.

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