Nutrient Intake, Body Composition, and Performance Measures of Wildland Firefighters: A Longitudinal Analysis

A Dissertation Proposal
Presented in Partial Fulfillment of the Requirements for the
Degree of Doctor of Philosophy
with a
Major in Education
in the
College of Graduate Studies
University of Idaho
by
Samantha Brooks

Major Professor: Ann Brown, Ph.D.
Committee Members: Joshua Bailey, Ph.D.; Annie Roe, Ph.D.; Clarissa Richardson, Ph.D.; Brent Ruby, Ph.D.
Department Administrator: David Paul, Ph.D.

May 2021

Authorization to Submit Dissertation

This dissertation of Samantha Brooks, submitted for the degree of Doctor of Philosophy with a Major in Education and titled “Nutrient Intake, Body Composition, and Performance Measures of Wildland Firefighters: A Longitudinal Analysis,” has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor: ______________________________ Date: ___________
Ann Brown, Ph.D.

Committee Members: ______________________________ Date: ___________
Joshua Bailey, Ph.D.

______________________________ Date: ___________
Annie Roe, Ph.D.

______________________________ Date: ___________
Clarissa Richardson, Ph.D.

______________________________ Date: ___________
Brent Ruby, Ph.D.

Department
Administrator: ______________________________ Date: ___________
David Paul, Ph.D.

Abstract

Background: WLFFs are tasked with performing arduous work in an unstable and adverse occupational environment causing them to make rapid adjustments to meet their energy intake needs during 14-21 days of constant wildfire suppression. The wildfire season (typically June-September) provides a unique environment in which nutrient intake, body composition, and performance may be altered**.** Therefore, the purpose of this longitudinal study was to examine differences in nutrient intake, body composition, performance measures, and biomechanics characteristics among WLFFs pre-season, post-season, and in the off-season. **Methods:** WLFFs (N=18) participated in laboratory testing at the Human Performance Lab at the University of Idaho at 3-time points: Visit 1 in June (Pre: pre-season), Visit 2 in October (Post: post-season), Visit 3 in February (Off: off-season). Laboratory testing included anthropometric measures, a dual energy x-ray absorptiometry scan, muscular strength and endurance testing, biomechanics testing, and the Diet History Questionnaire completion. Participants were asked to arrive to the HPL between the hours of 0800-1200, abstaining from exercise, caffeine and/or alcohol use, and nutritional supplements for 24 hours prior to their testing appointment. Body composition was measured using dual x-ray absorptiometry (DXA; Hologic Inc., Horizon W QDR Series, Bedford, MA, USA). Performance testing included a series of muscular strength and endurance measures including a load-carriage treadmill test, shoulder and knee sagittal plane isokinetic testing, and a kettlebell handgrip test. Upon completion of performance testing, participants completed the Diet History Questionnaire III (DHQ-III). Descriptive statistics were analyzed using the Statistical Package for Social Sciences 24 (SPSS v. 24). Participants' nutrient intake (macronutrients and micronutrients), body composition (LM, FM, ASMI, BMD, VAT), anthropometrics, shoulder and knee sagittal plane isokinetic measures (initial peak torque, fatigue index, average power), and biomechanics characteristics (mean and peak trunk inclination, stride length, stride frequency) were analyzed using a one-way repeated measures Analysis of Variance (ANOVA) to determine differences pre-season, post-season, and in the off-season. Multiple comparisons were computed with post hoc Bonferroni tests. **Results:** Participants included male (n=16; 89%) and female (n=2; 11%) WLFFs who spent an average of 32±21 days on wildfire assignments throughout the 2019 fire season. Twelve participants were unable to complete visit 3 due to crew dispersion (n=5), leaving the occupation (n=2), and proximity to the laboratory (n=5). A significant difference was observed for calories (kcal; p=0.014), fat (kcal; p=0.008), protein (g/kg; p=0.037) and carbohydrate (g; p=0.001, g/kg; p<0.001, kcal; p=0.001, %; p=0.003) between pre-season and off-season. Additionally, a significant difference in Sodium (p=0.020) and Vitamin B3 (mg; p=0.032) was observed between pre-season and off-season. No significant differences were observed for body composition measures, muscular strength and endurance measures, or biomechanics characteristics by visit (p>0.05). **Conclusion:** WLFFs macronutrient intakes and select micronutrient intakes were significantly different pre-season, and in the off-season, however no differences in body composition, performance measures, or biomechanics characteristics were observed. These data suggest WLFFs appear to maintain consistent body composition and muscular strength and endurance across the season and into the off season despite significant changes in self-selected dietary intake.

Acknowledgements

Ann Brown: Thank you for being the greatest mentor throughout this journey. Thank you for taking me on as your student and pushing me to be the best student, collaborator, and teacher. I will forever be grateful for your guidance and support.

Joshua Bailey: Thank you for your constant support throughout this program. Your knowledge in the field has broadened my views of research and teaching.

Annie Roe: Thank you for your constant support throughout my academic journey. Thank you for the years of mentorship.

Clarissa Richardson: Thank you for serving on my committee over the years.

Brent Ruby: Thank you for your support and expert knowledge in the field of wildland firefighter research. Your contribution to my committee during this journey has been invaluable.

Table of Contents

List of Tables

Chapter One: Introduction

The Pacific Northwest (PNW) comprises a unique environment in which wildfires are prevalent (Abatzoglou et al., 2014). Due to a rapidly changing climate, wildfire behavior has been projected to increase in severity, size, and length of fire season (Wimberly & Liu, 2014). Understanding the topography and fire regimes in the PNW is necessary to determine the appropriate allocation of resources, such as wildland firefighters (WLFFs). Therefore, the demands of WLFFs must also adapt to ensure optimal safety and preparedness for wildfire suppression. WLFFs' occupational requirements are arduous and strenuous where common duties include prescribed burning, wildfire suppressing, preparing for changes in fire behavior, carrying loads over rough terrain, for extended periods of time (Cuddy et al., 2007) and preventing wildfires from threatening individuals, homes, and communities.

Various types of WLFFs exist including, but not limited to, handcrews, hotshots, helitack, and smokejumpers. Most WLFFs begin their firefighting career as part of a handcrew, engine crew, or hotshot crew, with possible progression towards more highly specialized positions such as helitack and smokejumpers. Handcrews typically consist of twenty individuals who conduct a variety of operations on a fire assignment including constructing fire lines with chainsaws or hand tools, burning areas, and rehabilitating previously burned areas. Hotshots perform the same duties as handcrews, however are more specialized and placed in increasingly rugged terrain. Additionally, helitack crews consist of individuals who are transported to remote fires via helicopters, often rappelling (helirappel) from the helicopter to suppress a fire. To become a smokejumper, an individual must have previous WLFF experience, and learn to parachute from airplanes into remote and inaccessible areas. Smokejumper crews range from two to twenty individuals depending on the size of the fire and initial attack necessary. Due to the unpredictability of wildfires, WLFFs frequently change locations. Therefore, WLFFs go for extended periods of time performing arduous and strenuous activity, consuming meals at fire camps, away from home, and with limited time for recovery.

Due to the arduous physical demands of the job, WLFFs are held to specific physical fitness standards. The Interagency Wildfire Qualifications Standards classifies wildland firefighting as an arduous task and includes a pre-employment medical examination and completion of the arduous work capacity test, also known as the arduous pack test. The arduous pack test is a physical fitness test utilized to measure strength and endurance capacity of WLFFs (Sharkey et al., 1994; Sharkey & Rothwell, 1996) in which individuals must complete a 4.83-km hike on flat terrain with a 20.4-kg pack in 45 minutes or less (Sharkey & Rothwell, 1996). The arduous pack test has been correlated to measures of aerobic fitness including absolute $VO_{2\ peak}$ ($r_s = -0.79$ to 0.55, $p<0.01$), lactate threshold, and onset of blood lactate accumulation ($r_s = -0.65$ and -0.63, $p<0.01$, respectively) in field tasks, specifically treadmill walking (Lindberg et al., 2013). However, the pack test is an intended measure of occupational readiness, rather than a time trial. The multitude of training demands for WLFFs are comparable to collegiate and professional athletic activities, such as running, hiking, and lifting (Thomas et al., 2016). However, they encounter unique conditions which are highly comparable to military and police personnel, such as a load carriage, limited recovery time, compromised sleep and sleeping conditions, extreme temperatures, and terrain, and prolonged psychological stress. Additionally, environmental conditions and tactical components of the job provide additional physical and mental demands, compared to military and police personnel. Therefore, WLFFs comprise a unique occupation in which a multitude of factors are necessary to consider for job safety and success.

Due to rigorous occupational tasks performed in remote locations during wildfire suppression, measurement of WLFFs energy expenditure in the field has been difficult to obtain (Cuddy et al., 2015; Ruby et al., 2002). Energy expenditure has been previously measured, during an isolated fire assignments (located in Florida, Montana, Idaho, Washington, and California), in hotshots where an average total energy expenditure of 4,878±716 kcals/day was observed (Ruby et al., 2002). Energy expenditure in helitack and smokejumpers has not been previously identified. Additionally, fluctuations between individual hotshots' energy expenditure has been identified to fluctuate over consecutive days on a fire assignment, however within individual energy expenditures remains stable (Ruby et al., 2002) Furthermore, high energy demands of WLFFs can be met with adequate nutrient intake (Ruby et al., 2002).

In addition to the physical components of wildland firefighting, knowledge of nutrient intake is necessary to understand proper nutrition strategies, which may impact WLFF health and safety (Thomas, Erdman, & Burke, 2016). Nutrient intake is associated with metabolic adaptations and body composition, thus, possible changes in performance (Margolis et al., 2016). WLFFs nutrient intake has been reported to be 17.0±3.9 MJ/d for males and 13.5±3.0 MJ/d for females (2796-4469 kcal/d) on a fire assignment (Ruby et al., 2002). Potential decrements in nutrient intake, in relation to energy expenditure, could lead to long term alterations in body composition such as muscle, bone, and adiposity, and subsequent performance capabilities, and overall health. Nutrient intake of WLFFs has not been previously reported longitudinally (at multiple time points across a season) or for the various types of WLFFs. Due to WLFFs work seasons, fluctuations in energy expenditure and intake may exist. To meet high energy expenditure, timing of food consumption, specifically carbohydrates and protein, is imperative to maintain energy demands (Cuddy et al., 2007). Critical time periods during WLFFs work days have been identified as high energy expenditure times, specifically during the hours of 4–6, 8–10, and 10–12 of the work day (Cuddy et al., 2007). Efforts to optimize nutrient intake surrounding and during these times may be an effective strategy to reduce detrimental physiological consequences of inadequate nutrient intake during time of increased energy expenditure. Carbohydrate supplementation, specifically as shift-food, has been used to increase WLFFs work output during these critical times by providing glucose as an energy source to skeletal muscle (Cuddy et al., 2007). Additionally, the types of food consumed, also known as diet quality, is imperative to determine if the types of food consumed on a fire assignment are meeting nutrient needs of WLFFs (Cuddy et al., 2007). Recent data by Marks et al. demonstrated a novel approach to quantifying WLFFs nutrient intake through direct observation and plate waste (Marks et al., 2020). Understanding, WLFFs nutrient intake and energy expenditure during extended periods of fire suppression is a necessary step towards nutrition recommendations to optimize body composition, performance, and overall health on the fire line as well as across a fire season.

Energy expenditure and nutrient intake also contribute to WLFFs body composition. Body composition is a term used to describe an individual’s fat mass (FM), lean mass (LM), and bone mineral density (BMD). Many factors effect an individual’s body composition including diet, hydration status, and physical activity LM, or skeletal muscle mass, is necessary for daily function and performance to maintain physiological and metabolic function (Margolis et al., 2016). Body composition is subject to change across a year, specifically with a training and detraining cycle, due to alterations in energy expenditure and nutrient intake. Therefore, it is necessary to quantify WLFFs body composition in the pre-season, post-season, and in the off-season.

Setting the Problem

Considering the above and the arduous occupational demands of WLFFs, additional research is necessary to measure nutrient intake, body composition, and performance measures, longitudinally (at multiple timepoints across a year). Nutrient intake during isolated fire assignments has been previously reported (Montain et al., 2008; Ruby et al., 2002; Marks et al., 2020) and body composition, including FM and LM, has been assessed using magnetic resonance imaging (MRI) and dual-energy x-ray absorptiometry (DXA) across a single fire season (Coker et al., 2018). However, year-long, longitudinal nutrient intake and performance measures are major gaps in the literature among all types of WLFFs. Nutrient intake is associated with body composition and metabolic changes, thus, possible changes in performance (Coker et al., 2018). For WLFFs, changes in fitness are likely related to occupational oriented physical demands of the job requirements, overall health, and safety. Therefore, the objective of this study was to obtain a longitudinal understanding of WLFF nutrient intake, body composition, and muscular strength and endurance across the fire season and off-season.

Purpose Statement

The purpose of this longitudinal study was to examine differences in nutrient intake, body composition, performance measures, and biomechanics characteristics among WLFFs pre-season, post-season, and in the off-season.

Research Questions

1. Is there a difference in nutrient intake (macronutrients and micronutrients) among WLFFs pre-season, post-season, and in the off-season?
2. Is there a difference in body composition (LM, FM, ASMI, VAT, BMD) among WLFFs pre-season, post-season, and in the off-season?
3. Is there a difference in performance measures (isokinetic shoulder and knee flexion and extension, hand grip endurance) among WLFFs pre-season, post-season, and in the off-season?
4. Is there a difference in biomechanics characteristics (mean and peak trunk inclination, stride length, and stride frequency) among WLFFs pre-season, post-season, and in the off-season?

Research Hypotheses

1. There is a difference in nutrient intake (macronutrients and micronutrients) among WLFFs pre-season, post-season, and in the off-season.
2. There is a difference in body composition (LM, FM, ASMI, VAT, BMD) among WLFFs pre-season, post-season, and in the off-season.
3. There is a difference in performance measures (shoulder and knee sagittal plane isokinetic measures, hand grip endurance) among WLFFs pre-season, post-season, and in the off-season.
4. There is a difference in biomechanics characteristics (mean and peak trunk inclination, stride length, and stride frequency) among WLFFs pre-season, post-season, and in the off-season.

Delimitations

1. A convenience sample consisting of 30 male and female WLFFs (ages 18-57) in Idaho from May-June 2019 were recruited to participate in this study. All other WLFFs outside Idaho and the age range will be excluded.
2. Participants must meet the minimum fitness requirements to become a WLFF and remain USFS active employees.
3. Participants must participate in at least one fire assignments over the course of the study.
4. Participants must not have any metabolic diseases/disorders.
5. Participants must be absent of injuries and surgeries for the past 6 months.

Limitations

1. The sample size consists of a variety of WLFF crew types and may necessitate caution in extrapolation of the data to a larger WLFF population.
2. Nutrient intake of participants is not controlled, and the use of the Diet History Questionnaire will provide detailed information about all food and beverages consumed by WLFFs, may not be completed with honesty and accuracy.
3. Participants are recruited on a volunteer basis making them more likely to be more motivated that other WLFFs and therefore results may not be generalized to the larger WLFF population.

Assumptions

1. The test instruments are appropriate for the target population and are valid and reliable measures of nutrient intake, body composition, and performance measures.
2. The participants will be able to understand the directions as they are intended.

3. The participants will complete the test instruments to the best of their ability.
4. The participants are a representative sample of WLFFs in the Pacific Northwest.
5. The researchers will be sufficiently trained and capable of administering the test instruments.

Definition of Terms

1. Wildland firefighter (WLFF) - a technical specialist who engages in wildland fire suppression activity.
2. Hotshot- a WLFF who endures extended periods of fire suppression and specialize in the use of hand tools.
3. Smokejumper- a WLFF who parachutes from a plane into remote and inaccessible areas and who is first to the scene of a wildfire.
4. Fire assignment- an extended period of wildland fire suppression activity.
5. Fire season- a period of wildland fire suppression activity in one year.
6. Dual X-ray Absorptiometry (DXA) scan- a measure of body composition including bone density, LM, and fat mass of an individual.
7. Fat Mass (FM)- the proportion of the human body comprised of subcutaneous and visceral fat.
8. Lean Mass (LM)- the sum of total body water, total body protein, carbohydrates, nonfat lipids, and soft tissue minerals, excluding all fat and bone.
9. Bone Mineral Density (BMD)- a measure of bone mineral in bone tissue.
10. Energy expenditure- the number of kilocalories necessary to support physiological function, basal metabolic rate, and exercise activity by an individual.
11. Nutrient intake- all food and beverages consumed in 24- hours.

12. Isokinetic testing- movement at the same speed.
13. Trunk inclination- the degree at which the trunk segment of the body is positioned relative to a flat surface

Chapter Two: Review of Literature

Introduction

Wildland firefighting is a unique occupation in which a combination of strength (anaerobic training) and endurance (aerobic training) activities are sustained for long durations in strenuous conditions (Sol et al., 2018). In the last 60 years nearly 10% of the land in the US has burned due to approximately 6 million wildfires (NIFC, 2015), placing a large demand on wildland firefighters (WLFF). Wildfire suppression efforts have been challenged by steady population growth and consistently high ambient temperatures (Theobald & Romme, 2007). Therefore, WLFFs face additional occupational risks including the protection of others, resources, and property (Britton, Lynch, Ramirez, Torner, Buresh, & Peek-Asa, 2013).

The typical wildfire season is from May to September (Lui et al., 2014). During this time, the work environment for WLFFs involves making abrupt adjustments to nutrient intake and hydration to account for changes in ambient temperature, moderate to high altitude, and an exercise load during 14-21 days of constant wildfire suppression (Ruby et al., 2003). Therefore, successful performance for WLFFs is difficult to quantify due to the variability in wildfire conditions and environment each year (Sol et al., 2018). WLFFs are tasked with performing arduous work in an instable and adverse occupational environment causing them to make rapid adjustments to meet their energy and fluid needs (Ruby et al., 2003). However, given the confines of a fire camp, the environment makes it difficult for WLFFs to meet their dietary needs and maintain energy balance (Ruby et al., 2003). Therefore, understanding WLFFs seasonal variations in nutrient intake is critical to determine the longitudinal implications of arduous wildfire suppression over time.

Smoke exposure, sleep restriction, and physiological strain are major health risks to WLFFs (O’Hara et al., 2014). Smoke exposure may be a significant health risk to WLFFs, according to the Environmental Protection Agency (Cascio, 2018) and is detrimental to human health (Reisen, 2011). Short- and long-term smoke exposure to ambient air pollutants such as nitrogen dioxide, trioxygen, and particulate matter have been identified to reduced insulin sensitivity and increase in atherogenic blood lipids (Chen et al., 2016). Smoke exposure during wildland fire suppression cannot be removed, however maladaptive changes may be influenced by smoke-induced proinflammatory or oxidative stress responses combined with chronic stress, insufficient sleep, and a high fat diet (Wolkow et al., 2016). Sleep restriction is a common adverse working condition among WLFFs due to compromised sleeping conditions, extended work shifts, and little rest between work shifts during wildfire suppression, leading to an increased risk of injury and metabolic disease (Vincent et al., 2017). Sleep restriction does not affect physical performance during simulated wildland firefighting (Vincent et al., 2017), however has elicited acute inflammatory responses (Deyle et al., 2011). Sleep of less than 5 hours per night has been linked to a 50% increase incidence of metabolic syndrome (Iftikhar et al., 2015).

The average Total Energy Expenditure (TEE) of WLFFs during wildfire suppression has been reported as 17.5±6.9 MJ/d to 19.1±3.9 MJ/d (2800-6200 kcal/d) (Ruby et al., 2002; Cuddy et al., 2015) During 5 days of wildfire suppression, WLFFs in Idaho demonstrated the highest consistent measures of TEE 20.6-26.2 MJ/day (4920-6260 kcal/day) compared to Montana, California, Florida, and Washington due to location and terrain of the fire (Ruby et al., 2002).

Occupational demands

WLFF occupational demands are arduous and strenuous and these demands require them to hike with fireline pack (11-16kg), fire shelter (2kg), pulaski fireline tool (2kg), and chainsaw (7-9kg) (Ruby et al., 2003). Additionally, WLFFs may be assigned a tool for the day, including a chainsaw (11.4 kg) or an alternative handtool (3.6 kg). The use of this equipment involves upper and lower body muscle strength and endurance (Ruby et al., 2003). WLFF equipment also consists of 4-6 liters of water, any additional hydration beverages, food items for 12-24 hours, and job task specific equipment (Sol et al., 2018). The primary physical task of WLFFs is to create a fire line which can be defined as a fuel break or a physical barrier between a wildfire and its path. Firelines are typically constructed with the use of hand tools such as Pulaskis, shovels, rakes, and chain saws to cut trees and brush (Semmens, Domitrovich, Conway, & Noonan, 2016).

WLFFs face many physical demands including long workdays (12-16 hours) in a dangerous environment, compromised sleeping conditions, and environmental conditions including heat, altitude, and low humidity (Butler, 2014; Cuddy et al., 2007; Heil, 2002; Ruby et al., 2002). Common duties while on a wildfire assignment include hiking with a load, cutting and clearing trees and brush, digging containment line, working with aviation resources, and conducting fireline operations to create breaks between burned and unburned areas (Sharkey & Rothwell, 1996). Each fire assignment is unique and exhibits its own stressors which depend on the location, size, ambient conditions of the fire (Cuddy et al., 2007). Additional stressors include the number of days a WLFF is on a fire and the severity of the fire (Vincent et al., 2017). Therefore, WLFFs must make rapid adjustments to environmental variables (ambient temperature, moderate to high altitude, strenuous activity) to meet demands of the job for consecutive days of work (14-21 days for 14-16 hrs/day) (Ruby et al., 2002). WLFFs stay at a base camp which is where they eat breakfast, dinner, and sleep. Typically, this includes loud generators, sleeping in tents, crowded areas, and catered meals (Cuddy et al., 2007). However, WLFFs may stay in a spike camp or closer to the fireline in a coyote camp. Therefore, physical fitness tests and work capacity tests have been utilized to determine if an individual has the appropriate fitness level to be a successful WLFF.

The Arduous Work Capacity Test

Various work capacity tests have been developed to determine WLFFs fitness requirements for occupational preparedness. These assessments include muscular strength and endurance tests of both the upper and lower body. The first tool used to assess job readiness was a modified Astrand-Rhyming step test (Sharkey, 1994). However, a more comprehensive tool was necessary to determine long-term work capacity for WLFFs. Therefore, the arduous work capacity test (arduous pack test) was developed as a minimum standard of employment for WLFFs to assure they can sustain 50% of their maximal aerobic capacity during day-long operations (Sharkey & Rockwell, 1996). The arduous work capacity test consists of a 20.5 kg load carriage on flat terrain for 45 minutes and estimates an average oxygen consumption of 22.5 ml/kg/min to test an individual’s ability to sustain a similar amount of energy compared to job related tasks. Although this test qualifies an individual for an average physical requirement, it may underestimate job related tasks in which an above average energy expenditure is required (Sol et al., 2018).

Wildland Firefighter Crew Types

Various types of WLFFs exist including engine crews, hand crews, helitack, hotshots, smokejumpers, and additional managerial positions. Engine crews consist of three to 10 firefighters who perform initial and extended fire suppression performing tasks including hose lay, fireline construction with hand tools, burnout operations, and mopping up (removing heat from the area to prevent further ignition). Smokejumpers and hotshots are highly trained elite WLFFs However, hand crews consist of 18-20 WLFFs primary duties include constructing fire lines, burning out areas, and rehabilitation of old burn areas. Additional WLFF crews such as helitack, hotshots, and smokejumpers are highly specialized. Helitack crews utilize helicopter operations. Specifically, the use of helicopters can offer support, cargo, drop water, and transport personnel to wildfires. Smokejumpers are WLFFs who parachute from planes into remote and inaccessible areas and are typically first to the scene. Specifically, smokejumpers have high physical fitness standards, rigorous training, and canopy manipulation training. Smokejumpers are most often the initial attack, which is considered the most arduous task for WLFF.

Interagency hotshot crews (IHC) are comprised of 20-22 individuals who have career and temporary employment, with advanced firefighter qualifications, and have a reputation for being highly skilled professional WLFFs (Committee NIHCS, 2016). IHCs are a national resource and may be sent anywhere in the United States to assist with wildland fires (Sol et al., 2018). IHCs work shifts are frequently 12 or more hours in which crew members pack water, food, and supplies accordingly. Furthermore, Type 1 IHCs are some of the most experienced WLFFs in the United States and likely perform at a metabolic demand (as represented by $VO_{2\,max}$ estimates) greater than that of the arduous work capacity test (Sol et al., 2018).

Type 2 crews consist of 2-30 individuals (National Multi-agency Coordinating Group, 2017). Type 2 crews can include a twenty-person crew, initial attack, or a 3-5-person engine crew (National Multiagency Coordinating Group, 2017). The use of global positioning system (GPS) tracking has been utilized to record hiking distance, duration, and speed across diverse wildfire assignments (Sol et al., 2018). Type 2 crews carry less weight (4kg, $p<0.01$) and less weight relative to body mass compared to IHCs (Sol et al., 2018). However, IHCs hike more slowly compared to Type 2 crews (0.8±0.0 m/s and 0.9±0.0 m/s, $p=0.01$, respectively) (Sol et al., 2018). Females typically account for 10-15% of the WLFF population (Sol et al., 2018). Additionally, female WLFFs are shorter, weigh less, and carry less weight than male WLFFs (169±9 cm vs 179±8 cm, 67.8±9.3 kg vs 84.8±11.0 kg, and 22.9±4.9 kg vs 27.1±7.0 kg, for females and males, respectively, $p<0.01$), however there were no significant differences in hiking speed between sexes (Sol et al., 2018). Therefore, wildland firefighting requires a range of metabolic demands and may vary across crew types.

Physiological Demands of Hiking in WLFFs

A recent study by Sol et al (2018) delineated various types of hiking during wildfire assignment which have been classified into 4 main categories: ingress, shift, egress, and training hikes. Ingress hikes include any morning hike to wildfire assignment from crew vehicle or camp. A shift hike includes hiking during the work shift between ingress and egress hikes. Whereas an egress hike consists of leaving the fireline or work site back to the vehicles or camp in the evening. Training hikes are considered self-selected location and intensity hikes next to crew home base or district not on a wildfire assignment but wearing line gear pack and full Personal Protective Equipment (Sol et al., 2018).

Overall, heart rate during ingress hikes were significantly higher than egress hikes, however lower than training hikes ($p<0.01$) (Sol et al., 2018). However, core temperature was lower during ingress hikes compared to shift, egress, and training hikes ($p<0.01$) (Sol et al., 2018). Type 2 crews had a lower heart rate during ingress, shift, egress, and training hikes combined (124±23 vs 126±25 bmp, respectively, $p<0.05$), indicating various WLFF types demonstrate different physiological response to different hiking types (Sol et al., 2018).

Estimated VO_{2max}, from 84 hours of observed hiking was higher during ingress hikes compared to shift and egress hikes, and lower during training hikes ($p<0.01$) (Sol et al., 2018). All crew types spent approximately 60% of their time on a fire assignment at a lower VO_2 than the estimated VO_2 during the arduous pack test (<22.5 ml/kg/min) and 40% of their hiking time at a heart rate of 120 bmp or lower. However, IHCs spent 88% of their training hikes at >120bmp, with 47% of that time at a heart rate >160 bmp. Approximately 10-20% of the time on a wildfire assignment was spent at a VO_2 >35 ml/kg/min, or 50% higher metabolic demand compared to the arduous pack test. During training hikes, IHCs spent 78% of the time at a higher metabolic demand compared to the arduous pack test. Therefore, WLFF training hikes, during the pre-season, are of critical importance in maintaining physical fitness during the wildfire season as well as preparedness for wildfire assignments.

Despite the high metabolic demands of hikes during a wildfire assignment, no WLFF exceeded a core temperature greater than 39.5°C (103.1°F) (Sol et al., 2018). However, IHCs spent 36% of training hikes with a core temperature greater than 38.5°C (101.3°F) and 9% greater than 39.5°C (103.1°F). Additionally, during simulated escape route evacuations, participants who were not carrying a pack exhibited significantly faster transit time for men and women (21.5 and 26.3%, respectively) (Ruby et al., 2003). Additionally, mean VO_2 was higher for males during the no pack trial compared to the line gear pack trial (46.0±6.1 ml/kg/min and 41.1±6.0 ml/kg/min, respectively). Furthermore, the difference in blood lactate was significantly higher during the line gear pack trail compared to the no pack trial (9.8±4.8 mmol/L and 5.8±2.2 mmol/L, respectively), indicating a greater anaerobic contribution when hiking with a line gear pack. Aerobic fitness contributes to transit time during simulated escape route evacuation, as demonstrated by high correlations between peak VO_2 and transit rates (r=0.82 and r=0.87 for pack and no pack trials, respectively) Therefore, aerobic fitness is a critical determinant of work output and safety during wildfire suppression.

Physiological Effects of Wildfire Suppression

WLFFs face many operational stressors which may impact physiological and cardiovascular health. Coker et al. (2019) collected blood measures at the beginning and end of a wildfire season because it was hypothesized these measures are influenced by the demands of the wildfire season. Results from the study include an increase in total cholesterol from 161.8±28.1 mg/dL to 179.9±33.5 mg/dL ($p<0.05$) and an increase in LDL from 85.7±22.5 mg/dL to 100.3±31.5 mg/dL ($p<0.05$; beginning to end of fire season) ($p<0.05$) (Coker et al., 2019). No change was identified in VLDL (18.4±10.7 mg/dL to 21.8±8.1 mg/dL), HDL (54.7±18.9 mg/dL to 57.5±15.7 mg/dL), and glucose (87.0±5.7 mg/dL to 89.3±7.2 mg/dL) (Coker et al., 2019).. Therefore, the arduous conditions in which WLFFs are subjected to during the wildfire season may pose negative physiological effects. The impact of multiple seasons of wildland firefighting remains unknown. These results demonstrate a decline of cardiovascular and metabolic health indices from pre to post fire season (Coker et al., 2019). Additionally, negative hepatic function has been attributed to increased globulin and decreased albumin/globulin ratio to direct bilirubin, as markers of inflammation during the fire season (Coker et al., 2019). Possible influences of dysregulated lipid metabolism include nutrient intake, stress response, smoke exposure, and/or potential detraining (Coker et al., 2019). Furthermore, a decreased bilirubin profile is consistent with oxidative stress and chronic inflammation (Djoussé et al., 2001). Therefore, it may be concluded that the wildfire season may have negative physiological effects on WLFF metabolic health.

Macronutrient Intake Recommendations

Greater nutrient intake requirements exist to support the additional energy spent during training and exercise for athletes compared to the general population (Burke et al., 2011; Phillips & van Loon, 2011). Inadequate nutrient intake can have detrimental implications on performance and cognitive function (Thomas et al., 2016). However, nutrient recommendations vary considerably across populations and remain unclear for WLFFs.

WLFFs participate in a variety of self-selected nutritional and physical activities during a wildfire assignment (Cuddy & Ruby, 2011). WLFFs are exposed to unpredictable field stress and adverse environment including altitude, rugged terrain, and high ambient heat during wildfire suppression, which requires WLFFs to make abrupt adjustments to their nutrient intake and hydration (Ruby et al., 2003). WLFF sources of nutrient intake while on a wildfire assignment include catered breakfast and dinner of unlimited portions, as well as a prepared sack lunch, or field rations that may include military MRE or other backpack-oriented meals when crews are self-support (Cuddy et al., 2007).. The typical sack lunch during wildfire suppression contains 3.8-8.7 MJ (902-2086 kcals) (Cuddy et al., 2007; Marks et al., 2020). Additionally, some WLFFs bring other food items such as food bars, dried meats, or sports drinks to supplement their diet (Cuddy et al., 2007). However, these items are not always available due to extraneous variables including cost, policy, and location of the fire, which may negatively impact WLFFs and result in a negative energy balance, fatigue, work rate, and ultimately safety (Cuddy et al., 2007).

Due to the increased physiological demands of strenuous activity, physically active individuals, such as WLFFs, require additional nutrition to support optimal performance (Thomas et al., 2016). Previously reported WLFF energy demands consist of an average of 2800-6200 kcal/d (Ruby et al., 2002; Cuddy et al., 2015). Additionally, the average kilocalorie intake during the work shift has been quantified as 3.8-8.7 MJ/d 902-2086 (Marks et al., 2020). (Ruby et al., 2002) Previous literature has demonstrated WLFF nutrient intake is low in carbohydrates (<45-65% total intake) and high in fat (>20-35 % total intake) (Ruby et al., 2002; MArks et al., 2020; Cuddy et al., 2011; Montain et al., 2008). Therefore, there may be an opportunity for WLFF nutrition education efforts to specifically reduce the negative implications of chronic inadequate nutrient intake.

Carbohydrate Metabolism & Needs

Carbohydrates provide essential fuel for cognitive function, central nervous system, and working muscles and are the quickest form of usable energy for skeletal muscle and the brain. Carbohydrate stores are limited but can be manipulated by daily intake of carbohydrate rich foods. Subsequently, carbohydrate store depletion results in fatigue, decreased work rate, and compromised concentration (Thomas et al., 2016). The average carbohydrate intake for WLFFs has been quantified as 6.9 g/kg/day and may be inadequate to maintain glycogen stores for 12-16 hrs of wildfire suppression for five days (Ruby et al., 2002). Additionally, Cuddy et al (2011) demonstrated the food provided on a wildfire assignment was inadequate to maintain muscle glycogen levels between pre and post work shift.

The water requirement for glycogen storage is three grams per gram of ^2H_2O. Therefore, WLFF loss of total body water (TBW) may be attributed to glycogen depletion during wildfire suppression (Ruby et al., 2003). When glycogen levels are suppressed, protein degradation is increased (Blomstrand & Saltin, 1999). Muscle glycogen storage can be increased significantly with the addition of protein to a carbohydrate supplement (optimal 4:1 carbohydrate to protein ratio) due to the added advantage of decreasing post-exercise skeletal muscle damage promoting muscle protein accretion (Ivy, 2004). Therefore, if muscle glycogen levels are not maintained through nutrient intake, protein degradation will increase and may result in loss of LM (Ruby et al., 2003) The subtle difference between body mass and TBW (1.0 and 0.l9 kg, respectively) in WLFF during 5 day wildfire suppression and LM (1.3 kg) may be due to glycogen depletion from inadequate carbohydrate intake or increased protein degradation (Ruby et al., 2003).

Muscle glycogen decreased from pre to post wildfire work shift from 101±7 to 80±5 mmol/kg wet weight ($p<0.05$) (Cuddy et al., 2011). A high carbohydrate diet, containing 6-10 g/kg, is recommended for individuals engaging in intense training or physically demanding work, such as WLFFs (Achten & Jeukendrup, 2004; Montain et al., 1997; Montain & Young, 2003). A study by Cuddy et al., demonstrated liquid and solid carbohydrate sources increased self-selected work rate in WLFFS, compared to a placebo (Cuddy et al., 2007). Subjects during the carbohydrate trial demonstrated significantly higher ($p<0.05$) mean counts per hour the entire day compared to the placebo (CHO: 50,262±36,560, placebo: 40,159±35,969 counts per hour for 12 hours) (Cuddy et al., 2007). Additionally, activity counts during hours

2-5 and 7-12 were significantly higher than hour 1 ($p<0.05$). Furthermore, blood glucose was significantly elevated compared to pre-breakfast values at all time points during the day for the carbohydrate trial (Cuddy et al., 2007). Therefore, supplemental carbohydrate rich foods throughout the workday may result in a greater availability of carbohydrates, thus a maintenance in work output.

Protein Metabolism

Protein requirements in an athletic population often exceed the Recommended Daily Allowance (RDA) for the average population, however, optimal protein intake for occupational performance remains unknown. The RDA, for protein, for the general population has been determined as 0.8 g/kg/day. However, occupational athletes, including WLFFs, who are regularly involved in endurance and/or resistance training require additional protein in the diet to stimulate muscle protein synthesis and prevent muscle protein breakdown (Lieberman, 2003). Ingestion of essential amino acids (approximately 10g), either free or as part of a 20-40 g protein bolus, has been shown to maximally stimulate muscle protein synthesis (Kerksick et al., 2008). Dietary records indicate WLFF self-selected food at fire camps includes higher protein and fat than is recommended for arduous work, thereby reducing carbohydrate intake for on 5-day fire assignment (2.2±0.6 and 1.7±0.5 g/kg/d , for men and women respectively) which is similar to the recommended intakes (approximately 1.8 g/kg/d) for this type of work/exercise (Lemon, 2000; Ruby et al., 2002). Additionally, recent data by Marks et al., also demonstrated WLFFs relative protein intake is adequate (1.8 g/kg/d) (Marks et al., 2020).

Micronutrient Intake & Recommendations

Vitamins and minerals are critical components of many metabolic processes within the human body (Volpe, 2007). Previous literature suggests athletes require additional vitamins and minerals to support metabolic processes and rapid tissue growth and repair compared to sedentary individuals. Specifically, the intensity, duration, and frequency of activity may dictate the overall metabolic demands and necessity for increased amounts of specific vitamins and minerals (Kimura et al., 2003; Volpe, 2007). Electrolyte and fluid balance during wildfire suppression is critical to maintain work output and avoid health complications such as rhabdomyolysis, renal distress, hyponatremia, and heat exhaustion (Buller et al., 2008; Cuddy et al., 2007; Moran et al., 1998). Specifically, sodium, calcium, potassium, chloride, phosphate, and magnesium play essential roles in maintaining fluid balance during strenuous activities.

Dietary References Intakes (DRIs) refer to all vitamins and essential minerals required by the human body to support healthy function (Taylor & Meyers, 2012; et al., 2000; Whiting & Barabash, 2006). DRIs encompass RDA and Adequate Intakes (AI). The RDA provides adequate micronutrients to support 98% of the US population's health, whereas the AI is a speculated value used when an RDA cannot be determined. When overall energy intakes are sufficient to support an individual's activity level, most individuals' micronutrient requirements may be met. However, if energy intakes are not adequate to support strenuous activity, micronutrient intakes may not be sufficient. Therefore, it is critical to determine if WLFFs consume the recommended amount of micronutrients to support overall health and wildfire suppression's physical demands. However, a lack of knowledge on micronutrient intakes for WLFFs exists.

Nutrient Timing

Nutrient timing incorporates the use of intentional preparation and eating whole foods, fortified foods, and dietary supplements (Kerksick et al., 2008). The timing of nutrition is imperative for supporting the body during times of increased demands of training and performance. Timing of food consumption, specifically protein and carbohydrate, is warranted for firefighters to meet the high energy demands (Cuddy et al., 2007). The timing of nutrient intake and the ratio of certain ingested macronutrients may enhance recovery and tissue repair and augment muscle protein synthesis following high volume or intensity exercise (Kerksick et al., 2008). Endogenous glycogen stores are maximized by a high carbohydrate diet (8-12 g/kg/day), whereas these stores may be depleted most by high volume exercise (Kerksick et al., 2008). If rapid restoration of glycogen is required (<4 hours recovery time), then the following strategies should be considered: aggressive carbohydrate refeeding post exercise bout (1.2 g/kg/hr) with a preference towards carbohydrate sources that have a high glycemic index (>70), the addition of caffeine (3-8 mg/kg), and a combination of carbohydrate (0.8g/kg/hr) and protein (0.2-0.4 g/kg/hr) (Kerksick et al., 2008).

Extended bouts of high intensity (>60 mins and >70% VO_{2max}) challenge fuel and fluid regulation, thus carbohydrate should be consumed at a rate of 30-60 g of carbohydrate/hr in a 6-8% carbohydrate electrolyte solution (6-12 ounces) every 10-15 minutes throughout the entire exercise bout, particularly if the exercise bout is greater than 70 mins (Kerksick et al., 2008). When carbohydrate delivery is inadequate, adding protein may help ameliorate muscle degradation, promote euglycemia, and facilitate glycogen resynthesis (Kerksick et al., 2008). Meeting the total daily intake of protein should be the primary emphasis for exercising individuals. Specifically, consumption of protein (20-30g) in evenly spaced feedings approximately every 3 hours throughout the day, has demonstrated the most effective method for protein consumption while maintain satiation (Kerksick et al., 2008). Specifically, during wildfire suppression efforts, WLFFs, have utilized supplemental feeding strategies to deliver nutrients while in the field. Individuals have demonstrated an increased ability to sustain physical work, greater than 2 hours, through supplemental feedings (Cuddy et al., 2007). Therefore, supplemental carbohydrate during wildfire suppression is critical for maintaining nutrient intake and work output. However, nutrient timing and intake should be tailored to the shift requirements. Specifically, during staging, lookout, or low intensity fireline work, minimal hourly intake is necessary, whereas during more difficult line construction and extended load carriage supplementals commensurate with the intensity.

Dietary Intake Methodologies

Many methodologies exist for estimating dietary intakes in human subjects (Johnson, 2002). However, due to the large variation in nutritional status and dietary intake in individuals it is difficult to develop a precise self-reporting tool (Toorang et al., 2019). Most commonly, tools such as food frequency questionnaires, food records/logs, and 24-hour diet recalls rely on self-reported information provided by subjects themselves (Johnson, 2002). Food frequency questionnaires are used to provide estimates of dietary intake over a specified time period, which may vary from one month to one year (Johnson, 2002). Whereas, food records/logs have been used to estimate an individual’s dietary intake for 3-7 days (Johnson, 2002). Furthermore, the 24-hour recall was designed to estimate current dietary intake. However, the 24-hour recall may not be reflective of an individual’s dietary intake. Inherent error exists when relying on self-reported data due to frequent over reporting of food perceived as “good” and underreporting of foods perceived as “bad” (Lichtman et al., 1992;

Nelson et al., 1997; Pendergast et al., 2017). Therefore, biomarkers, such as urine, have been used to validate self-reported dietary intake data through objective measures. Various methodological techniques have been utilized to capture WLFF nutrient intakes during wildfire suppression (Ruby et al., 2002; Montain et al., 2008; Marks et al., 2020). Most recently, nutrient intake was quantified during wildfire suppression in which a trained researcher followed a subject and recorded their dietary intake during the work shift (Marks et al., 2020). Additionally, plate waste was recorded to quantify nutrient intake during catered breakfast and dinner meals (Marks et al., 2020).

Thermoregulation & Fluid Balance

Sweat rate can vary considerable between individuals due to antidiuretic hormone (ADH) signaling to the hypothalamus to reabsorb water in the kidneys. Additionally, aldosterone production in the kidneys increases sodium reabsorption from the extracellular fluid and water. This can be controlled through the renin-angiotensin-aldosterone feedback system. The hydration demand, as calculated from water turnover rates of ^2H_2O elimination (a dynamic measure of water flux in and out of the total body water pool), of WLFFs is extreme and amounts to minimal ingestion of approximately 6-8 L of water per day from beverages and food sources (Ruby et al., 2003). Additionally, WLFF fluid demands can be an average of 6.7±1.4 L/d due to 12-16 hours of physical labor per day in hot and unpredictable environments (Ruby et al., 2003). However, when water turnover as expressed relative to total body mass, values range from 74.0 to 136.8 ml/kg/d for WLFFs, exceeding those reported during trekking, at moderate altitude and mountaineering at high altitude ascent and descent (79±17 ml/kg/day; 73±20 ml/kg/day; and 83±17 ml/kg/day, respectively (Westerp et al., 1992). Possible explanations for extreme water turnover rates of WLFFs include high ambient temperatures, adverse weather conditions, individual sweat rates, and elevated energy expenditure (Ruby et al., 2002).

WLFF can lose an average of 0.9 kg TBW during 5 days of wildfire suppression, which impacts body composition, and may result in deflated LM values (Ruby et al., 2003) However, hydration status, as measured by urine specific gravity (USG) and osmolality, is unable to accurately detect actual changes in whole-body hydration and TBW (Ruby et al., 2003). During 5 days of wildfire suppression, urine specific gravity (USG) values were significantly higher ($p=0.01$) in recreationally active college students (RACS) compared to WLFFs (1.017±0.006 and 1.023±0.007, respectively). Additionally, urine osmolality was significantly higher ($p=0.049$) in RACS compared to WLFFs (596±196 and 751±244 mOsmol, respectively) (Ruby et al., 2003).Therefore, it can be suggested that WLFFs are competent in adjusting daily water intake to nearly meet their hydration demands during acute periods of wildfire suppression (Ruby et al., 2003).

WLFF who consumed water versus water and electrolytes during one day of wildfire suppression demonstrated no significant differences between groups for body mass, drinking frequency, temperature, activity, or USG from pre to post shift (1.019±0.007 to 1.023±0.010 vs 1.019±0.005 to 1.024±0.009, respectively; $p<0.05$) (Cuddy et al., 2008). However, body mass decreased from pre to post shift (78.1±13.3 and 77.3±13.3 kg, respectively; $p<0.05$) (Cuddy et al., 2008). The group consuming water only consumed significantly more fluid during the work shift compared to the water and electrolyte group (504±472 vs 285±279 ml/hr, respectively; $p<0.05$) (Cuddy et al., 2011). The addition of an electrolyte mixture to plain water decreased the overall fluid consumption by 220 ml/h (3.3 L/day) for WLFFs during a work shift on a wildland fire assignment (Cuddy et al., 2008). However, the addition of electrolytes to plain water may decrease the amount of fluid necessary to consume as well as minimize carrying excessive weight, thereby possible reducing fatigue during wildfire suppression (Cuddy et al., 2008). Mean core temperature during 3 days of wildfire suppression was 37.6±0.2 °C, mean chest skin temperature was 34.1±1.0 °C, and mean heart rate was 112±13 bpm (Cuddy et al., 2015). Therefore, WLFFs fluid needs may be met with plain water, whereas electrolyte replacement must be further investigated. Additionally, electrolytes in food items contribute to total sodium intakes during wildfire suppression. A recent study by Marks et al. demonstrated WLFFs dietary intake of sodium as 6513±3555 mg/d (Marks et al., 2020). Sodium intake during periods of large total body water loss may not be detrimental to overall health.

Hydration status may be of critical concern for WLFF due to high ambient temperatures, dry conditions, and sustained physical work outputs. Water turnover rates of an average of 6.7±1.4 L/day (94.8±24.1 ml/kg/day), with an associated loss of 1 kg body mass, and 0.9 kg loss in total body water during 5 days of wildfire suppression (Ruby et al., 2003). Adequate hydration can be achieved through water consumption, however liquid carbohydrate provides both fluids and calories for sustained activity which may be beneficial when intake of other food items is less accessible or tolerable.

Body Composition

Body composition is a term used to describe an individual’s tissue components, fat mass (FM), lean mass (LM), and bone mineral density (BMD). Many factors effect an individual’s body composition including genetic predispositions, nutrient intake, and physical activity. LM, or skeletal muscle mass, is necessary for daily function and performance (Margolis et al., 2016). In order to maintain skeletal muscle mass, positive energy balance must be achieved through nutrient intake meeting the demands of training. If negative energy balance occurs, skeletal muscle or adipose tissue may be used for energy during exercise (Margolis et al., 2016). Therefore, protein intake is critical for preserving skeletal muscle through protein synthesis. Skeletal muscle protein may be broken down into amino acids, which are precursors for energy metabolism. Antonio et al. (2015), has demonstrated that a high protein (3.4 g/kg/day) diet in conjunction with resistance exercise can positively alter body composition, compared to a moderate or low protein diet. Specifically, individuals on a high protein diet exhibited greater increases in LM, a greater loss in FM, and a decreased body mass between pre-and post-testing, compared to the normal protein group (Antonio et al., 2015). Therefore, WLFFs may require additional protein, above the recommended daily allowance (RDA=0.8 g/kg/d) intake for optimized skeletal muscle mass during bouts of vigorous activity.

Diets primarily focused on FM losses are derived by a sustained caloric deficit (Aragon et al., 2017). Slower rates of weight loss can preserve LM in lean subjects (Aragon et al., 2017). Diets focused on accruing LM are derived by a sustained caloric surplus to facilitate anabolism and support increasing resistance training demands, however the magnitude of caloric surplus and training status of the individual can influence the desired body composition (Aragon et al., 2017). Increasing dietary protein beyond current recommendations for athletic populations may result in an improved body composition, specifically increases in LM and lower FM. Specifically, high protein intakes (2.3-3.1 g/kg FFM) may be required to maximize LM retention. Additionally, protein intakes as high as 3 g/kg have demonstrated thermic, satiating, and LM preservation (Aragon et al., 2017).

Dual x-ray absorptiometry (DXA) has been used to assess WLFF body composition pre and post fire season to measure LM and FM (Coker et al., 2019). On an average of 63±10 days on wildfire assignments WLFFs weight significantly increased from 78.7±12.8 kg to 79.7±12.3 kg ($p<0.05$), body mass index (BMI) significantly increased from 23.9±2.7 kg/m^2 to 24.5±2.7 kg/m^2 ($p<0.05$), total fat mass significantly increased 12.4±5.2 g to 13.9±4.9 g ($p<0.05$), and visceral fat significantly increased from 318±47 g to 419±48 g from pre fire season to post fire season ($p<0.05$) (Coker et al., 2019). There were no differences in total LM, arm lean soft tissue, or leg lean soft tissue between pre and post fire season. Additionally, no changes in upper thigh muscle area were observed ($p<0.05$) (Coker et al., 2019). However, a recent study by Gaskill et al. demonstrated a significant decrease in weight, FM, and LM from pre to post fire season (Gaskill et al., 2020). Therefore, it can be concluded body composition may change as a result of the fire season.

Additionally, WLFF body composition has been calculated from ^2H_2O dilution and skinfold methodologies (Ruby et al., 2003). Prior to 5-d of wildfire suppression WLFFs FFM and FM were 58.8±9.9 kg and 13.1±5.0 kg, respectively. WLFFs demonstrated a significant decrease in FFM across 5-d of wildfire suppression using ^2H_2O dilution ($p=0.0001$) and skinfold ($p=0.03$) methodologies, whereas RACS maintained FFM (^2H_2O dilution, $p=0.54$; skinfold $p=0.16$) (Ruby et al., 2003). FM calculated using ^2H_2O dilution was significantly higher compared to skinfold assessment at all time points in both groups ($p<0.05$), however neither group demonstrated a significant changes in FM across the experimental period (Ruby et al., 2003). However, variations in ^2H_2O dilution and skinfold methodologies may be responsible for these reported differences in FM.

WLFF tend to lose total body mass and total body water, even during acute periods (5 d) of wildfire suppression (Ruby et al., 2003). During 5-d wildfire suppression, the average body mass loss was 1.4±0.5 kg (Ruby et al., 2002). Following 5-d wildfire suppression, WLFFs demonstrated a significant (p=0.0001) decrease in total body mass and TBW (p=0.005) (Ruby et al., 2003). Therefore, pre-season, post-season, and in the off-season are critical timepoints to determine longitudinal impacts of alteration in WLFFs body composition. Specifically, the off-season measure is new to existing literature. It has been established that abnormal seasonal changes occur as a result of the wildfire season as shown by increased FM. However, body composition alterations during the off-season remain unknown.

Energy Expenditure

The amount of energy utilized by the body is known as energy expenditure (Mountjoy et al., 2014). Total daily energy expenditure includes resting energy expenditure and exercise energy expenditure where resting energy expenditure consists of the energy required for basal metabolic processes (Mountjoy et al., 2014). In contrast, exercise energy expenditure is the amount of energy used during physical activity (Ruby et al., 2002). WLFFs demonstrate a consistently high energy expenditure on a wildfire assignment (Ruby et al., 2002). Energy expenditure associated with physical activity (EEA) was 8.8±3.0 MJ/day for days 1-3 and 8.9±6.1 MJ/day for days 4-5 (Ruby et al., 2002). Understanding the specific physiological demands, such as energy expenditure, of wildland firefighting is necessary to minimize the occupational health and safety risks as well as provide proper nutrient intake recommendations. Extreme environmental circumstances may contribute to a negative energy balance impairing skeletal muscle mass maintenance, which may result in a decreased performance.

The doubly labeled water technique is the gold standard for measuring total energy expenditure in free-living individuals (Schoeller, 1999; Westerterp, 1999). Additionally, total energy expenditure (TEE) during wildfire suppression has been quantified as 17.4±3.7 MJ/d to 19.1±3.9 MJ/d using the doubly labeled water technique (Ruby et al., 2002; Cuddy et al., 2015). Variation in TEE is dependent on many factors including the location of the fire, type of terrain, work task, hiking volume, and fireline construction tasks (Ruby et al., 2002). TEE of WLFFs can increase up to 3.6 times basal metabolic rate (BMR) due to challenged energy balance during arduous and extended fire assignments. However, TEE during 5-d wildfire suppression is primarily dependent on the terrain and daily shift length (Ruby et al., 2002). TEE was 17.4±3.7 (3,274-5,043 kcal/d) during days 1-3 on a wildfire assignment and 17.5±6.9 MJ/day (2,533-5,832 kcal/d) for days 4-5 (Ruby et al., 2002). TEE on the fire line may be impacted by body size, sex, self-selected work rate, job assignment, and topography of the fire assignment and may approximate nearly three times estimated resting metabolic rates (11.4-26.2 MJ/d or 2868-6214 kcal/d) (Cuddy et al., 2007, 2011, 2015; Ruby et al., 2002). The average steady-state energy expenditure, as measured through job comprehension analyses, is approximately 7.5 kcal/min during (22.5 ml/kg/min) during job tasks (Sharkey, 1999). WLFFs face a large range of metabolic demands during wildfire operations due to the variability in the amount of load carried, terrain, speed of traverse, and grade (Cuddy et al., 2015).

Body composition is impacted by a positive and negative energy balance and may be due to variations in eating environment, dietary food choices, and work output (Cuddy et al., 2007; Ruby et al., 2002; Sol et al., 2018). Rapid adjustments to environmental variables (ambient temperature, altitude, exercise) are necessary to meet demands of the job for consecutive days of work (14-21 days for 14-16 hrs/d) (Ruby et al., 2003). Energy balance during arduous wildfire suppression is largely dependent on food availability given the complexity of fire camp (Ruby et al., 2003). WLFF exhibit a negative energy balance based on significant decreases in BM and LM, however nearly all BM changes can be attributed to calculated loss in TBW during the fire season (Ruby et al., 2003). WLFFs with an average defect of only 5-10 MJ/d may cause a negative energy balance (Ruby et al., 2003). However, carbohydrate balance as a result of negative energy balance may be of concern due to implications on muscle glycogen.

Biomechanics of Wildfire Suppression

Limited research has identified specific tasks preformed during wildfire suppression which pose significant musculoskeletal demands on WLFFs. Specifically, Neesham-Smith et al (2013) identified fireline construction as very posturally demanding with 86% of time spent in severe sagittal trunk flexion (>45%) (Neesham-Smith et al., 2014). When severe trunk flexion occurs, the mass of the upper body is supported by a passive extension moment causing viscoelastic creep within the spine (Shin et al., 2007)**.** However, if sustained for an extended period, the spinal column may become lax leading to injuries including intervertebral subluxation, ligament rupture, facet fracture, or vertebral compression (Adams & Dolan, 2005; McGill, 1992, 1997; Shin et al., 2007; Solomonow, 2004)**.** Previous literature has identified the optimal recovery time from viscoelastic creep of the spine as 6-7 times the duration of exposure (Hoops et al., 2007; Le et al., 2007)**.** Therefore, tasks such as the line dig may necessitate work-to-rest ratios allowing for adequate recovery time in severe trunk flexion positions. However, such work-to-rest ratios may not be feasible during fire line construction depending on the personnel available, terrain, and severity of the fire. Therefore, training interventions focused on strengthening the trunk may be beneficial to prevent injury during fire line construction

Conclusion

The occupational demands of wildland firefighting are arduous and strenuous (Ruby et al., 2002; Sol et al., 2018; Cuddy et al., 2015). WLFFs must make rapid adjustments to their nutrient intake and energy expenditure to adapt to environmental conditions (Ruby et al., 2003). The average nutrient intake, as represented by kilocalories, on a wildfire assignment has been determined as 17±3.9 MJ/d for men and 13.5±3.0 MJ/d for women (Ruby et al., 2002). However, the average energy expenditure during wildfire suppression has been identified as 12.6-26.2 MJ/d (3000-6260 kcal/d (Ruby et al., 2002) . Given the ranges of previously reported nutrient intake and energy expenditure, some WLFFs may be above and below an adequate energy balance. Therefore, subsequent body composition changes may occur across a wildfire season due to inadequate maintenance of energy balance. The off-season consists of a time period in which occupational demands are not present for WLFFS and a detraining effect may occur causing them to be unprepared for the strenuous nature of the fire-season. However, longitudinal analysis of nutrient intake, body composition, and performance measures have not been examined pre fire season, post fire season, and off season in WLFFs.

Chapter Three: Research Design & Methodology

Participants

WLFFs (N=30) from the United States Forest Service (USFS) bases in Idaho were recruited to participate in the study. Specifically, purposive sampling was used to obtain various type 1 and type 2 WLFFs including smokejumpers, hotshots, helitack, engine crew and handcrew members.

Inclusion & exclusion

Participant eligibility was based on the requirements to fulfill the WLFF job position (i.e., arduous work capacity test and physical fitness testing). Participants included males and females, ages 18-57 years, and were included in the study if they meet all of the following requirements: 1) current WLFF between the ages of 18-57, 2) had no contraindications to exercise based on the American College of Sports Medicine and American Heart Association (ACSM/AHA) risk stratification criteria including uncontrolled hypertension, currently taking blood pressure medications, or have been diagnosed with cardiovascular disease, stroke, diabetes, thyroid, or kidney dysfunction, 3) had no risk factors for cardiovascular disease as determined by ACSM guidelines, and 4) had no significant musculoskeletal injuries or other medical conditions over the past 6 months.

Procedures

Recruitment & Compliance

Thirty WLFFs were recruited to participate in the study. Researchers visited WLFF bases to recruit participants two weeks prior to beginning the fire season. USFS national approval was received prior to participant recruitment. Recruitment involved a brief explanation of the study and the time commitment required. Using a contact list of the USFS bases in Idaho, researchers began contacting base managers and overhead personnel to discuss the study. Those interested in participating were asked to complete an interest form and to provide contact information. Participants were given a plain language statement and consent form to sign prior to participation (Appendix A). Participants were incentivized to participate in three lab visits in one year. Each participant received a series of gifts valued at $100 upon completion of segments of the study. Furthermore, they received a $30 gift after the second laboratory visit and $70 gift upon completion of the third laboratory visit. Participant identity was kept anonymous and limited to researchers only. The University of Idaho Institutional Review Board reviewed and approved this study.

Laboratory testing

Laboratory visits occurred at the Human Performance Laboratory (HPL) at the University of Idaho (UI) at 3-time points: visit 1 in June (Pre: pre-season), visit 2 in October (Post: post-season), visit 3 in February (Off: off-season). Laboratory testing included anthropometric measures, a dual energy x-ray absorptiometry (DXA) scan, performance testing, and the Diet History Questionnaire completion (DHQ-III). Participants were asked to arrive to the HPL between the hours of 0800-1200, abstaining from exercise, caffeine and/or alcohol use, and nutritional supplements for 24 hours prior to their testing appointment.

Dual Energy X-ray Absorptiometry scan

Upon arrival to the HPL, participants completed a medical history questionnaire (Appendix B), and participants' body composition was measured using dual x-ray absorptiometry (DXA; Hologic Inc., Horizon W QDR Series, Bedford, MA, USA). Prior to the scan, participants wore athletic clothing in which height and weight were measured using a stadiometer and digital clinical scale (Detecto Apex model; Webb City, MI). The DXA was calibrated daily using a phantom spine provided by the manufacture. Each DXA scan included one anteroposterior view of the whole-body lying supine. Measurements including lean mass (LM; % and kg), fat mass (FM; % and kg), visceral adipose tissue (VAT; g), appendicular skeletal mass (ASM; kg), appendicular skeletal muscle mass index (ASMI; kg/m^2), and bone mineral density (BMD; t-score), were obtained for analysis (Appendix C).

Performance testing

Performance testing included a series of muscular strength and endurance measures including a load-carriage treadmill test, isokinetic shoulder flexion and extension, isokinetic knee flexion and extension, and a kettlebell handgrip test.

For the load-carriage treadmill test, participants were fitted with a 58-pound backpack. A custom cluster full body marker set was used for motion capture during the load-carriage test. Reflective markers were attached to bony landmarks to represent body segments. The cluster-based makers were placed on thigh and shank segment and secured by elastic wraps (SuperWrap, fabrifoam®, Applied Technology International, Ltd., Exton, PA, USA). The three-dimensional motion capture system (VICON Motion Systems Ltd., Oxford, UK) was used to capture the test with an 8-infrared camera (VANTAGE 5, VICON Motion Systems Ltd., Oxford, UK). Next, participants were instructed to warm-up on the treadmill for 3 minutes. To prevent participants from tripping, or falling, subjects were instructed to look at a focal point in front of them during the trials. Following the warm-up participants began the first condition (C1) by walking on the treadmill for 5 minutes at a 1.3 m/s (3 MPH) and a 5% grade (Sol et al., 2018). Then, participants stepped off the treadmill and rested for 2 minutes. Following the rest period, participants began condition 2 (C2) in which they walked on the treadmill for 5 minutes at 1.3 m/s (3MPH) and a 10% grade (Sol et al., 2018). Motion capture data was collected during the last 30 seconds of each trail. Following condition 2, the backpack and reflective markers were removed. Participants were then instructed begin isokinetic testing.

Prior to isokinetic testing, individual range of motion (ROM) was determined for each participant. Isokinetic shoulder testing, of the dominant arm, included a 5-repetition warm-up followed by a 20-repetition maximal effort test at 120 degrees per second. Isokinetic knee testing, of the dominant leg, included a 5-repetition warm-up followed by a 25-repetition maximal effort test at 90 degrees per second. Following isokinetic testing participants were instructed to begin the kettlebell handgrip test.

For the kettlebell handgrip test, participants stood with feet hip width apart and picked up a 65-pound kettlebell in each hand. Participants were instructed to hold each kettlebell at their sides until volitional fatigue. Participants were able to drop one kettlebell while holding the other as long as possible. Once a kettlebell hit the ground, a time in seconds was recorded for each hand.

Diet History Questionnaire

Upon completion of performance testing, participants completed the Diet History Questionnaire III (DHQ-III). The DHQ-III is an on-line food frequency questionnaire for adults 19 years or more. The DHQ-III is widely utilized by researchers to assess food and dietary supplement intake of 135 food and beverage line items and 26 dietary supplement questions. Each line-item asked participants to record their frequency of intake and portion size of each item in the past 30 days. The use of the DHQ-III in this study was be used to provide insight into potential differences nutrient intake between 3-time points: visit 1 in June (Pre: pre-season), visit 2 in October (Post: post-season), visit 3 in February (Off: off-season).

Statistical Analyses

Descriptive statistics of demographic and questionnaire information was analyzed using the Statistical Package for Social Sciences 24 (SPSS v. 24). Additionally, WLFF participant's body composition measurements including LM, FM, VAT, ASM, ASMI, and BMD was analyzed using a one-way repeated measures Analysis of Variance (ANOVA) to determine potential changes in-season and off-season (V1: pre-season, V2: post-season, and V3: off-season. The difference in WLFFs performance including trunk inclination, stride length and strides frequency, isokinetic knee and shoulder extension and flexion as well as handgrip endurance, were analyzed using one-way repeated measures ANOVA to determine changes in-season and off-season (Pre: pre-season, Post: post-season, and Off: off-season). Multiple comparisons were computed with post hoc Bonferroni tests. Data are reported as mean ± standard deviation and significance set at $p<0.05$.

Chapter Four: Results

Macronutrient Intake Characteristics

Macronutrient intake outcomes are reported in Table 1. A significant difference was observed for calories (kcal; p=0.017), protein (g/kg; p=0.024), carbohydrate (g; p=0.001, g/kg; p<0.000, kcal; p=0.001, % p=0.002), and fat (kcal; p=0.006) by visit. No significant differences were observed for protein (%; p=0.143), fiber (g; p=0.165), and fat (g; p=0.104, %; p=0.827) by visit. Post-hoc analyses revealed significant differences for fat (kcal; p=0.039) by pre and post. Additionally, post-hoc analyses revealed significant differences for carbohydrate (%; p=0.019) by post and off. Furthermore, post-hoc analyses reveled significant differences for calories (kcal; p=0.014), fat (kcal; p=0.008), protein (g/kg; p=0.037) and carbohydrate (g; p=0.001, g/kg; p<0.001, kcal; p=0.001, %; p=0.003) by pre and off.

Table 1. Wildland Firefighters' Macronutrient intake

	Pre (n=17)	**Post (n=17)**	**Off (n=17)**
Calories (kcal)	3406±1583	2634±988	2168±1109†
Protein (g)	144±73	103±42	100±48
Protein (g/kg)	1.7±1.0	1.2±0.5	1.2±0.5†
Protein (kcal)	576±293	414±166	400±192
Protein (%)	16±1	15±2	16±2
Carbohydrates (g)	401±191	307±118	211±109†
Carbohydrates (g/kg)	4.8±2.1	3.7±1.3	2.5±1.2†
Carbohydrates (kcal)	1606±762	1228±470	846±435†
Carbohydrates (%)	48±8	47±7	39±9†*
Fiber (g)	26±14	19±10	19±10
Fat (g)	126±65	94±42	91±50
Fat (kcal)	1286±651	848±375†	738±416†*
Fat (%)	38±12	31±6	41±27

†p<0.05, significantly different from pre, *p<0.05, significantly different from post, Kcal = calories, d = day, g = grams, kg = kilograms

Micronutrient Intake Characteristics

Micronutrient intake outcomes are reported in Table 2. A significant difference was observed for Sodium (mg; p=0.017) and Vitamin B3 (mg; p=0.035) by visit. A post-hoc analysis revealed a significant difference in Sodium (p=0.020) and Vitamin B3 (mg; p=0.032) by pre and off. No significant differences were observed for Vitamin D (mcg; p=0.264), Zinc (mg; p=0.081), Calcium (mg; p=0.280), Iron (mg; p=0.219), Magnesium (mg; p=0.207), Potassium (mg; p=0.065), Phosphorous (mg; p=0.054), Vitamin A (mcg; p=0.493), Vitamin B1 (mg; p=0.092), Vitamin B2 (mg; p=0.160), Vitamin B6 (mg; p=0.057), Vitamin B12 (mcg; p=0.075), Vitamin C (mg; 0.624), Vitamin E (mg; p=0.127), Folate (mcg; p=0.363), and Vitamin K (mcg; p=0.261) by visit.

Table 2. Wildland Firefighters' Micronutrient intake

	Pre (n=17)	**Post (n=17)**	**Off (n=17)**
Vitamin D (mcg)	10±7	7±5	7±6
Zinc (mg)	20±10	16±8	14±8
Calcium (mg)	1523±740	1242±690	1161±684
Iron (mg)	20±9	17±9	15±8
Magnesium (mg)	502±267	396±180	386±180
Potassium (mg)	4388±2105	3259±1264	3220±1433
Sodium (mg)	5496±2613	4001±1645	3596±1595†
Phosphorous (mg)	2354±1199	1740±751	1627±796
Vitamin A (mcg)	1206±733	1334±828	995±535
Vitamin B1 (mg)	2±1	2±1	2±1
Vitamin B2 (mg)	4±2	3±2	3±2
Vitamin B3 (mg)	53±32	39±20	32±17†
Vitamin B6 (mg)	5±3	4±2	3±2
Vitamin B12 (mcg)	11±8	8±5	7±5
Vitamin C (mg)	112±60	94±59	101±47
Vitamin E-a-Toco (mg)	16±9	16±9	11±7
Folate (mcg DFE)	582±266	488±244	473±221
Vitamin K (mcg)	303±252	178±209	273±226

†p<0.05, significantly different from pre, IU = international units, mg = milligrams, mcg = micrograms, RAE = retinol activity equivalents, NE = niacin equivalents, DFE = dietary folate equivalents.

Body Composition Characteristics

Body composition outcomes are reported in Table 3. No significant differences were observed for weight (kg; p=0.952), LM (kg; p=0.983, %; p=0.643), FM (kg; p=0.699, %; p=0.622), VAT (g; p=0.907), ASMI (kg/m^2; p=0.862), and BMD (g/cm^3; p=0.436) by visit.

Table 3. Body Composition

	Pre (n=18)	**Post (n=18)**	**Off (n=18)**
Weight (kg)	84.5±16.2	84.7±17.2	86.1±17.7
LM (kg)	63.8±11.2	64.0±11.4	63.3±10.8
LM (%)	76.1±4.7	76.0±4.6	74.6±5.5
FM (kg)	17.2±6.4	17.5±6.8	19.1±8.1
FM (%)	20.3±4.9	20.4±5.0	21.8±6.0
VAT (g)	78.4±38.8	74.1±33.1	73.7±34.3
ASMI (kg/m^2)	9.6±1.2	9.5±1.2	9.4±1.1
BMD (g/cm^3)	1.2±0.1	1.2±0.1	1.2±0.1

kg = kilograms; LM = lean mass, % = percent, FM= fat mass, VAT = visceral adipose tissue, g = grams, ASMI = appendicular skeletal muscle mass index, m = meters, BMD = bone mineral density, cm = centimeters

Muscular Strength and Endurance Characteristics

Muscular strength and endurance outcomes are reported in Table 4. No significant differences were observed for knee initial peak torque (extension; p=0.989, flexion; p=0.652), fatigue index (extension; p=0.855, flexion; p=0.572), and average power (extension; p=0.521, flexion; p=0.935) by visit. Additionally, no significant differences were observed for shoulder initial peak torque (extension; p=0.877, flexion; p=0.881), fatigue index (extension, p= 0.057, flexion; p=0.668), and average power (extension; p=0.732, flexion; p=0.895) by visit. No significant differences were observed for hand grip (right; p=0.902, left; p=0.846) by visit.

Table 4. Muscular strength and endurance

	Pre (n=18)	Post (n=18)	Off (n=18)
Knee			
Initial Peak Torque (NM)			
Extension	152±54	152±44	150±44
Flexion	110±38	109±29	119±35
Fatigue Index			
Extension	13±42	19±17	16±21
Flexion	18±41	29±15	26±30
Average Power (W)			
Extension	128±32	139±33	130±31
Flexion	105±29	103±26	106±29
Shoulder			
Initial peak torque (NM)			
Extension	83±53	88±22	85±24
Flexion	53±15	56±15	55±16
Fatigue Index			
Extension	0±39	18±12	18±16
Flexion	27±15	24±9	27±10
Average Power (W)			
Extension	123±41	120±27	114±31
Flexion	63±20	66±25	64±23
Hand Grip			
Right (s)	189±78	200±84	189±87
Left (s)	194±83	189±85	187±84

NM= Newton-Meters, W= watts, s= seconds

Biomechanics Characteristics

Trunk inclination and gait characteristic outcomes by visit are reported in Table 5. No significant differences were observed for mean trunk inclination (C1; p=0.091, C2; p=0.215), peak trunk inclination (C1; p=0.120, C2; p=0.221), stride length (C1; p=0.884, C2; p=0.959), and stride frequency (C1; p=0.894, C2; p=0.973) by visit. Additionally, significant differences were observed for mean trunk inclination (p<0.0001), peak trunk inclination (p<0.0001), stride length (p=0.015), and stride frequency (p=0.002) by condition. Significant differences were observed for mean trunk inclination (p<0.0001), peak trunk inclination (p<0.0001), stride length (p=0.015), and stride frequency (p=0.002) by condition.

Table 5. Biomechanics characteristics

	Pre (n=15)	**Post (n=15)**	**Off (n=15)**	**All**
Condition 1 (C1)				
Mean trunk inclination (°)	25.9±5.2	22.4±4.1	28.4±11.0	25.5±7.7
Peak trunk inclination (°)	29.4±5.5	25.9±4.4	31.4±10.4	28.8±7.5
Stride length (m)	1.5±0.1	1.5±0.1	1.5±0.1	1.5±0.1
Stride frequency (spm)	54.1±2.7	54.0±2.5	53.6±3.2	53.9±2.7
Condition 2 (C2)				
Mean trunk inclination (°)	33.2±6.7	29.0±5.5	32.3±8.0	31.5±6.9†
Peak trunk inclination (°)	37.8±7.3	33.2±5.9	36.8±9.0	36.0±7.6†
Stride length (m)	1.5±0.1	1.5±0.1	1.5±0.1	1.4±0.1†
Stride frequency (spm)	54.7±3.3	54.7±3.6	54.4±3.8	54.6±3.5†

†$p<0.05$, significantly different from condition 1

°= degrees, m= meters, spm= strides per minute

Chapter Five: Discussion

The present study aimed to obtain an understanding of WLFFs nutrient intake, body composition, and muscular strength and endurance during pre-fire season, post-fire season, and off season. WLFFs macronutrient intake has been well established in field studies during the wildfire season (Ruby 2002, Marks 2020), however dietary behavior during the off season has not previously been investigated. Data on micronutrient intake is also limited (Marks et al., 2020) in this population across all three timepoints that this study captured. Previous research has assessed WLFFs body composition (Coker et al., 2019; Gaskill et al., 2020), and VO_2 performance (Sol et al., 2018), however to the authors knowledge, this is the first study to examine WLFFs nutrient intake, body composition, and muscular strength and endurance during the off season.

WLFFs seasonal occupation poses unique dietary and physical demands due to the extreme ambient conditions, terrain, and extended bouts of strenuous activity. Each wildfire season varies in the number of fires an individual is assigned to, the length of each fire assignment, as well as the terrain. Therefore, daily nutrient intake requirements for WLFFs exceed those of average healthy individuals (2,000 kcals/d) during the wildfire season (Cuddy et al., 2015). Therefore, it is critical to support these aforementioned additional energy demands during strenuous occupational activities, such as wildland firefighting, through increased nutrient intake (Burke et al., 2011; Casa et al., 2010; Lieberman, 2003; Phillips & van Loon, 2011). In the current study, a significant decrease in self-reported nutrient intake was observed between pre- season and off-season (Pre: 3406±1583 kcal/d; Off: 2168±1109 kcal/d, p=0.033 Additionally, no significant difference was observed between pre-season and post-season. These data indicate WLFFs may be self-regulating dietary intake based on energy expenditure with the greatest intake during the pre-season training period (3406±1583 kcal/d) and the lowest intake during the off-season (2168±1109 kcal/d). Previously reported WLFF energy demands are 2800-6200 kcal/d (Ruby et al., 2002; Cuddy et al., 2015) and the average nutrient intake during the work shift has been previously quantified as ranging from 2200-5800 kcal/d (Marks et al., 2020; Ruby et al., 2002; Montain et al., 2008). Although total energy demands are of primary importance for this demanding occupation, appropriate macronutrient distribution is imperative to support arduous work demands.

Macronutrient Intake

Macronutrient recommendations for strenuous occupations (such as WLFF and military operations) and endurance athletes include 6-10 g/kg body mass of carbohydrate, 1.2-1.7 g/kg body mass of protein, and 20-35% of total kilocalorie intake from fat (Jeukendrup, 2004; Montain & Young, 2003; Tharion et al., 1997). Diets comprised of high carbohydrate (>65% total nutrient intake) have consistently demonstrated enhanced work output when engaged in strenuous occupational or physical activity (Jeukendrup, 2004; Montain et al., 1997; Montain & Young, 2003). The present study was in agreement with previous research that WLFFs are not meeting carbohydrate recommendations of >65% total dietary intake from carbohydrates (Ruby et al., 2002; Marks et al., 2020). A significant decrease in carbohydrate was observed between pre-season and off-season (Pre: 4.8±2.1 g/kg and 48±8%; Off: 2.5±1.2 g/kg and 39±9%) and post-season and off-season (Post: 47±7%; Off: and 39±9%). Additionally, carbohydrate was below the recommended 6-10 g/kg body weight of carbohydrates for arduous work which may result in decreased muscle glycogen stores available for mechanical work, compromising reaction time and overall health and safety. Similarly, Ruby et al. demonstrated low carbohydrate intake among Type 1 crews (53±9%)

during the fire season (Ruby et al., 2002). Unlike the present study, Marks et al. demonstrated females consumed a significantly greater amount of carbohydrate compared to males during the fire season (F: 3±1 g/kg and 57±10%; M: 2±1 g/kg and 50±10%) but overall still fell far below recommendations (Marks et al., 2020). Therefore, it would likely be beneficial for WLFFs to ingest supplemental carbohydrates during wildfire suppression to maintain adequate nutrient intakes and sustain work output. Furthermore, WLFFs may be self-regulating their nutrient intakes across the pre-season, post-season, and in the off-season.

Protein requirements for arduous occupations often exceed the recommended daily allowance (RDA:0.8 g/kg) for the average healthy population to avoid adverse health implications such as losses in LM; however, optimal protein intake for specific WLFF performance remains unknown. Protein intakes of 1.2-1.7 g/kg have been recommended for arduous occupations including military personnel (Jeukendrup, 2004; Montain & Young, 2003; Tharion et al., 1997). WLFFs, who are regularly involved in endurance and/or resistance training, require additional dietary protein to stimulate skeletal muscle protein synthesis and prevent muscle protein breakdown (Lieberman, 2003). Previous literature has demonstrated ingestion of 20-40 grams of protein following strenuous activity maximally stimulates skeletal muscle protein synthesis (Kerksick et al., 2008). In the present study, protein intake fell within the recommended range at all timepoints and no significant differences were observed between visits in the present study (Pre: 1.7±1.0 g//kg/d, Post: 1.2±0.5 g/kg/d, Off: 1.2±0.5 g/kg/d). Although the observed protein intakes were on the lower end of the acceptable macronutrient distribution range (10-25% total calories), relative protein consumption was within the recommended range of 1.2-1.7 g/kg. These data are in agreement with detailed food inventory methods of 1.8 g/kg protein intakes during wildfire suppression (Marks et al., 2020).

WLFF fat intake has been previously reported as greater than recommended (>20-35% of total kilocalorie intake from fat) for arduous work which is similar to the present study where WLFF dietary fat intake was in excess at all timepoints (Pre: 38±12%, Post: 31±6%, Off: 41±27%) (Ruby et al., 2002). Similarly, to our findings, previous literature demonstrated high fat intake in WLFF (32±7% and 44±3 %) during wildfire assignments (Ruby et al., 2002; Marks et al., 2020). Diets high in dietary fat may contribute to unfavorable metabolic profiles and may specifically, increase total cholesterol and serum low-density lipoproteins (Clifton, 2019). WLFFs have previously experienced unfavorable metabolic profiles associated with the wildfire season, including increased total cholesterol and low-density lipoproteins, and negative implications on body composition largely attributed to increased body fat and visceral adipose tissue (Coker et al., 2019). In the present study, a significant reduction in fat intake was observed between pre-season and off-season (Pre: 1216±624 kcal/d and Off: 738±416 kcal/d). This may be attributed to pre-packaged food options available to WLFFs during wildfire suppression compared to ad libitum food choices during the off-season. Furthermore, pre-packaged food items are designed for increased shelf-stability, improved satiation during long work hours, and innately high in fat.

Micronutrient Intake

One previous study has investigated micronutrient intake in WLFFs and there are no specific recommendations for this population (Marks et al., 2020). Therefore, this study sought to increase the existing micronutrient data on WLFF in order to identify possible deficiencies critical to health and job performance. Specifically, during periods of increased activity, micronutrients are responsible for energy and macronutrient metabolism, oxygen and nutrient delivery, as well as skeletal muscle repair (Gombart et al., 2020). In the present study, Vitamin D intake was below recommendations (RDA= >10 mcg/d) during post-season and off-season (Post: 7±5 mcg, and Off: 7±6 mcg) This is of particular concern because Vitamin D has been recognized as a moderator of skeletal muscle function indirectly through calcium related protein transcription as well as total body calcium levels (Hamilton, 2010; Weaver & Fleet, 2004). However, to determine clinical Vitamin D deficiency, serum Vitamin D would be needed to determine clinical deficiency in this population, which this study did not assess. A prevalent clinical symptom of Vitamin D deficiency is skeletal muscle weakness indicating that physically active individuals may require even higher doses of Vitamin D beyond the RDA. However, a predominant source of Vitamin D for many individuals is through sunlight exposure. Many factors impact Vitamin D production, including latitude, season, sunblock usage, and the amount of clothing covering the body (Anders et al., 2008). It is very likely that WLFFs do not acquire the RDA for Vitamin D through sunlight exposure because of the extensive required personal protective equipment for wildfire suppression and therefore is critical for this population to obtain adequate Vitamin D through the diet.

In the present study, a significant decrease in sodium (mg; p=0.017) and Vitamin B3 (mg; p=0.035) were observed. Furthermore, sodium intakes were above the recommendations (RDA= <1500 mg/d) at all timepoints (Pre: 5496±2613 mg, Post: 4001±1645 mg, Off: 3596±1595 mg). Similarly, sodium intakes were above RDA during wildfire suppression (6513±3555 mg/d) (Marks et al., 2020). Although the present study observed elevated sodium intake above the RDA, this may be necessary for individuals participating in strenuous activity due to increased sodium loss through sweat (Von Duvillard et al., 2004). However, excessive sodium intake may contribute to hypertension and cardiovascular irregularities as well (Grillo et al., 2019). Therefore, chronically high sodium intakes could also lead to decreases in occupational performance and overall health. However, during periods of high sodium losses through sweat and high total body water loss, sodium intakes may not be detrimental to overall health. Pre-packaged and non-perishable food items provided during wildfire suppression may be contributing to WLFFs high sodium intakes during fire season, however it is unclear why sodium continues to be high in the off-season.

Body Composition

Seasonal changes in body composition have been a concern for WLFFs due to the strenuous nature of the occupation combined with increasingly long fire seasons (Gaskill et al., 2020). Previous research has demonstrated little to no change in body composition metrics across the fire season using various methodologies including hydrodensiometry, DXA, MRI, and skinfold assessment (Coker et al., 2019; Collins, 2018; Gaskill et al., 2020; Lui et al., 2014). The present study was the first to collect body composition data during the off season using DXA in order to observe possible fluctuations between fire season and off season. In the current study, no changes in body composition metrics were observed at all time points. Similarly, to previous research, no change in weight was observed pre- and post-fire season (Pre: 84.5±16.2 kg, Post: 84.7±17.2 kg, and Off: 86.1±17.7 kg) Coker et al. evaluated changes in body composition (using DXA) pre- and post-fire season finding a significant increase in body mass (78.7±12.8 versus 79.7±12.3 kg, $p<0.05$) and FM (12.4±5.2 kg versus 13.9±4.9 kg, $p<0.05$) while no observed changes in LM ($p>0.05$) as a result of the fire season (Coker et al., 2019). However in the present study, no significant differences were observed in LM and FM (Pre: 60.9±11.3 kg, and 17.4±5.8 kg, Post: 61.3±11.2 kg, and 17.3±6.1 kg, Off: 63.3±10.8 kg, and 19.1±8.1 kg, respectively). These data are surprising considering the TEE of arduous work performed during wildfire suppression and suggest WLFFs may exibit a seasonal maintenance of body composition across the season and in the off-season (Cuddy et al., 2015; Ruby et al., 2002; Montain et al., 2008) Conversely to the present study, Gaskill et al. found a significant decrease in FM from pre to post fire season (-1.94±1.1 kg and -1.7± 1.4 %, $p<0.01$) using hydrostatic weighing as well as a significant decrease in LM from pre to post fire season (-0.38 ±1.24 kg, $p<0.05$) (Gaskill, 2020). Furthermore, Coker et al. (2019) demonstrated a significant increase in VAT from pre to post fire season using a DXA scan (318±47 g versus 419±48 g, $p<0.05$). However, the findings of the present study found no significant differences in VAT by tiumepoint (Pre: 377.9±187.0 g, Post: 368.2±148. g, Off: 355.2±164.7 g). Overall, participants in the presents study exhibited greater VAT compared to Coker et al. Individuals with greater visceral adiposity generally experience greater metabolic consequences compared to individuals who store a greater proportion as subcutaneous fat (Montague & O'Rahilly, 2000). However, in the present study visceral adiposity does not appear to be of concern due to relatively low VAT values compared to the general population (Miazgowski et al., 2017). Discrepancies in visceral adiposity measures may be attributed to participants in each study, demands of the fire seasons, body composition techniques (DXA versus MRI), and dietary intakes. It has been well established that reductions in VAT, with or without weight loss, have occurred with exercise interventions (Rao et al., 2019; Ross et al., 2002; Ross & Després, 2009). Therefore, WLFFs visceral adiposity may be influenced by alterations in physical activity and dietary intake during the wildfire season and in the off-season. The data from the present study suggest WLFFs may maintain body composition when the off-season timepoint is considered.

Muscular Strength and Endurance

In occupations such as wildland firefighting, physical work capacity including muscular strength and aerobic power, is critical for optimal work performance. Aerobic work capacity is most frequently studied and moderate aerobic capacities (50% VO_2 max) deemed important for work performance (Budd et al., 1997; Sol et al., 2018). High levels of aerobic fitness and muscular strength are required for WLFFs to perform occupational demands such as hiking in rugged terrain, chainsaw work, and digging line (Gledhill & Jamnik, 1992). However, this study is the first to examine isokinetic measures of muscular strength and endurance in WLFFs in addition to endurance hand grip.In the present study, no significant differences in isokinetic knee and shoulder flexion and extension measures of peak torque or average power were observed by timepoint. Additionally, no significant differences in grip strength (either hand) were observed by timepoint. These data suggest WLFFS may maintain muscular strength and endurance across the season and into the off-season.

Biomechanics Characteristics

Little is known about the biomechanical implications of carrying a fire-line gear pack on WLFFs. This study was the first to evaluate the impact of a fire line gear pack on WLFFs trunk inclination and gait characteristics while walking at 1.3 meters per second (m/s) on a treadmill at two incline grades. Although relative pack weight varied for each participant, the observed conditions remained consistent between participants. As treadmill grade increased (5% to 10%), forward trunk inclination increased, stride length decreased, and stride frequency increased. In the present study, treadmill walking at a 10% incline (C1) resulted in a significantly greater trunk inclination compared to a 5% incline (C2) (C1: 31.5±6.9°; C2: 25.5±7.7°, $p<0.0001$). These data suggest uphill hiking at a greater incline increases trunk inclination. Greater forward trunk inclination while walking carrying a load is a well-established adaptive mechanism by adjusting body position to counterbalance load carriage, which is critical for maintaining balance (Attwells et al., 2006; Harman et al., 2000; Kinoshita, 1985; Loverro et al., 2015). However, greater forward trunk inclination can lead to increased muscular strain in the shoulders and lower back, which may lead to heightened risk for injury on the job (Attwells et al., 2006; Harman et al., 2000). Therefore, it may be necessary to monitor WLFFs job related injuries, specifically related to shoulder and low back strain as well as develop pre-season training protocols to increase shoulder and back strength.

In this study, no significant seasonal changes in trunk inclination were observed from post to pre-season for both conditions (C1: 22.4±4.1° versus 25.9±5.2°, C2: 29.0±5.5° versus 33.2±6.7). However, stride length significantly decreased (C1: 1.4±0.1 m versus C2: 1.5±0.1 m, p=0.015) and stride frequency significantly increased (C1: 53.9±2.7 spm versus C2: 54.6±3.5 spm; p=0.002) with an increase in treadmill incline. Our findings were to be expected as previous literature has established decreases in stride length with an increase in load carriage at level grade walking (Birrell & Haslam, 2009; Fellin et al., 2016; James et al., 2015). Considering the weight of the pack used in this study 26.4 kg (58 lbs) it was assumed shorter strides would be adopted while carrying a load at an incline Additionally, shorter strides may be adopted to bring the center of mass closer to the moving base of support (Espy et al., 2010). Therefore, hiking at a greater incline during wildfire suppression may have implications on WLFFs safety and escape time. Additional research is necessary to determine the implications of hiking in steep terrain on trunk inclination and gait characteristics in the field.

Limitations

Data collected from this study were of WLFFs from different crews including smokejumpers, helitac, handcrews and engine crews. Additionally, participants were recruited based on convenience and availability to travel to the laboratory. Nutrient intake is difficult to capture in human subjects due to various recording methods and human error. Under reporting of self-perceived “bad foods” and over reporting of “good foods” are common reporting errors (Lichtman et al., 1992; Nelson et al., 1997; Pendergast et al., 2017). Macronutrient intakes are difficult to compare to previous research due to differences in timepoints in this study (pre-season and post-season) versus field studies (during arduous wildfire suppression). In the present study, heart rate data was not usable for analysis due to video and monitors during the biomechanics conditions as well as difficulty capturing accurate heart rate readings. Additionally, it is difficult to translate laboratory performance metrics to the field, specifically due to the uneven terrain and self-selected velocities in individuals. However, future research could be used to evaluate with inertial measurement units outside in the field.

Conclusion

To the authors’ knowledge, this is the first study to collect data on WLFFs nutrient intakes, body composition, and performance measures longitudinally (pre-season, post-season, and in the off-season). Overall, differences were observed in macronutrient intakes and select micronutrients between pre-season and the off-season. Muscular strength and endurance measures were not different by timepoint. These data suggest WLFFs may maintain seasonal stability in overall muscular strength and endurance as well as body composition across the season and in the off-season.

References

Abatzoglou, J. T., Rupp, D. E., & Mote, P. W. (2014). Seasonal climate variability and change in the pacific northwest of the united states. *Journal of Climate*, *27*(5), 2125–2142. https://doi.org/10.1175/JCLI-D-13-00218.1

Achten, J., & Jeukendrup, A. E. (2004). Relation between Plasma Lactate Concentration and Fat Oxidation Rates over a Wide Range of Exercise Intensities. *International Journal of Sports Medicine*, *25*(1), 32–37. https://doi.org/10.1055/s-2003-45231

Adams, M. A., & Dolan, P. (2005). Spine biomechanics. *Journal of Biomechanics*, *38*(10), 1972–1983. https://doi.org/10.1016/j.jbiomech.2005.03.028

Anders, M., Tuma, I., & Rösslerova, H. (2008). A surveillance study of escitalopram treatment of depressed patients. *Expert Opinion on Pharmacotherapy*, *9*(1), 1–6. https://doi.org/10.1517/14656566.9.1.1

Antonio, J., Ellerbroek, A., Silver, T., Orris, S., Scheiner, M., Gonzalez, A., & Peacock, C. A. (2015). A high protein diet (3.4 g/kg/d) combined with a heavy resistance training program improves body composition in healthy trained men and women - a follow-up investigation. *Journal of the International Society of Sports Nutrition*, *12*(1). https://doi.org/10.1186/s12970-015-0100-0

Aragon, A. A., Schoenfeld, B. J., Wildman, R., Kleiner, S., VanDusseldorp, T., Taylor, L., Earnest, C. P., Arciero, P. J., Wilborn, C., Kalman, D. S., Stout, J. R., Willoughby, D. S., Campbell, B., Arent, S. M., Bannock, L., Smith-Ryan, A. E., & Antonio, J. (2017). International society of sports nutrition position stand: Diets and body composition. In *Journal of the International Society of Sports Nutrition* (Vol. 14, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s12970-017-0174-y

Attwells, R. L., Birrell, S. A., Hooper, R. H., & Mansfield, N. J. (2006). Influence of carrying heavy loads on soldiers’ posture, movements and gait. *Ergonomics*, *49*(14), 1527–1537. https://doi.org/10.1080/00140130600757237

Birrell, S. A., & Haslam, R. A. (2009). The effect of military load carriage on 3-D lower limb kinematics and spatiotemporal parameters. *Ergonomics*, *52*(10), 1298–1304. https://doi.org/10.1080/00140130903003115

Blomstrand, E., & Saltin, B. (1999). Effect of muscle glycogen on glucose, lactate and amino acid metabolism during exercise and recovery in human subjects. *Journal of Physiology*, *514*(1), 293–302. https://doi.org/10.1111/j.1469-7793.1999.293af.x

Britton, C., Lynch, C. F., Ramirez, M., Torner, J., Buresh, C., & Peek-Asa, C. (2013). Epidemiology of injuries to wildland firefighters. *American Journal of Emergency Medicine*, *31*(2), 339–345. https://doi.org/10.1016/j.ajem.2012.08.032

Budd, G. M., Brotherhood, J. R., Hendrie, A. L., Jeffery, S. E., Beasley, F. A., Costin, B. P., Zhien, W., Baker, M. M., Cheney, N. P., & Dawson, M. P. (1997). Project Aquarius 1. Stress, strain, and productivity in men suppressing Australian summer bushfires with hand tools: Background, objectives, and methods. *International Journal of Wildland Fire*, *7*(2), 69–76. https://doi.org/10.1071/WF9970069

Buller, M. J., Latzka, W. A., Yokota, M., Tharion, W. J., & Moran, D. S. (2008). A real-time heat strain risk classifier using heart rate and skin temperature. *Physiological Measurement*, *29*(12). https://doi.org/10.1088/0967-3334/29/12/N01

Burke, L. M., Hawley, J. A., Wong, S. H. S., & Jeukendrup, A. E. (2011). Carbohydrates for training and competition. *Journal of Sports Sciences*, *29*(SUPPL. 1), 17–27. https://doi.org/10.1080/02640414.2011.585473

Butler, B. W. (2014). Wildland firefighter safety zones: a review of past science and summary of future needs. *International Journal of Wildland Fire*, *23*(3), 295. https://doi.org/10.1071/WF13021

Casa, D. J., Stearns, R. L., Lopez, R. M., Ganio, M. S., McDermott, B. P., Yeargin, S. W., Yamamoto, L. M., Mazerolle, S. M., Roti, M. W., Armstrong, L. E., & Maresh, C. M. (2010). Influence of hydration on physiological function and performance during trail running in the heat. *Journal of Athletic Training*, *45*(2), 147–156. https://doi.org/10.4085/1062-6050-45.2.147

Cascio, W. E. (2018). Wildland fire smoke and human health. *Science of the Total Environment*, *624*, 586–595. https://doi.org/10.1016/j.scitotenv.2017.12.086

Chen, Z., Salam, M. T., Toledo-Corral, C., Watanabe, R. M., Xiang, A. H., Buchanan, T. A., ... & Trigo, E. (2016). Ambient air pollutants have adverse effects on insulin and glucose homeostasis in Mexican Americans. *Diabetes care*, *39*(4), 547-554.

Clifton, P. M. (2019). Diet, exercise and weight loss and dyslipidaemia. In *Pathology* (Vol. 51, Issue 2, pp. 222–226). Elsevier B.V. https://doi.org/10.1016/j.pathol.2018.10.013

Coker, R. H., Coker, M. S., Bartlett, L., Murphy, C. J., Priebe, K., Shriver, T. C., Schoeller, D. A., & Ruby, B. C. (2018). The energy requirements and metabolic benefits of wilderness hunting in Alaska. *Physiological Reports*, *6*(21). https://doi.org/10.14814/phy2.13925

Coker, R. H., Murphy, C. J., Johannsen, M., Galvin, G., & Ruby, B. C. (2019). Wildland Firefighting: Adverse Influence on Indices of Metabolic and Cardiovascular Health. *Journal of Occupational and Environmental Medicine*, *61*(3), E91–E94. https://doi.org/10.1097/JOM.0000000000001535

Collins, C. (2018). *Understanding Factors Contributing to Wildland Firefighter Health, Safety, and Performance: A Pilot Study on Smokejumpers | Theses and Dissertations Collection*. https://www.lib.uidaho.edu/digital/etd/items/collins_idaho_0089n_11459.html

Committee NIHCS (2016). *Standards for Interagency Hotshot Crew Operations.* Boise, ID: National Interagency Fire Center.

Cuddy, J. S., Gaskill, S. E., Sharkey, B. J., Harger, S. G., & Ruby, B. C. (2007). Supplemental feedings increase self-selected work output during wildfire suppression. *Medicine and Science in Sports and Exercise*, *39*(6), 1004–1012. https://doi.org/10.1249/mss.0b013e318040b2fb

Cuddy, J. S., Ham, J. A., Harger, S. G., Slivka, D. R., & Ruby, B. C. (2008). Effects of an electrolyte additive on hydration and drinking behavior during wildfire suppression. *Wilderness and Environmental Medicine*, *19*(3), 172–180. https://doi.org/10.1580/07-WEME-OR-114.1

Cuddy, J. S., & Ruby, B. C. (2011). High work output combined with high ambient temperatures caused heat exhaustion in a wildland firefighter despite high fluid intake. *Wilderness and Environmental Medicine*, *22*(2), 122–125. https://doi.org/10.1016/j.wem.2011.01.008

Cuddy, J. S., Slivka, D. R., Tucker, T. J., Hailes, W. S., & Ruby, B. C. (2011). Glycogen levels in wildland firefighters during wildfire suppression. *Wilderness and Environmental Medicine*, *22*(1), 23–27. https://doi.org/10.1016/j.wem.2010.09.019

Cuddy, J. S., Sol, J. A., Hailes, W. S., & Ruby, B. C. (2015). Work Patterns Dictate Energy Demands and Thermal Strain During Wildland Firefighting. *Wilderness and*

Environmental Medicine, *26*(2), 221–226. https://doi.org/10.1016/j.wem.2014.12.010

Deyle, S., Banz, V. M., Wagner, M., Becker, K., Inderbitzin, D., Gloor, B., & Candinas, D. (2011). Estimation of physiologic ability and surgical stress score does not predict immediate outcome after pancreatic surgery. *Pancreas*, *40*(5), 723–729. https://doi.org/10.1097/MPA.0b013e318212c02c

Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids. (2000). *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids*. https://doi.org/10.17226/9810

Djoussé, L., Levy, D., Cupples, L. A., Evans, J. C., D'Agostino, R. B., & Ellison, R. C. (2001). Total serum bilirubin and risk of cardiovascular disease in the Framingham Offspring Study. *American Journal of Cardiology*, *87*(10), 1196–1200. https://doi.org/10.1016/S0002-9149(01)01494-1

Espy, D. D., Yang, F., Bhatt, T., & Pai, Y. C. (2010). Independent influence of gait speed and step length on stability and fall risk. *Gait and Posture*, *32*(3), 378–382. https://doi.org/10.1016/j.gaitpost.2010.06.013

Fellin, R. E., Seay, J. F., Gregorczyk, K. N., & Hasselquist, L. (2016). Spatiotemporal parameters are not substantially influenced by load carriage or inclination during treadmill and overground walking. *Journal of Human Kinetics*, *50*(1), 27–35. https://doi.org/10.1515/hukin-2015-0138

Fyock-Martin, M. B., Erickson, E. K., Hautz, A. H., Sell, K. M., Turnbaugh, B. L., Caswell, S. V., & Martin, J. R. (2020). What do Firefighting Ability Tests Tell Us About Firefighter Physical Fitness? A Systematic Review of the Current Evidence. *Journal of Strength and Conditioning Research*, *34*(7), 2093–2103.

https://doi.org/10.1519/JSC.0000000000003577

Gaskill, S. E., Dumke, C. L., Palmer, C. G., Ruby, B. C., Domitrovich, J. W., & Sol, J. A. (2020). Seasonal changes in wildland firefighter fitness and body composition. *International Journal of Wildland Fire, 29*(3), 294–303. https://doi.org/10.1071/WF19104

Gledhill, N., & Jamnik, V. K. (1992). Development and validation of a fitness screening protocol for firefighter applicants. *Canadian Journal of Sport Sciences = Journal Canadien Des Sciences Du Sport*, *17*(3), 199–206. https://europepmc.org/article/med/1325259

Gombart, A. F., Pierre, A., & Maggini, S. (2020). A review of micronutrients and the immune system–working in harmony to reduce the risk of infection. *Nutrients*, *12*(1), 236. https://doi.org/10.3390/nu12010236

Grillo, A., Salvi, L., Coruzzi, P., Salvi, P., & Parati, G. (2019). Sodium Intake and Hypertension. *Nutrients*, *11*. https://doi.org/10.3390/nu11091970

Hamilton, B. (2010). Vitamin D and Human Skeletal Muscle. *Scandinavian Journal of Medicine and Science in Sports*, *20*(2), 182–190. https://doi.org/10.1111/j.1600-0838.2009.01016.x

Harman, E., Han, K. H., Frykman, P., & Pandorf, C. (2000). The effects of backpack weight on the biomechanics of load carriage. In *Security* (Issue October). https://apps.dtic.mil/sti/citations/ADA377886

Heil, D. P. (2002). Estimating energy expenditure in wildland fire fighters using a physical activity monitor. *Applied Ergonomics*, *33*(5), 405–413. https://doi.org/10.1016/S0003-6870(02)00042-X

Hoops, H., Zhou, B. H., Lu, Y., Solomonow, M., & Patel, V. (2007). Short rest between cyclic flexion periods is a risk factor for a lumbar disorder. *Clinical Biomechanics*, *22*(7), 745–757. https://doi.org/10.1016/j.clinbiomech.2007.03.010

Iftikhar, I. H., Donley, M. A., Mindel, J., Pleister, A., Soriano, S., & Magalang, U. J. (2015). Sleep duration and metabolic syndrome: An updated dose-risk metaanalysis. *Annals of the American Thoracic Society*, *12*(9), 1364–1372. https://doi.org/10.1513/AnnalsATS.201504-190OC

Ivy, J. L. (2004). Regulation of muscle glycogen repletion, muscle protein synthesis and repair following exercise. *Journal of sports science & medicine*, *3*(3), 131.

James, C. R., Atkins, L. T., Yang, H. S., Dufek, J. S., & Bates, B. T. (2015). Kinematic and ground reaction force accommodation during weighted walking. *Human Movement Science*, *44*, 327–337. https://doi.org/10.1016/j.humov.2015.10.004

Jeukendrup, A. E. (2004). Carbohydrate intake during exercise and performance. *Nutrition*, *20*(7–8), 669–677. https://doi.org/10.1016/j.nut.2004.04.017

Johnson, R. K. (2002). Dietary intake--how do we measure what people are really eating? *Obesity Research*, *10 Suppl 1*. https://doi.org/10.1038/oby.2002.192

Kerksick, C., Harvey, T., Stout, J., Campbell, B., Wilborn, C., Kreider, R., Kalman, D., Ziegenfuss, T., Lopez, H., Landis, J., Ivy, J. L., & Antonio, J. (2008). International society of sports nutrition position stand: Nutrient timing. In *Journal of the International Society of Sports Nutrition* (Vol. 5). https://doi.org/10.1186/1550-2783-5-17

Kimura, N., Fukuwatari, T., Sasaki, R., Hayakawa, F., & Shibata, K. (2003). Vitamin intake in Japanese women college students. In *Journal of Nutritional Science and Vitaminology* (Vol. 49, Issue 3). https://doi.org/10.3177/jnsv.49.149

Kinoshita, H. (1985). Effects of different loads and carrying systems on selected biomechanical parameters describing walking gait. *Ergonomics*, *28*(9), 1347–1362. https://doi.org/10.1080/00140138508963251

Le, P., Solomonow, M., Zhou, B. H., Lu, Y., & Patel, V. (2007). Cyclic load magnitude is a risk factor for a cumulative lower back disorder. *Journal of Occupational and Environmental Medicine*, *49*(4), 375–387. https://doi.org/10.1097/JOM.0b013e318046eb0b

Lemon, P. W. R. (2000). Beyond the Zone: Protein Needs of Active Individuals. *Journal of the American College of Nutrition*, *19*, 513S-521S. https://doi.org/10.1080/07315724.2000.10718974

Lichtman, S. W., Pisarska, K., Berman, E. R., Pestone, M., Dowling, H., Offenbacher, E., Weisel, H., Heshka, S., Matthews, D. E., & Heymsfield, S. B. (1992). Discrepancy between Self-Reported and Actual Caloric Intake and Exercise in Obese Subjects. *New England Journal of Medicine*, *327*(27), 1893–1898. https://doi.org/10.1056/nejm199212313272701

Lieberman, H. R. (2003). Nutrition, brain function and cognitive performance. *Appetite*, *40*(3), 245–254. https://doi.org/10.1016/S0195-6663(03)00010-2

Lindberg, A. S., Oksa, J., Gavhed, D., & Malm, C. (2013). Field Tests for Evaluating the Aerobic Work Capacity of Firefighters. *PLoS ONE*, *8*(7). https://doi.org/10.1371/journal.pone.0068047

Loverro, K. L., Brown, T. N., Coyne, M. E., & Schiffman, J. M. (2015). Use of body armor protection with fighting load impacts soldier performance and kinematics. *Applied Ergonomics*, *46*(Part A), 168–175. https://doi.org/10.1016/j.apergo.2014.07.015

Lui, B., Cuddy, J. S., Hailes, W. S., & Ruby, B. C. (2014). Seasonal heat acclimatization in wildland firefighters. *Journal of Thermal Biology*, *45*, 134–140. https://doi.org/10.1016/j.jtherbio.2014.08.009

Margolis, L. M., Rivas, D. A., Berrone, M., Ezzyat, Y., Young, A. J., McClung, J. P., Fielding, R. A., & Pasiakos, S. M. (2016). Prolonged calorie restriction downregulates skeletal muscle mtorc1 signaling independent of dietary protein intake and associated microRNA expression. *Frontiers in Physiology*, *7*(OCT). https://doi.org/10.3389/fphys.2016.00445

Marks, A. N., Sol, J. A., Domitrovich, J. W., West, M. R., & Ruby, B. C. (2020). Total Energy Intake and Self-Selected Macronutrient Distribution During Wildland Fire Suppression. *Wilderness and Environmental Medicine*, *31*(2), 188–196. https://doi.org/10.1016/j.wem.2020.01.009

McGill, S. M. (1992). A myoelectrically based dynamic three-dimensional model to predict loads on lumbar spine tissues during lateral bending. *Journal of Biomechanics*, *25*(4), 395–414. https://doi.org/10.1016/0021-9290(92)90259-4

McGill, S. M. (1997). The biomechanics of low back injury: Implications on current practice in industry and the clinic. *Journal of Biomechanics*, *30*(5), 465–475. https://doi.org/10.1016/S0021-9290(96)00172-8

Miazgowski, T., Kucharski, R., Sołtysiak, M., Taszarek, A., Miazgowski, B., & Widecka, K. (2017). Visceral fat reference values derived from healthy European men and women aged 20-30 years using GE Healthcare dual-energy x-ray absorptiometry. *PLoS ONE*, *12*(7). https://doi.org/10.1371/journal.pone.0180614

Montain, S. J., Shippee, R. L., & Tharion, W. J. (1997). Carbohydrate-electrolyte solution effects on physical performance of military tasks. *Aviation Space and Environmental Medicine*, *68*(5), 384–391. https://europepmc.org/article/med/9143747

Montain, Scott J., Baker-fulco, C. J., Niro, P. J., Reinert, A. R., Cuddy, J. S., & Ruby, B. C. (2008). Efficacy of eat-on-move ration for sustaining physical activity, reaction time, and mood. *Medicine and Science in Sports and Exercise*, *40*(11), 1970–1976. https://doi.org/10.1249/MSS.0b013e31817f4d58

Montain, Scott J., & Young, A. J. (2003). Diet and physical performance. *Appetite*, *40*(3), 255–267. https://doi.org/10.1016/S0195-6663(03)00011-4

Moran, D. S., Shitzer, A., & Pandolf, K. B. (1998). A physiological strain index to evaluate heat stress. *American Journal of Physiology - Regulatory Integrative and Comparative Physiology*, *275*(1 44-1). https://doi.org/10.1152/ajpregu.1998.275.1.r129

Mountjoy, M., Sundgot-Borgen, J., Burke, L., Carter, S., Constantini, N., Lebrun, C., Meyer, N., Sherman, R., Steffen, K., Budgett, R., & Ljungqvist, A. (2014). The IOC consensus statement: Beyond the Female Athlete Triad-Relative Energy Deficiency in Sport (RED-S). *British Journal of Sports Medicine*, *48*(7), 491–497. https://doi.org/10.1136/bjsports-2014-093502

Neesham-Smith, D., Aisbett, B., & Netto, K. (2014). Trunk postures and upper-body muscle activations during physically demanding wildfire suppression tasks. *Ergonomics*, *57*(1), 86–92. https://doi.org/10.1080/00140139.2013.862308

Nelson, G. J., Schmidt, P. C., Bartolini, G. L., Kelley, D. S., & Kyle, D. (1997). The effect of dietary docosahexaenoic acid on plasma lipoproteins and tissue fatty acid composition in humans. *Lipids*, *32*(11), 1137–1146. https://doi.org/10.1007/s11745-997-0146-5

National Multi-agency Coordinating Group (2017). *National Interagency Mobilization Guide*. Boise, ID: National Interagency Fire Center.

NIFC. (2015). Total wildland fires and acres (1960-2014). Accessed April 2018

O'Hara, R., Henry, A., Serres, J., Russell, D., & Locke, R. (2014). Operational stressors on physical performance in special operators and countermeasures to improve performance: a review of the literature. *Journal of Special Operations Medicine : A Peer Reviewed Journal for SOF Medical Professionals*, *14*(1), 67–78. https://europepmc.org/article/med/24604441

Pendergast, F. J., Ridgers, N. D., Worsley, A., & McNaughton, S. A. (2017). Evaluation of a smartphone food diary application using objectively measured energy expenditure. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 1–10. https://doi.org/10.1186/s12966-017-0488-9

Phillips, S. M., & van Loon, L. J. C. (2011). Dietary protein for athletes: From requirements to optimum adaptation. *Journal of Sports Sciences*, *29*(SUPPL. 1). https://doi.org/10.1080/02640414.2011.619204

Pitkin, R., Allen, L., Bailey, L., Washington, M. B.-, DC, undefined, & 2000, undefined. (n.d.). Dietary Reference Intakes for Thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, Pantothenic acid, biotin and choline. *Nationalacademies.Org*. Retrieved April 7, 2021, from https://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=s6015

Rao, S., Pandey, A., Garg, S., Park, B., Mayo, H., Després, J. P., Kumbhani, D., de Lemos, J. A., & Neeland, I. J. (2019). Effect of Exercise and Pharmacological Interventions on Visceral Adiposity: A Systematic Review and Meta-analysis of Long-term Randomized

Controlled Trials. *Mayo Clinic Proceedings*, *94*(2), 211–224. https://doi.org/10.1016/j.mayocp.2018.09.019

Reisen, F., Hansen, D., & Meyer, C. M. (2011). Exposure to bushfire smoke during prescribed burns and wildfires: Firefighters' exposure risks and options. *Environment international*, *37*(2), 314-321.

Ross, R., Aru, J., Freeman, J., Hudson, R., & Janssen, I. (2002). Abdominal adiposity and insulin resistance in obese men. *American Journal of Physiology - Endocrinology and Metabolism*, *282*(3 45-3). https://doi.org/10.1152/ajpendo.00469.2001

Ross, R., & Després, J.-P. (2009). Abdominal Obesity, Insulin Resistance, and the Metabolic Syndrome: Contribution of Physical Activity/Exercise. In *Wiley Online Library* (Vol. 17, Issue SUPPL. 3). https://doi.org/10.1038/oby.2009.381

Ruby, B. C., Leadbetter, G. W., Armstrong, D. W., & Gaskill, S. E. (2003). Wildland firefighter load carriage: Effects on transit time and physiological responses during simulated escape to safety zone. *International Journal of Wildland Fire*, *12*(1), 111–116. https://doi.org/10.1071/WF02025

Ruby, B C., Schoeller, D. A., & Sharkey, B. J. (2001). Evaluation of Total Energy Expenditure (Doubly Labeled Water) Across Different Measurement Periods During Arduous Work. *Medicine & Science in Sports & Exercise*, *33*(5), S274. https://doi.org/10.1097/00005768-200105001-01545

Ruby, Brent C., Schoeller, D. A., Sharkey, B. J., Burks, C., & Tysk, S. (2003). Water turnover and changes in body composition during arduous wildfire suppression. *Medicine and Science in Sports and Exercise*, *35*(10), 1760–1765. https://doi.org/10.1249/01.MSS.0000089348.39312.4D

Ruby, Brent C., Shriver, T. C., Zderic, T. W., Sharkey, B. J., Burks, C., & Tysk, S. (2002). Total energy expenditure during arduous wildfire suppression. *Medicine and Science in Sports and Exercise, 34*(6), 1048–1054. https://doi.org/10.1097/00005768-200206000-00023

Schoeller, D. A. (1999). Recent advances from application of doubly labeled water to measurement of human energy expenditure. *The Journal of nutrition*, *129*(10), 1765-1768.

Sharkey, B. (1999). Development and validation of a job-related work capacity test for wildland firefighters. Wildland firefighter health and safety recommendations of the April 1999 conference. Missoula, MT: International Assoication of Wildland Fire.

Sharkey, B. & DeLorenzo-Green, T. (1994). Development of a job-related work capacity test for wildland firefighters. *Medicine and Science in Sports and Exercise*. 28:S79.

Sharkey, B., Rothwell T., (1996). Validation and field evaluation of a work capacity test for wildland firefighters. *Medicine and Science in Sports and Exercise*. 26:S88.

Semmens, E. O., Domitrovich, J., Conway, K., & Noonan, C. W. (2016). A cross-sectional survey of occupational history as a wildland firefighter and health. American Journal of Industrial Medicine, 59(4), 330-335.

Shin, D. S., Lee, K., & Kim, D. (2007). Biomechanical study of lumbar spine with dynamic stabilization device using finite element method. *CAD Computer Aided Design*, *39*(7), 559–567. https://doi.org/10.1016/j.cad.2007.03.005

Sol, J. A., Ruby, B. C., Gaskill, S. E., Dumke, C. L., & Domitrovich, J. W. (2018). Metabolic Demand of Hiking in Wildland Firefighting. *Wilderness and Environmental Medicine, 29*(3), 304–314. https://doi.org/10.1016/j.wem.2018.03.006

Solomonow, M. (2004). Ligaments: a source of work-related musculoskeletal disorders. *Journal of Electromyography and Kinesiology*, *14*(1), 49–60. https://doi.org/10.1016/j.jelekin.2003.09.011

Taylor, C. L., & Meyers, L. D. (2012). Dietary reference intakes. *Modern Nutrition in Health and Disease: Eleventh Edition*, 1480–1489. https://doi.org/10.1016/s0002-8223(98)00160-6

Tharion, W. J., Montain, S. J., O'Brien, C., Shippee, R. L., & Hoban, J. L. (1997). Effects of military exercise tasks and a carbohydrate-electrolyte drink on rifle shooting performance in two shooting positions. *International Journal of Industrial Ergonomics*, *19*(1), 31–39. https://doi.org/10.1016/0169-8141(95)00087-9

Theobald, D. M., & Romme, W. H. (2007). Expansion of the US wildland-urban interface. *Landscape and Urban Planning*, *83*(4), 340–354. https://doi.org/10.1016/j.landurbplan.2007.06.002

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. *Journal of the Academy of Nutrition and Dietetics*, *116*(3), 501–528. https://doi.org/10.1016/j.jand.2015.12.006

Toorang, F., Sasanfar, B., Razeghi Jahromi, S., Ebrahimpour Koujan, S., Narmcheshm, S., Rafei, A., & Zendehdel, K. (2019). Validation of diet history questionnaire in assessing energy and nutrient intakes of Iranian population. *Iranian Journal of Public Health*, *48*(6), 1074–1081. https://doi.org/10.18502/ijph.v48i6.2906

Trumbo, P., Yates, A., … S. S.-J. of the A., & 2001, undefined. (n.d.). Dietary reference intakes: vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. *Jandonline.Org*. Retrieved April 7, 2021, from https://jandonline.org/article/S0002-8223%2801%2900078-5/abstract

Vincent, G. E., Aisbett, B., Larsen, B., Ridgers, N. D., Snow, R., & Ferguson, S. A. (2017). The impact of heat exposure and sleep restriction on firefighters'work performance and physiology during simulated wildfire suppression. *International Journal of Environmental Research and Public Health*, *14*(2). https://doi.org/10.3390/ijerph14020180

Volpe, S. L. (2007). Micronutrient Requirements for Athletes. *Clinics in Sports Medicine*, *26*(1), 119–130. https://doi.org/10.1016/j.csm.2006.11.009

Von Duvillard, S. P., Braun, W. A., Markofski, M., Beneke, R., & Leithäuser, R. (2004). Fluids and hydration in prolonged endurance performance. *Nutrition*, *20*(7–8), 651–656. https://doi.org/10.1016/j.nut.2004.04.011

Weaver, C. M., & Fleet, J. C. (2004). Vitamin D requirements: current and future. *The American Journal of Clinical Nutrition*, *80*(6 Suppl). https://doi.org/10.1093/ajcn/80.6.1735s

Westerterp, K. R. (1999). Body composition, water turnover and energy turnover assessment with labelled water. *Proceedings of the nutrition society*, *58*(4), 945-951.

Whiting, S. J., & Barabash, W. A. (2006). Dietary Reference Intakes for the micronutrients: Considerations for physical activity. *Applied Physiology, Nutrition and Metabolism*, *31*(1), 80–85. https://doi.org/10.1139/h05-021

Wimberly, M. C., & Liu, Z. (2014). Interactions of climate, fire, and management in future forests of the Pacific Northwest. *Forest Ecology and Management*, *327*, 270–279.

https://doi.org/10.1016/j.foreco.2013.09.043

Wolkow, A., Aisbett, B., Reynolds, J., Ferguson, S. A., & Main, L. C. (2016). The impact of sleep restriction while performing simulated physical firefighting work on cortisol and heart rate responses. *International Archives of Occupational and Environmental Health*, *89*(3), 461–475. https://doi.org/10.1007/s00420-015-1085-3

Appendix A

University of Idaho

Department of Movement Sciences

Informed Consent Form for Research Involving Human Subjects

Title: Wildland Firefighter In-Season and Off-Season Variation in Dietary Practices, Body Composition & Fitness: A Longitudinal Analysis

Primary Investigator: Ann Brown, Ph.D., CISSN

Co-Investigators: Samantha Brooks, M.S.

Participant's Printed Name:

____

You are being asked to take part voluntarily in the research project described below. Please take your time in deciding. Before agreeing to take part in this research study, it is important that you read the consent form. Please ask the researcher to explain any words or information that you do not understand.

VOLUNTARY CONSENT

I voluntarily and without element of force or coercion, consent to be a participant in the research project entitled "Wildland Firefighter In-Season and Off-Season Variation in Dietary Practices, Body Composition & Fitness: A Longitudinal Analysis." This study is being conducted by Dr. Ann Brown, and Samantha Brooks, of the College of Education at the University of Idaho. This study has been reviewed and approved by the University of Idaho Institutional Review Board.

PURPOSE

The primary purpose of this study is to assess changes in diet, body composition and performance over the 2019-2020 fire season and off season among wildland firefighters.

I must meet the following criteria to be included in the study: (1) current wildland firefighter between the ages of 18-57, (2) have no contraindications to exercise based on the American

College of Sports Medicine and American Heart Association (ACSM/AHA) risk stratification criteria including uncontrolled hypertension, currently taking blood pressure medications, or have been diagnosed with cardiovascular disease, stroke, diabetes, thyroid, or kidney dysfunction, (3) have no risk factors for cardiovascular disease as determined by ACSM guidelines, and (4) have no significant musculoskeletal injuries or other medical conditions over the past 6 months.

PROCEDURES

If you agree to take part in this study, the research team will ask you to attend 3 laboratory visits: visit 1 in May (pre-fire season), visit 2 in October (post-fire season) and visit 3 in February (-off season). Each visit will take approximately 5 hours and all measurements and assessments are described in detail below. You will record dietary intake for 3 days which will take approximately 30 minutes total. The total time for this study is 17 hours over 12 months.

Measurements include: (1) medical history questionnaire, (2) dietary recall; (3) body composition and; (4) performance tests.

Human Performance Laboratory (HPL) Visits

Upon arrival to the HPL, I will sign the written informed consent and complete the medical history questionnaire.

<u>Medical History Questionnaire</u>: A questionnaire will be used to gather information about medical history, injury history, and dance background. This private information will be held in the utmost confidence. Questionnaire information will not include my name and will be coded by a subject number to which only the researchers have access.

Dietary History Questionnaire: Dietary history will be measured using the Dietary History Questionnaire (DHQ). I will be asked to maintain normal eating patterns and habits throughout the study.

Height and weight: Height and weight will be measured with a DETECTO sonar stadiometer and a digital scale before completing a DXA scan. A measurement of my height and weight, without shoes, will be taken.

Body composition with DXA: My body composition will be assessed via DXA scan. I will be asked to change into clothing that is free of metal and/or hard plastic (buttons, zippers, snaps, etc.) and asked to remove all metal from the body (jewelry, eyeglasses, hair accessories, etc). The body composition of my total body will be measured noninvasively via the use of the Hologic DXA Scanner (Hologic Horizon™), with one scan; anteroposterior (AP) view of the total body lying supine. Very low doses of radiation are used; however, this test is non-invasive. Testing will be completed according to the manufacturer's instructions and specifications by a certified X-ray technician. My hands and feet will be secured in place to avoid unwanted movements during the body scan. The scan will take approximately 10 minutes to complete. From the scan, my lean soft tissue (kg), fat free mass (kg) and bone density will be determined.

Performance testing: Two hours prior to the visit, I will be instructed to abstain from outside exercise (other than dance) for 24 hours. I will preform a 10 minute treadmill test with a 58 pound backpack. Then I will preform shoulder and knee flexion and extension exercises. Lastly, I will preform a kettlebell handgrip test to volitional fatigue.

DISCOMFORTS AND RISKS

I understand there is a minimal level of risk involved if I agree to participate in this study. Body composition will be evaluated by Dual-Energy X-ray Absorptiometry (DXA). This involves low exposure to radiation less than 5 mREMs per DXA scan. Doses received from DXA examinations are small in comparison to other common radiation sources and are believed to represent no significant health risk. No risk of adverse health conditions have been established for lower exposures of 5000 mREM or less. By comparison, natural background radiation is about 300 mREM/year, an x-ray of the spine is 70 mREM, a mammogram is 45 mREM, and a round trip transcontinental plane flight is 6 mREM. The measurement of body composition using DXA is non-invasive. For your safety, a research team member will be with you at all times during test procedures.

There is also a possibility to feel discomfort during performance testing as well as muscle soreness up to 48 hours following testing. This is common with exercise testing but first aid and ice packs will be provided if necessary.

If I am identified to be at risk for emotional distress I will be referred to the appropriate medical provider (i.e. campus dietician and/or counseling center).

POSSIBLE BENEFITS

You can gain knowledge of your diet, body mass index, body composition, bone mineral density (BMD) and performance capabilities. The benefit to society relates to a better understanding of changes over fire season and off season in the wildland firefighter population.

STATEMENT OF CONFIDENTIALITY

The results of this study may be published but my name or identity will not be revealed. Information obtained during the course of the study will remain confidential, to the extent allowed by law. My name will not appear on any of the results. No individual responses will be reported. Only group responses will be reported in the publications. Confidentiality will be maintained by assigning each subject a code number and recording all data by code number. The only record with my name and code number will be kept by the principal investigator, Dr. Ann Brown, in a locked drawer in her office. Data will be kept for 10 years and then destroyed.

CONTACT INFORMATION FOR QUESTIONS OR CONCERNS

You may ask any questions you have now. If you have questions later, you may call Ann Brown at the number or email listed below.

Dr. Ann Brown	Samantha Brooks
(208) 885-7986	word9534@vandals.uidaho.edu
afbrown@uidaho.edu	

If you have questions or concerns about your participation as a research subject, please contact the University of Idaho Institutional Review Board (IRB) at (208) 885-6340.

SIGNATURE AND CONSENT TO PARTICIPATE IN RESEARCH

The nature, demands, benefits and risks of the study have been explained to me. I knowingly assume any minimal risk involved. I have read the above informed consent form. I understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of the benefits to which I may otherwise be entitled. In signing this consent form, I am not waiving my legal claims, rights or remedies. A copy of this consent form will be given to me.

Participant Name: ________________________________

Participant Signature: ______________________________ Date: __________ Time:

I have discussed this research study with the subject and his or her authorized representative, using language that is understandable and appropriate. I believe I have fully informed the subject of the possible risks and benefits, and I believe the subject understands this explanation. I have given a copy of this form to the subject.

Signature of Investigator: ___________________________ Date: __________ Time:

Appendix B

Human Performance Laboratory

University of Idaho

Department of Movement Sciences Exercise Science & Health

HEALTH AND FITNESS HISTORY QUESTIONNAIRE

The following questions are designed to obtain a thorough preliminary medical history. The information you provide will help us to make the best determination about your eligibility for this study. Please answer all questions and provide as much information as possible. This questionnaire and any other medical information will be kept confidential and will not be shared with any unauthorized person or organization unless you specifically request us to do so.

Name: ______________________________ Job Description: ____________________________

Date of Birth (mm/dd/yy): ____________ Age: ______ Sex: M F Race: ____________

Address: ____________________________ City: __________ State: _____ Zip Code: ________

Phone: (___) _________________________ Email address: ______________________________

PERSONAL HEALTH HISTORY

Have you ever been hospitalized or had surgery? *Y* *N*

Please list all hospitalizations and surgeries to the best of your recollection.

Date *Reason for hospitalization, disease, or injury*

____

____

____

List any disease or illness you have had not listed above *(e.g., pneumonia, strep, etc.)*

____

Have you ever had a stress fracture? *Y* *N*

If yes, please list stress fracture history.

Date *Body Part*

HEALTH CONCERNS

Are you currently seeing a doctor or other health care provider for any reason (depression, anxiety, sleeping difficulties, acupuncture, etc.)?

Y *N* If yes, please explain: ____________________________________

Do you smoke or use smokeless tobacco?

Y *N*

Do you exercise regularly outside of your sport?

Y *N*

How often do you have required practice or training? Please be detailed in the description of an average week of training.

FEMALES ONLY

MENSTRUAL HISTORY

At what age did you first begin your menstrual cycle? _______

Do you still have a monthly menstrual period (*circle one*)?

a. *Y*

b. *N*

What was the first day of your last menstrual cycle? ________

Is your menstrual cycle regular (*circle one*)?

a. *Y*

b. *N* If no, please explain ______________________________________

Have you had prolonged, absent periods for > 3 months?

Y

N

Have you had prolonged, absent periods for > 6 months?

Y

b. *N*

7. Are you currently taking any form of birth control (*circle one*)?

Y

N If yes, what kind? ____

MEDICAL HISTORY

Have you ever been diagnosed as having any of the following and if yes, how are you currently treating the condition?

Y *N* High Blood Pressure
Last known blood pressure reading _______/_______

Y *N*
High Cholesterol or High Triglycerides
Please indicate last known reading
Cholesterol: _______
Triglycerides: ______

Y *N*
Diabetes (*circle one*) *Type 1 Type 2*
Note: Type 1 diabetes is insulin-dependent diabetes mellitus. It is typically diagnosed at an early age and requires insulin shots or insulin pump upon diagnosis. Type 2 diabetes is often diagnosed at an older age (past age 20) and is usually treated with changes in diet and/or medication.

Y *N* Hypoglycemia (low blood sugar)

Y *N* Asthma (*circle one*) Regular OR Exercise induced
Have you ever had the following tests?

N Glucose tolerance test

If yes, what were the results? ____________________________________

Y *N* Fasting blood sugar test

If yes, what were the results? ____________________________________

Does anyone in your immediate family (including your grandparents) have a history of cardiovascular disease (heart attacks, stroke, etc.)?

N If yes, please explain ____

Do you have any neurological problems including fainting, dizziness, headaches or seizures?

N If yes, please explain ____

Signature: _____________________________ Date:

____

Appendix C

ID #_____________ Visit #_____

Height (in)______________________ Weight

(lbs/kg)_____________________/_____________________ Age______________

Test Administrators: ______________________

DEXA

Body Fat (kg): ______________

Body Fat (%):______________

Lean soft tissue (kg): ______________

Lean soft tissue (%):______________

BMD: ______________

T-score:______________