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Intermittent scheduled feedings increase work output during wildfire suppression

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INTERMITTENT SCHEDULED FEEDINGS INCREASE WORK OUTPUT DURING WILDFIRE SUPPRESSION

by

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Chairperson: Brent C. Ruby

The purpose of this study was to determine the impact of supplemental feeding strategies on work output during wildland fire suppression. 76 wildland firefighters (WLFF) from 8 different elite Hot Shot crews were studied during August of 3 seasons. During the first 2 seasons subjects consumed (in addition to their sack lunch): 1) either liquid CHO (200 $ml \cdot hr^{-1}$, 20% CHO (669 $kj \cdot hr^{-1}$)) or placebo (PLA) every hour (L CHO trial), or 2) liquid CHO every even hour and solid CHO (25g CHO, 10g protein, 2g fat, 669 $kj \cdot hr^{-1}$) every odd hour or PLA (L+S CHO trial) using counter-balanced crossover designs. During the final season, subjects consumed their sack lunch (SL) halfway through their shift or snack foods (SNA) at 90-minute intervals following breakfast in a randomized cross-over design (isocaloric energy intake, 6418 ± 1109 $kj \cdot shift^{-1}$). Work output was monitored by CSA and MiniMitter actigraphy units.

During the L CHO trials, CHO demonstrated significantly higher average CSA counts across the entire day compared to PLA, (50,262 ± 36,560 and 40,159 ± 35,969 $counts \cdot hr^{-1} \cdot 12hr^{-1}$, respectively; $p<0.05$). For the L+S CHO trials, the day by time interaction was significant, showing higher average $counts \cdot min^{-1}$ for CHO compared to PLA for 2 hours before lunch and the last 4 hours of the shift ($p<0.05$). For the SNA and SL trials, the day by time interaction was significant, demonstrating higher average $counts \cdot min^{-1}$ for SNA during the final 2 work hours compared to SL, (521 ± 421 vs. 366 ± 249 $counts \cdot min^{-1} \cdot 2hr^{-1}$, respectively; $p<0.05$). Liquid and/or solid supplemental CHO and regular feedings increased self-selected work rates during wildland fire suppression, particularly during latter hours of the work shift.

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Chapter One: Statement of the Problem

Introduction

Supplemental feeding during long-duration exercise has been consistently shown to increase the subject's ability to complete physical work[1, 2, 4, 7-11, 13, 15, 16, 18, 19, 21-23, 25, 26, 35, 38, 40]. The majority of previous research has compared the effects of liquid carbohydrate (CHO) feedings versus placebo (PLA) for measures such as time to exhaustion, high intensity performance after fatigue, and metabolic stress. Most of these studies are done with well-trained subjects and typically do not last longer than 4 hours. When measuring work sustainability in humans, absolute measures (metabolic equivalents, METS or scaling work based on basal metabolism) or relative measures (%HR Max or rating of perceived exertion, RPE) can be used[29]. Additionally, physical labor can be classified as endurance or energy intensive based on the task and its duration[29]. During wildland fire suppression, both types of labor are needed, with a stronger demand for endurance over long shifts rather than intensive effort per unit time; however, rigorous and exhausting work is periodically required.

Nutrition and hydration are important factors for performance in athletic events and sustained physical labor. The wildland firefighter (WLFF) is exposed to a multitude of adverse working conditions, including hiking up steep terrain, digging fire lines, and chain sawing. Previous research done in this laboratory has determined the estimated total energy expenditure (TEE) of the WLFF to be 12-26 $MJ \cdot day^{-1}$, or 2.0–4.3 $kcal \cdot min^{-1}$ [33]. For wildland firefighters (WLFF), it is critical to provide food sources during the workshift that meet required energy demands while providing an adequate degree of satisfaction. While energy balance may be maintained with adequate intake, the macro and micro nutrient balance influences work output[30,31]. Historically, high protein foods were thought to be the best for those performing large amounts of work[16]. However, today it is known that high CHO diets are the preferred food choice to maximize work output for those engaging in intense training or working physically demanding jobs[16, 17]. In addition to the types of foods eaten, consumption timing is vital to maintaining steady work output and to prevent gastrointestinal discomfort[7, 10, 11, 21, 38].

Despite high-energy demands of WLFF, work from this laboratory has demonstrated that WLFF are able to maintain energy balance. A problem previously identified is that total body water (TBW) appears to be more compromised over five days of arduous work[32]. Maintaining energy balance and body weight over the course of the fire season is essential for optimal performance. In two other studies by this laboratory, regular CHO feedings in addition to the standard lunch increased work output, particularly during the second half of the work shift[30, 31]. The increase in work output was equivalent to 2 additional hours over the course of a 10-hour day, suggesting that self-selected work rate is higher when CHO are ingested. The WLFF consuming the CHO feedings were ingesting 160 $kcal \cdot hr^{-1}$ more than the other group. Ruby et al. have reported that WLFF fall short in their CHO intake and consume more protein and fat than normally suggested for such physical work demands, but did not show that an increase in CHO improved performance[32]. Traditionally, the WLFF diet consists of a fully catered breakfast and dinner of unlimited proportions and a sack lunch consisting of ~1500-2000 kcals. In addition to the sack lunch, many WLFF supplement their diets with convenient foods such as granola bars, power pars, cereal bars, and a variety of sport drinks.

The Problem

WLFF are provided a sack lunch of about 5.4 to 8.4 MJ (1300-2000 kcals). It is unknown if this is appropriate to meet the energy requirements necessary to sustain a steady work output over a long day of arduous work. The current lunch feeding program for WLFF appears to waste large amounts of unused food, as WLFF often discard provided food items and may supplement their lunches with personal food choices. The current approach to the feeding of the WLFF is costly and it is unknown if it is providing the appropriate energy requirements to sustain a high steady work output. The purpose of this study is to determine the effects of a regimented approach of steady feedings throughout the day on work output and subject satisfaction.

Research Hypotheses

When food sources are consumed at regular intervals throughout the day, WLFF will perform more work compared to when food is consumed during a single lunch break[1, 2, 7-9, 11, 13, 15, 16, 18, 19, 21, 22, 25-27, 30, 31, 35, 38].

RPE will be similar in the post lunch hours for both groups despite a decline in work output for the group consuming their lunch at one time[30, 31].

The regular interval feeding strategy will have higher satisfaction ratings than the lunch that is consumed at one time.

Significance of Study

This study can provide valuable feedback for WLFF, as well as those in jobs requiring sustained work over a long period of time, in regards to improving feeding strategies to sustain high work output. It is well known that regularly timed feedings, particularly CHO, will improve work performance. It is currently unknown if it is better to snack regularly over the course of an arduous work day, or eat an isocaloric lunch in the middle of the day.

Rationale for Study

Previous research in areas of work physiology, particularly wildland fire suppression, has not addressed isocaloric feeding strategies comparing one midday meal with similar small meals spread over the work shift. Numerous studies have compared the effects of CHO versus PLA feedings and the impact on athletic performance[2-4, 6-13, 15, 18-21, 24, 25, 27, 28, 35, 38, 39]. Those studies that have been described as long duration typically do not exceed 4 hours of exercise. Thus, over an extended and arduous work scenario (~12 hr) the impact of isocaloric feedings provided at regular time intervals is unknown.

Limitations

Day to day work assignments can differ dramatically for WLFF during a multiple day trial with different conditions. The crossover design used in this study will minimize the daily differences in weather, work assignment, rest, and diet.

The fatigue status of subjects prior to entering the study has the potential to impact work output, heart rate, and RPE. There is little researchers can do to control this other than test multiple individuals.

Equipment failure in the field may not provide consistent data and it is anticipated that data from a number of subjects will be unusable. To overcome this, we will work to test more subjects than required for adequate statistical power.

Subjects may consume foods not provided by the researchers. Every effort will be made to accurately interview the subjects on their food intake.

Delimitations

The regular interval feeding strategy proposed as an intervention is different and novel for the WLFF with new types of food. The WLFF might respond with more enthusiasm due to the novelty or the intervention compared to the sack lunch.

If subjects are biased toward the traditional sack lunch feeding strategy they may provide lower scores for it and higher scores for the regular feeding strategy on the satisfaction surveys.

Subjects may discuss their opinions about each feeding strategy with other subjects. This has the potential to skew the results in one direction.

Definition of Terms

Abbreviation	Meaning	Definition
EE	Energy expenditure	The amount of energy expended, typically expressed in kilocalories or kilojoules.
EEA	Energy expenditure from activity	The amount of energy expended during physical activity, independent measure from energy expended at rest.
TEE	Total energy expenditure	The sum of energy expended during rest and activity, typically measured in a 24 hour period.
RPE	Rating of perceived exertion	The perception for how difficult a task is to complete on a scale of 6-20, where 6 is sitting and 20 is maximal work.
WLFF	Wildland firefighter	A firefighter who fights fires in wilderness areas, such as mountains.
METS	Metabolic equivalent	1 MET = VO_2 of 3.5 $ml \cdot kg \cdot min^{-1}$; way to express work relative to rest. Ex: 5 METS would be an EE 5 times that of resting EE.
CHO	Carbohydrate	Macronutrient that comprises the bulk of one's diet; supplement for extended duration exercise or work.
HR	Heart rate	The number of heart beats in one minute.
TBW	Total body water	The amount of water in an individual's body.
SL	Sack lunch	The traditional lunch WLFF consume that is provided by the particular

		caterer working at the fire.
FSR	First strike ration	A feeding strategy based upon consuming high-energy foods at regular intervals throughout the day.
Kcals	Kilocalories	The amount of heat required to raise the temperature of 1000 grams of water 1 degree C; the unit used to express the heating value of foods and to measure metabolic rate.
Kj	Kilojoules	SI standard to measure energy. A kilocalorie is equal to 4.184 kilojoules.
	Satisfaction surveys	Surveys consisting of questions regarding the likes and dislikes, satiety, convenience, and satisfaction with the different feeding strategies (SL or FSR).
	Work output	The amount of activity counts a subject achieves doing daily work tasks.
	Accelerometer	A name for devices that measure human movement by ascribing counts (an arbitrary unit) to the amount of work a person is performing.
BMR	Basal metabolic mate	The metabolic rate at rest for a 24 hr period.
FFM	Fat free mass	The muscle and bone component toward one's total mass; it excludes fat mass.
PLA	Placebo	A sweetened liquid that has no treatment value. It is used to compare the effect of the treatment, typically in this paper this will be CHO.
FFA	Free fatty acids	Fatty acids present in the blood stream.
VO_2	Volume of oxygen	Steady state oxygen consumption by the working muscles during exercise.
VO_2 max	Maximal volume of oxygen	The maximal oxygen consumption by the working muscles during exercise to volitional fatigue.
BG	Blood glucose	Glucose present in the blood stream.
MCT	Medium chain triglycerides	Shorter fatty acids than those typically found in most fats and oils.

Chapter Two: Review of Literature

Energy expenditure in field

Determining energy expenditure (EE) in field environments presents a challenge to researchers because of the difficulties of the various techniques. Considered the gold standard for calculating EE, the doubly labeled water methodology most accurately predicts EE during most free living environments[34, 36]. Briefly, this technique consists of consuming $^{2}H_2{}^{18}O$ in a sufficient amount based on the individual's body weight. The levels of the two isotopic tracers, ^{2}H (deuterium) and ^{18}O, elevate in the body following ingestion. The deuterium leaves the body via water loss (sweat, urine, water vapor) while the ^{18}O leaves via water loss and CO_2. Thus, from the differences in the rate of loss of the two tracers EE expenditure can be estimated based upon CO_2 production.

Despite the challenges of using this technique in the field environment, it can provide accurate EE under free-living conditions. In an attempt to determine total energy expenditure (TEE) in WLFF, Ruby et al. used the doubly labeled water methodology in 8 male and 9 female Type 1 (hotshot) firefighters during short-term (3-5 d) wildfire suppression[33]. It was hypothesized that TEE would be similar to those found during military operations and mountainous/arctic expedition. Overall, men had higher rate of absolute daily EE, but no differences between sexes existed when TEE was expressed as a multiple of BMR. The males also had significantly higher EE from activity compared to the females, but expressed relative to body weight there were no differences. It was concluded that TEE ranged from 12.9 to 26.2 $MJ \cdot d^{-1}$ in the WLFF. EEA ranged from 3.9

to 16.4 MJ · d^{-1}. The primary determinants of TEE were described as work assignment, self-selected work intensity, and the location of the fire.

Due to high costs and difficulty of the doubly labeled water methodology, other techniques are used to determine EE under free-living conditions. In recent years, accelerometry has become a widely used method for monitoring human movement and estimating EE[5, 37]. In order to determine EE using activity monitors, the relationship between the metabolic cost (EE via indirect calorimetry) of an activity and the activity counts associated with it must be determined. Heil et al. developed EE prediction models using indirect calorimetry and activity monitors for 7 tasks associated with wildland fire suppression[14]. The prediction equations are categorized based on two ranges of activity counts and worked well for all activities except uphill hiking. The conclusion was that gross summary measures of EE can be accurately predicted using activity monitors in WLFF when work activities are carefully coordinated with accelerometry data. In short, the doubly labeled water methodology is the gold standard for estimating EE. Activity monitors cannot accurately predict actual EE in kcal·min^{-1}, but are a practical and valid way to predict work patterns and monitor human movement in WLFF.

Nutrition in field

In a thorough review article by Montain and Young on the effects of feeding and performance in military studies dating back to the 1920s, several key observations were made[26]. First, long term underfeeding (2+ months) during times of sustained high EE consistently demonstrates a decrease in physical performance capability. In these studies, researchers either restricted the amount of kcals in one group and compared it to the other, or tested soldiers on performance pre and post operations. Next, periods of short-term (~4-10 days) underfeeding have limited impact on muscle strength and aerobic endurance[26]. Kcals were highly restricted in many studies in efforts to determine the minimum intake necessary to prevent ketosis, diuresis, negative nitrogen balance, and loss of performance. Another finding was that CHO feedings (primarily in the liquid form) improve soldier performance and aid in increasing energy intake. It was found that soldiers performed better in uphill running, marksmanship, and running time to exhaustion. In short, adequate kcal consumption is necessary to sustain performance over longer periods of time, but short term underfeeding appears to not hinder physical capabilities.

As stated previously, the TEE for WLFF can range from 12.9 to 26.2 $MJ \cdot d^{-1}$ (3000 to 6300 $kcals \cdot d^{-1}$, respectively)[33]. With such high energy demands over the course of several months of firefighting, body weight maintenance can become an issue with inadequate food consumption. A study by Ruby et al. determined the effects of exertion during wildfire suppression on water turnover and changes in body composition in WLFF during a 5-day period[32]. 14 WLFF and 13 recreationally active college students (RACS) were subjects for the study. Water turnover and changes in body composition were determined using ^{2}H labeled water over a 5-day period. For the WLFF, the 5 days were during shifts in fires in the western United States. The RACS were followed over a 5-day period during the early part of the fall semester. The same protocol for collection of urine, body weights, and skinfold measurements was used for both groups. Urine osmolality and urine specific gravity were determined in both groups.

Rates of water turnover during the experimental period were 6.7 ± 1.4 and 3.8 ± 1.0 $L \cdot d^{-1}$ for the WLFF and RACS, respectively, and values for specific gravity and urine osmolality were higher in the RACS compared with the WLFF[32]. The WLFF demonstrated a significant decrease in FFM across the experimental period for the ^2H_2O dilution and SKF methods, while the RACS group maintained FFM according to both methodologies[32]. Thus, short-term wildland fire suppression can negatively alter body composition (by the loss of FFM). However, these data do not suggest a loss in FFM (other than water loss) as the change in body weight was similar to drop in total body water. However, unlike previous military studies, the effect of these changes on performance measures specific to wildland firefighting was not evaluated.

During the annual Swiss mountain marathon in Switzerland, a team of researchers studied the nutrient intake of 42 amateur runners. Trained personnel were at check stations and recorded the amounts of food and drink consumed by participants. For such an event, recommended fluid intakes range between 400 and 800 $ml \cdot hr^{-1}$ [4, 40]. Recommended CHO intake ranges between 30 and 60 $g \cdot hr^{-1}$ [1]. The mean fluid consumption was 3,777 ml (545 $ml \cdot hr^{-1}$) and the mean energy intake was 971 kilocalories (88% CHO). The mean body mass loss during the run was 2.9 kg, associated with a lower fluid intake. 18 runners consumed more than 30 $g \cdot hr^{-1}$ CHO, while only 3 consumed 60 $g \cdot hr^{-1}$. Interestingly, those who consumed higher amounts of CHO and fluid had faster times. The main finding of the study was that the majority of participants did not meet the recommended amounts of fluid and CHO; those who were close to meeting the recommendations performed better. Thus, supplemental feeding and fluid intake during a mountain marathon (mean running time 7 h 3 min; range 4 h 37 min to 9 h 20 min) was associated with increased performance and a better maintenance of body mass.

Ergogenic effects of carbohydrate

When long duration or fatiguing exercise is performed without supplemental feeding, research has consistently demonstrated similar metabolic responses. In a 4-hour cycling field study, Meyer et al. described the metabolic and cardiovascular reactions to long-term steady-state endurance training under conditions of varying CHO supplementation[23]. 14 subjects cycled at 70% of AT for 4 hours in a field setting. On three separate occasions subjects consumed either 0%, 6%, or 12% CHO solution at a rate of 50 ml fluid per kg body weight throughout each test. Researchers collected power output, O_2 uptake, heart rate, blood glucose, lactate concentration, blood FFA, and blood glycerol every 30 or 60 minutes.

Power output, O_2 uptake, and heart rate were similar across all 3 trials. Heart rate demonstrated an upward drift beyond 2 hours of exercise regardless of the CHO solution. During exercise, differences in blood glucose were statistically significant between the 0% solution trial and the 6% and 12%. There were no statistical differences between the 6% and 12% solution trials except for 1-hour post exercise. Though not statistically significant, mean blood glucose values were lower at all time points for the 6% solution when compared to the 12% solution. During exercise, blood lactate concentrations did not differ among the 3 trials. FFA and glycerol were significantly different in a dose dependent manner, i.e. 0% had the highest, 6% in the middle, and 12% the lowest. RER declined as CHO concentration declined across all 3 trials. CHO oxidation remained stable during the 12% trial (70.8% CHO during 30-60 minutes and 67.5% CHO during 210-240 minutes) while it declined during the 0% and 6% trials (67.5% to 47.2% and 70.8% to 57.5% for the 0% and 6% trials, respectively. In short, this study demonstrates that supplemental CHO feeding leads to an enhanced reliance on glucose metabolism in a dose-dependent manner[23].

Similar findings were demonstrated in the early 1980s when research on CHO as a performance-enhancing tool was becoming popular. Researchers initially thought that supplemental CHO feedings delayed muscle glycogenolysis and thus increased time to exhaustion compared to PLA trials. In a study by Ivy et al., researchers examined the effects of CHO ingestion on endurance during low-intensity exercise[15]. Subjects walked at 45% of VO_2 max until exhaustion and received either a PLA or CHO drink (120 g CHO administered in four equal amounts at 60, 90, 120, and 150 min). After the point of exhaustion, subjects rested for 30 minutes and then exercised to exhaustion at 80% VO_2 max.

Endurance performance was increased significantly (11.5%) when CHO was consumed during the second hour of exercise. Exhaustion time for the CHO trial was 299.0 ± 9.8 min and for the PLA trial 268.3 ± 11.8 min. There was no difference in RPE or VO_2. CHO oxidation was 0.53 $g \cdot min^{-1}$ ($p<0.05$) higher during the CHO trial. Plasma FFA and glycerol increased linearly over the first hour of exercise for both treatments but was attenuated in the CHO trial once CHO were administered. In the PLA trial they continued to rise until exhaustion. While not statistically significant, exercise to exhaustion at 80% VO_2 max was 10.1 ± 1.2 min for the CHO trial and 8.3 ± 1.3 min for the PLA trial (20% longer, $p<0.10$). Prior to the run, blood glucose and insulin were significantly elevated during the CHO trial. Blood glucose levels declined linearly during the PLA trial but the drop was reversed and then attenuated in the CHO trial. In short, time to exhaustion was increased with CHO feeding and subjects were able to perform better on a higher intensity task.

In another early study, Coyle et al. evaluated the effects of CHO feeding during exercise on the development of fatigue and reduction in work capacity in trained individuals during exercise lasting 2-3 hours[9]. Subjects cycled at 74% ± 2% of VO_2 max for as long as possible under two different testing conditions, CHO (~6% solution) and PLA. The point of exhaustion was when the cyclists could no longer sustain an intensity of 50% VO_2 max or 180 min was reached. During the PLA trial, 7 of 10 subjects showed a decline in blood glucose (BG) after 1 h of exercise. By 90 min BG had fallen significantly below the resting level. 3 subjects showed no decrease in BG during the PLA trial. During the CHO trial subjects maintained BG throughout, having it slightly above resting levels. The 7 subjects who had a decrease in BG during the P trial delayed fatigue (drop of work rate by 10% VO_2 max) during the CHO trial at 159 ± 6 versus 126 ± 3 min in the PLA trial. After reaching the point of fatigue, they were able to finish the 180 min. The 3 subjects who showed no drop in BG during the PLA trial completed 6.6% more work during the CHO trial. Their time to fatigue was not affected by either treatment. For the entire group, exercise time to fatigue was 134 ± 6 min without and 157 ± 5 with CHO.

Thus, researchers concluded that CHO feeding during prolonged exercise (70-80% VO_2 max) can postpone development of fatigue in some trained individuals by possibly postponing muscle glycogen depletion[9]. The decline was seen only in those subjects who had decreases in BG, suggesting that when BG is constant the muscles are using BG rather than stored glycogen.

Similar to the study discussed earlier, Hargreaves et al. investigated the effects of solid CHO ingestion on muscle glycogen utilization during 4 h of cycling exercise[13]. 10 male subjects cycled for 4 hrs [30 minute blocks: 20 min at 50% VO2 max, 10 min of intense, intermittent exercise (30 s at 100% VO2 max followed by 2 min rest)]. Upon completion of the 4 hrs, subjects completed a maximal sprint trial. In one trial subjects consumed 43 g sucrose, 9 g fat, 3 g protein, and 400 ml H_2O at 0, 1, 2, and 3 h exercise. Muscle biopsies were taken before and after 1 and 4 h of exercise. Blood samples and respiratory gas were collected at regular intervals.

Compared to the PLA trial, total muscle glycogen usage was significantly lower during CHO trial (102.6 mmol·kg-1 w.w. vs. 124.2 mmol·kg-1 w.w., a difference of 21.6 mmol·kg-1 w.w.). RER was higher during the CHO trial, suggesting greater total CHO oxidation. Blood glucose was maintained by the CHO feedings but, after an initial rise, declined steadily during the PLA trial. Blood lactates were similar between both trials. During the CHO trial subjects performed 45% longer during the sprint ride (126.8 ± 24.7 sec vs 87.2 ± 17.5 sec, $p<0.05$). Researchers concluded that solid CHO feedings reduce muscle glycogen depletion during prolonged exercise and improve sprint performance following long duration exercise.

In another 4 hr cycling study by the same research team, Fielding et al. examined the effects of a smaller CHO intake (21.5 g·hr-1) on substrate use during exercise[11]. In this study, researchers manipulated the timing of feedings. Male subjects (n=9) participated in three randomized 4 hour trials. Subjects were given a solid feeding containing 86 g CHO, 18 g fat, and 6 g protein over the 4 hour period during the 2 experimental trials, the dosage (D) and frequency (F) trials. During the F trial subjects consumed equal portions every 30 minutes along with 200 ml of water. During the D trial subjects consumed equal portions every hour, beginning with 0. Thus, there were 8 feedings in the F trial and 4 in the D trial but each trial had the same total kcal and macronutrient distribution. In the C trial subjects drank 400 ml of H_2O (artificially sweetened) every hour beginning with 0. Muscle biopsies were taken at 0, 1 hour and immediately before the final sprint ride.

Muscle glycogen concentration at 0, 1, and 4 hour of exercise revealed no significant differences among the 3 trials. RER was higher during the D and F trials compared to the C trial, indicating higher CHO oxidation during supplemental feeding. Blood glycerol and FFA increased in a linear fashion during the C trial, but there were no differences in glycerol between the D and F trial. During the F CHO trial, subjects performed significantly longer during the sprint ride compared to the C trial (120.7 ± 9.6 s vs 81.0 ± 7.1 s for trials F and C, respectively). There were no differences between D and F and D and C (110.6 ± 13.9 s for D trial). With an 80% reduction in muscle glycogen, the researchers concluded that muscle glycogen should be considered a primary fuel source in exercise of this intensity and duration[11]. However, they also suggested that the exogenous substrate provided may not have been of sufficient quantity to result in a significant reduction in the use of muscle glycogen during this kind of trial[11].

In a later study by Coyle et al., researchers tried to directly measure muscle glycogen utilization during strenuous exercise with and without CHO feedings to determine whether muscle glycogen sparing can explain the postponement of fatigue[8]. 7 trained cyclists completed two 4-hour cycling protocols at 70-74% VO_2 max, slightly below their LT. During the PLA trial the subjects consumed an artificially sweetened drink at a rate of 4 $ml \cdot kg^{-1}$ body weight at 20 minute intervals throughout the trial. For the CHO trial, they received CHO in the amount of 2 $g \cdot kg^{-1}$ body weight in a 50% solution during the 20th minute of exercise and 0.4 $g \cdot kg^{-1}$ body wt in a 10% solution every 20 min thereafter. Biopsies from the vastus lateralis were taken prior to exercise, after 2 hours of exercise, at the time they fatigued during the PLA trial (~3 hrs) and during the CHO trial. (~4 hrs).

Mean exercise time was 33% longer when subjects were fed CHO compared to the PLA, ranging from 21 to 149 min. During the CHO trial blood glucose was maintained throughout, while it steadily dropped in the PLA trial. RER was stable for the first 2 hours of the PLA trial, then declined toward exhaustion; conversely, the RER was steady for the CHO trial from start to finish. The additional 60 ± 16 min of exercise performed before fatiguing when subjects were fed CHO was accomplished without a significant reduction in glycogen within the vastus lateralis (in other words, levels were the same at fatigue for both trials, the CHO trial just delayed the depletion). Plasma FFA levels rapidly increased after 2 hrs in the PLA trial whereas CHO feedings blunted this response. RPE was similar between trials during the first 2.5 hrs, and then increased rapidly in the PLA trial until failure.

Researchers concluded that fatigue during exercise during the PLA trial was associated with a decrease in CHO oxidation, whereas the postponement of fatigue during the CHO trial was associated with a high rate of CHO oxidation[8]. They also suggested that the lowering of blood glucose during the latter stages of prolonged strenuous exercise plays a major role in the development of fatigue by not allowing leg glucose uptake to increase sufficiently in order to offset reduced glycogen availability[8]. In short, this study showed that CHO feedings do not spare muscle glycogen utilization at the point of fatigue during intense continuous cycling, even though the time to fatigue increases.

In a few more recent studies, CHO ingestion increased time to exhaustion during cycling exercise[2, 19, 22]. Exercise time to exhaustion was increased by ~30% when CHO (8% solution) was ingested versus PLA[22]. In this study, subjects cycled at 69 ± 1% peak VO_2 until volitional fatigue. In another study, subjects performed two 80 mile cycling time trials at a self-selected pace[19]. Finishing times were ~5% faster when subjects consumed CHO versus PLA. Interestingly, intensities upon completion of the time trial were 64.7 ± 1.9% VO_2 max and 55.3% ± 1.9% VO_2 max for the CHO and PLA trials, respectively, demonstrating the ability to sustain higher intensity work over the same distance. During three 100 km time trials, subjects cycled 7 and 5% faster than PLA when ingesting CHO or CHO plus medium-chain triglycerides (MCT)[2]. Subjects consumed 6% CHO, 6% CHO + 4.3% MCT, or a sweetened PLA. No differences were found between the 2 CHO trials for average work rate, CHO oxidation, fat oxidation, plasma glucose, plasma lactate, plasma FFA, and plasma insulin. This suggests that CHO alone is just as effective for enhancing performance as CHO + MCT (which provides more kcals).

In two 30 km running races, subjects competed against one another and were provided either CHO (5% solution) or PLA[35]. This study was unique in the sense it measures performance over an actual racecourse rather than endurance capacity (time to exhaustion). Subjects consumed 1L of fluid during the race; thus, total CHO ingestion was only 50 g. During the CHO trial, subjects completed the course in 128.3 ± 19.9 versus 131.2 ± 18.7 during the PLA trial ($p<0.01$, 2.3% faster). Speeds were not different at 5, 10, 15, 20, and 25 km during the trials, but during the P trial subjects slowed their pace during the last 5K. Again, this study demonstrates the ability for higher intensity work later in exercise when consuming CHO.

To demonstrate the impact on supplemental CHO feedings in wildland firefighters during a 12-hour shift, Ruby et al. had 29 subjects consume both liquid and solid CHO throughout the day or liquid PLA and solid CHO[30]. Subjects consumed the solid CHO every odd hour and the fluid (CHO or P) every even hour. Subjects consuming the solid and liquid CHO received 160 $kcal \cdot hr^{-1}$ compared to the P trial. Work rate was determined via accelerometers and the activity counts were extrapolated to kcal expenditure according to Heil et al.[14]. Blood glucose was taken at 2 hour intervals. During the morning shift (first 6 hours), work output was similar between groups. The group consuming both liquid and solid CHO performed significantly more work during the 6 hours post lunch shift (241 ± 56 and 202 ± 47 $kcal \cdot hr^{-1}$, $p<0.05$). The hourly difference combined over the span of 6 hours amounted to ~2 hours more work during the afternoon shift. Blood glucose was significantly higher prior to lunch and at 4 and 6 hr post lunch for the group consuming solid and liquid CHO. In short, self-selected work rate is higher during the second half of wildfire suppression shifts when high CHO foods are delivered at a rate of 160 $kcal \cdot hr^{-1}$.

Collectively, these studies consistently demonstrate several key factors in CHO vs PLA feeding strategies. First, levels of FFA and glycerol in the blood increase in a dose-dependent manner as subjects consume no CHO to higher amounts of CHO. Second, BG drops over time (~60+ minutes depending on intensity) when subjects do not consume CHO. Also, CHO consumption can attenuate falling BG if it is ingested during the middle of an exercise session. Third, blood lactates do not appear to be affected by CHO supplementation; however, it should be noted that the long duration trials are at intensities that typically do not cause a rise in lactate. Fourth, muscle glycogen sparing may or may not occur. The evidence appears to be that muscle glycogen is not spared by supplemental feedings, but a few of the aforementioned studies contradict this. Fifth, CHO consumption during exercise increases the time to exhaustion during long duration exercise trials. Finally, CHO intake appears to increase the ability to generate maximal power for fatiguing sprint bouts following long duration exercise, as well as sustaining greater intensities later in exercise.

Chapter Three: Methods

Introduction

A fundamental key to success for maximal performance under strenuous physical conditions is appropriate nutrition. The wildland firefighter (WLFF), who regularly performs a physically demanding job often in extreme environmental conditions, must consume the appropriate amount and type of food and fluids to meet the energy requirements necessary to safely sustain a high work output throughout an arduous day on the fire line.

Research Design

The design included a two-day crossover study with approximately 30 WLFF. Subjects consumed two different isocaloric lunches, the traditional sack lunch (SL), which consisted of items provided by the caterer, and a First Strike Ration (FSR), which consisted of food items provided by the researchers (the items came from the U.S. Army's First Strike Ration). On Day 1 half of the subjects consumed the SL and the other half consumed the FSR; on Day 2 subjects consumed the opposite of what they had on Day 1. The SL was consumed during a two-hour window during the middle of the day, 1100 to 1300 or 1200 to 1400, while the FSR was divided into 8 equal quantities and 1 was consumed every 90 minutes. Dependent variables that were continually measured during the work day included work output and RPE. In addition, at the end of each day subjects completed a form that reports their satisfaction with the feeding strategy in regards to the convenience, enjoyment, variety, and quantity of the lunch.

Subjects

The subject population consisted of all WLFF deployed at the I-90 Complex (Tarkio, MT) and Blackerby (Grangeville, ID) fires during the 2005 fire season. The total number of WLFF at these two fires was estimated to be approximately 300-500. The sample population used in this study included 45 WLFF from the Bear Divide (Santa Clarita, CA) Flathead (Hungry Horse, MT), and Ukonom (Orleans, CA) Type I Hotshot crews. Of the 45 subjects measured, 16 were not used in the data analysis due to inconsistent caloric intake between day 1 and day 2 or because complete data was not collected. The total number of WLFF from each crew was 13, 15, and 17, respectively; of these, 8, 11, and 10 were used for the data analysis. 41 males and 4 females participated in the study; 26 males and 3 females were used for the analysis.

Researchers met with the crew boss on the evening or morning prior to the study to recruit subjects. They discussed the obligations, objectives, and protocol for the study. On the morning of the first day subjects were informed about the study, the research protocol, and read and signed the informed consent forms. Subjects were then randomly assigned to SL or FSR. The University of Montana's Institutional Review Board approved the research.

Following completion of the informed consent subjects were weighed using a digital scale (Befour Inc, Cedarburg, WI). The purpose of the weight was to evaluate major changes during the shift. Subjects wore their Nomax pants, their Nomax shirt, and their standard work boots. All subjects emptied their pockets prior to weigh in. Subjects verbally provided their age and height information to the researchers.

Feeding Strategies

Prior to the first experimental day, researchers met with the food services staff to determine food items and amounts that would be provided in the scheduled SL on the experimental days. Researchers asked questions regarding the amounts of food, methods of preparation, and possible changes that might be made at the last minute regarding the SL food contents. Following the meeting with the catering services, a nutritional analysis was completed on the planned SL using a computer based dietary program (Dietary Analysis 5.0, Salem, OR, USA). The nutrition analysis results were tabulated to determine total kilocalories (kcals) and kcals of CHO, fat, and protein. When the subjects received the SL as the intervention, they were permitted to drink a maximum of 40 ounces of Gatorade. This addition to the SL was to compensate for the drink mixes in the FSR.

Food items from the FSR were separated based on category (sandwiches, bagels, hoo-ah bars, dessert bars, drink mix, applesauce, beef jerky, and trail mix). The nutritional content of each item was recorded based on the nutritional facts label on the outside of each package.

Based upon the kilocalories planned for the SL over the two day trial, the same quantity of kcals was provided in the FSR lunch by selecting various items (by type and kcal amount) and adding up the kcals until it matched the SL. Thus, the two intervention lunches (SL and FSR) were isocaloric and contained similar categories of food items. Half of the subjects received the FSR and half of the subjects received the SL on each day.

The main intervention was the timing of eating during the shift. The SL group consumed their entire lunch between the hours of 1100-1300 or 1200-1400, whichever was more convenient for them. The FSR group consumed one food item (~150-400 kcals) every 90 minutes, beginning 90 minutes following breakfast.

Data Collection

ActiCal® actigraphy units (MiniMitter, Bend, Oregon) were used for determining activity counts and assessing work output. The unit was placed on a white foam square (~3 in x 3 in) to keep the monitor in a stable and secure position, as well as protect the unit from damage. It was inserted into the left chest pocket of each subject to determine total body activity more accurately since WLFF frequently use their upper body for daily work tasks.

Each subject received a daily task card prior to beginning the shift. On one side the card has spaces for each hour of the day and a line where there work task completed during that hour can be recorded. On the other side of the card there is an RPE chart, as well as spaces for each hour of the day and a line where subjects can record their RPE during that hour. Subjects completed the cards either during their shift or immediately following the shift. They recorded their duties for each individual hour as well as their RPE while doing the task. This data was recorded on an hourly basis.

Following the end of the work shift prior to eating dinner, subjects were given surveys to determine their satisfaction with the day's lunch. Researchers designed the surveys to ask specific questions about a lunch's convenience, variety, appearance, and quantity. In addition, the surveys included questions about the subject's perception of his ability to work during the day and the overall satisfaction with the feeding strategy.

Researchers collected trash from the FSR lunches to determine what the subjects consumed out of the FSR lunch. SL subjects were interviewed regarding what they ate out of the lunch. An item-by-item list was discussed and subjects verbally responded with a yes or no to the items they ate. In addition, foods consumed that were not provided by the researchers were recorded (the type and amount). Researchers analyzed the foods consumed for lunch to determine nutritional intake.

If subjects consumed an excessively large amount of foods on day 1, researchers provided additional foods for day 2 to maintain the isocaloric nature of the meals.

Statistical Procedures

The independent variable was the lunch consumed (either the SL or the FSR) and time (AM, PM, various time points during the day). The dependent variables were work output (activity counts), RPE, and satisfaction ratings.

Activity counts and RPE from each crew were normalized to the time after consumption of breakfast and lunch. Activity counts were averaged into two hour blocks, post breakfast 0-2, 2-4, and 4-6; post lunch 0-2, 2-4, and 4-6. To analyze work output by different intensities, activity counts were divided into three categories: sedentary (0-99 counts·min^{-1}), light (100-1499 counts·min^{-1}), and moderate/vigorous ($\geq$1500 counts·min^{-1}). The minutes spent in three different intensities were compiled for each two hour block. Activity counts were analyzed in four different ways.

- Total daily activity counts from each group (FSR and SL) were analyzed with a one-way ANOVA.
- To compare hourly activity counts between groups, a 2 (group) x 6 (time) ANOVA was used. The time components were broken down into mean counts per hour for 2 hour time intervals (post breakfast 0-2, 2-4, and 4-6; post lunch 0-2, 2-4, and 4-6).
- Activity counts were divided into 3 categories: sedentary, low, and moderate/high (need to come up with ranges for these).To analyze time spent at different intensities a 2 (group) x 6 (intensity) ANOVA was used for each intensity.

RPE was analyzed using two 2 (group) x 3 (time) ANOVAs. The groups were the FSR and SL feeding strategy. The time components were the reported RPE counts for the 2 hour time intervals during the post breakfast (0-2, 2-4, and 4-6) and post lunch shifts (0-2, 2-4, and 4-6).

For satisfaction ratings, a dependent t-test was performed between both groups for each score and/or group of scores. Additionally, the total score for each of the questions was compared in the form of percentages.

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Supplemental feedings increase self-selected work output during wildfire suppression

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Running Title: Supplemental feedings increase work output

ABSTRACT

Purpose: The purpose of this study was to determine the impact of supplemental feeding strategies on work output during wildland fire suppression. **Methods**: 76 wildland firefighters (WLFF) from 8 different elite Hot Shot crews were studied during August of 3 seasons. During the first 2 seasons subjects consumed (in addition to their sack lunch): 1) either liquid CHO (200 $ml \cdot hr^{-1}$, 20% CHO (669 $kj \cdot hr^{-1}$)) or placebo (PLA) every hour (L CHO trial), or 2) liquid CHO every even hour and solid CHO (25g CHO, 10g protein, 2g fat, 669 $kj \cdot hr^{-1}$) every odd hour or PLA (L+S CHO trial) using counter-balanced crossover designs. During the final season, subjects consumed their sack lunch (SL) halfway through their shift or snack foods (SNA) at 90-minute intervals following breakfast in a randomized cross-over design (isocaloric energy intake, 6418 ± 1109 $kj \cdot shift^{-1}$). Work output was monitored by CSA and MiniMitter actigraphy units. **Results**: During the L CHO trials, CHO demonstrated significantly higher average CSA counts across the entire day compared to PLA, (50,262 ± 36,560 and 40,159 ± 35,969 $counts \cdot hr^{-1} \cdot 12hr^{-1}$, respectively; $p<0.05$). For the L+S CHO trials, the day by time interaction was significant, showing higher average $counts \cdot min^{-1}$ for CHO compared to PLA for 2 hours before lunch and the last 4 hours of the shift ($p<0.05$). For the SNA and SL trials, the day by time interaction was significant, demonstrating higher average $counts \cdot min^{-1}$ for SNA during the final 2 work hours compared to SL, (521 ± 421 vs. 366 ± 249 $counts \cdot min^{-1} \cdot 2hr^{-1}$, respectively; $p<0.05$). **Conclusion**: Liquid and/or solid supplemental CHO and regular feedings increased self-selected work rates during wildland fire suppression, particularly during latter hours of the work shift.

Keywords: FIREFIGHTING, SUPPLEMENTAL FEEDING, CARBOHYDRATE,

OCCUPATIONAL PHYSIOLOGY

INTRODUCTION

Paragraph Number 1 Wildland firefighters (WLFF) are exposed to a multitude of physical and mental demands, including long work shifts (12-16 hr) in an arduous and dangerous work setting, difficult sleeping conditions, and extreme environmental surroundings (heat, altitude, and low humidity). Our laboratory has previously determined the total energy expenditure (TEE) of the WLFF to be 12-26 $MJ \cdot day^{-1}$ using the doubly labeled water methodology[28].

Paragraph Number 2 Historically, high protein foods were thought to be the best for those performing large amounts of work[15]. However, it has been clearly demonstrated that high carbohydrate (CHO) diets are preferred to maximize work output for those engaging in intense training or working physically demanding jobs[2, 15, 24, 25]. Ruby et al. reported dietary recall data showing that selection of food at WLFF camps may cause necessary CHO intake to be displaced by a high intake of dietary protein and fat during wildfire suppression[28]. In addition to the types of foods eaten, other investigators have shown that the timing of consumption is vital to the maintenance of steady work output and the prevention of gastrointestinal discomfort[5, 8, 9, 21, 30].

Paragraph Number 3 Adequate hydration can also be of concern for WLFF because of high ambient temperatures, dry conditions, and sustained physical labor. Our laboratory has shown daily water turnover rates in WLFF of $6.7 \pm 1.4\ L \cdot d^{-1}$ with a concomitant 1.0 kg loss of nude body weight, and a 0.9 kg loss in total body water over a five day work cycle[27].

Paragraph Number 4 With the exception of a few studies[10, 20, 23], supplemental feeding during long-duration exercise (2+ hr) has been consistently shown to increase the subject's ability to complete physical work [1, 3-7, 9, 11, 12, 19, 22, 24, 29, 30]. The majority of previous research has compared the effects of liquid CHO versus PLA for measures such as time to exhaustion, high intensity performance after fatigue, and metabolic stress. However, the majority of these studies were done with well-trained subjects and typically do not last longer than 4 hours, with small exception [24, 25].

Paragraph Number 5 The WLFF is exposed to a multitude of adverse working conditions, including hiking up steep terrain, digging fire lines, brush clearing, and chain sawing for up to 12 hours a shift continuously for 14 days. Because of these occupational requirements, it is critical to provide food sources during the work shift that meet required energy demands while providing an adequate degree of satisfaction. Traditionally, the WLFF diet consists of a fully catered breakfast and dinner of unlimited proportions and a sack lunch (SL) consisting of ~6.3-8.4 MJ. In addition to the SL, many WLFF supplement their diets with convenient foods such as miscellaneous food bars, meat jerky, power pars, and a variety of sport drinks. However, these are not always available due to policy, cost, and availability in remote locations.

Paragraph Number 6 There is a paucity of literature regarding the impacts of supplemental feeding on extended duration (8-12 hr) physical labor or exercise in field settings. Thus, the purpose of these studies over a period of 3 years was to determine the impact of supplemental feeding strategies on work output during wildland fire suppression. We hypothesized that regular supplemental feedings, particularly those high in CHO, would increase work output compared to placebo.

METHODS

Paragraph Number 7 **Subjects.** Subjects included WLFF (N=76) from 8 different Interagency Hot Shot Crews during the 2002, 2003, and 2005 fire seasons. Subjects were recruited and enrolled in the study based on their work assignments and duration of the crew deployment at a particular fire. The study protocol and consent form was approved by The University of Montana's Institutional Review Board (IRB) prior to data collection. Subjects were informed about the obligations, objectives, and protocol for the study and provided written informed consent prior to involvement in the study.

Paragraph Number 8 **Research Designs.** *Liquid CHO versus Liquid PLA (L CHO) and Liquid CHO + Solid CHO versus Liquid PLA (L+S CHO) designs.* In both of these studies, subjects consumed their regular lunch on both days within a two-hour window during the middle of the day, 1100 to 1300 or 1200 to 1400. The typical sack lunch supplied to WLFF contains ~6.3 to 8.4 MJ if eaten completely. In addition to their lunch, subjects consumed one of two hypercaloric diets during the work shift: 1) L CHO: liquid CHO (200 $ml \cdot hr^{-1}$, 20% maltodextrin (669 $kj \cdot hr^{-1}$) every hour or a similarly flavored PLA, 2) L+S CHO: liquid CHO (200 $ml \cdot hr^{-1}$, 20% maltodextrin (669.4 $kj \cdot hr^{-1}$) every even hour and a solid CHO (energy bar: 25g CHO, 10g protein, 2g fat, 669.4 $kj \cdot hr^{-1}$) every odd hour or a similarly flavored placebo (PLA) drink in counter-balanced crossover designs. Subjects were allowed ad lib water intake. In an attempt to compare one experimental trial (L CHO) to typical feeding strategies, subjects consumed food and fluids ad lib on an additional study day. Researchers verbally instructed subjects to eat their sack lunch as they normally do, and provided no specific guidance on how subjects should feed.

Paragraph Number 9 Sack Lunch and Snack Food (SL-SNA) design. Subjects consumed two different isocaloric feeding approaches (traditional sack lunch (SL), which consisted of items provided by the fire caterer, and a series of eat-on-the-go snack food items (SNA) developed as part of the US Army's First Strike Ration feeding program) during the work shift in a counter-balanced crossover design. The SL was consumed over a two-hour window during the middle of the day, 1100 to 1300 or 1200 to 1400, while the SNA was divided into 8 equal quantities (~628-1674 kj per food item) with the consumption of one food item every 90 minutes following the completion of breakfast.

Paragraph Number 10. Prior to the first SL-SNA experimental day, researchers analyzed scheduled food items and amounts in the SL using a computer based dietary program (Dietary Analysis 5.0, Salem, OR, USA). When subjects received the SL as the intervention, they were permitted to drink a maximum of 40 ounces of a commercial sport drink (14 g CHO per 240 ml (6%), 110 mg sodium) to compensate for drink mixes provided by the SNA.

Paragraph Number 11 Food items from the SNA were separated based on category (sandwiches, bagels, energy bars, dessert bars, drink mixes, applesauce, beef jerky, and trail mix). Based upon the energy and macronutrients planned for the SL over the two day trial, the same quantity of kilocalories (balanced for CHO, FAT, and PRO) was provided in the SNA by selecting items and matching them to the energy content of the SL.

Paragraph Number 12 Researchers collected used packaging from the SNA lunches to determine what the subjects consumed. SL subjects were interviewed regarding what they consumed. An item-by-item list was discussed and subjects verbally responded with a yes or no to the items they consumed. In addition, foods eaten that were not provided by the researchers were recorded (type and amount).

Paragraph Number 13 **Data Collection.** *Actigraphy.* Two different actigraphy units were used for monitoring activity. During the first fire season, CSA activity monitors (Model 7164; Computer Science and Applications, Inc., Shalimar, FL) were used and in subsequent summers ActiCal® actigraphy units (MiniMitter, Bend, Oregon) were used. Monitors were initialized and distributed to crew members to determine activity counts and assess self-selected work output. The units were secured in a white foam core square (~7.6 cm x 7.6 cm) to keep them in a stable and secure position, as well as protect the unit from damage. Each accelerometer was inserted into the left chest pocket of each subject's nomex fire shirt to determine total body activity and movement. This location was standardized for all data collection since WLFF frequently use their upper body for daily work tasks. Activity counts were normalized to time post-breakfast and post-lunch. Average counts·min^{-1} were expressed in one-hour intervals for the CSA monitors and two-hour intervals for the Actical® monitors. To analyze work output by different intensities when using the Actical® monitors, activity counts were divided into three ranges: sedentary (0-99 counts·min^{-1}), light (100-1499 counts·min^{-1}), and moderate/vigorous (≥1500 counts·min^{-1}). The minutes spent in the three different intensities were compiled for each two hour block during the work shifts.

Paragraph Number 14 *Rating of Perceived Exertion.* Each subject received a daily task card prior to beginning the shift. One side the card provided spaces for each hour of the day to record work tasks (digging line, hiking, chain sawing, etc.) completed during each hour. The other side of the card included Borg's 6-20 Rating of Perceived Exertion (RPE) scale and spaces to record RPE during each hour of the work shift. Subjects completed the cards during their shift. Reported times of RPE was normalized to the time after consumption of breakfast and lunch.

Paragraph Number 15 Blood glucose. Researchers trained subjects how to monitor blood glucose (BG) using OneTouch® Ultra® blood glucose monitoring systems (LifeScan Inc., Milpitas, CA). Subjects were blinded to the BG values, but were able to see if the reading was successful. BG collections were completed every 2 hours during the first two seasons (L CHO and L+S CHO trials) but not during the SL+SNA trials.

Paragraph Number 16 Statistical Procedures. All descriptive data are expressed as means ± SD. For the L CHO trial, a 3 x 12 repeated measures ANOVA was used to determine differences in hourly activity counts. For the L+S CHO and SL+SNA studies, a 2 x 5 repeated measures ANOVA was used to determine differences in hourly activity counts and time spent in different intensities. A one-way repeated measures ANOVA was used to determine differences in total activity counts for the L+S CHO and SL+SNA studies. A 2 x 10 repeated measures ANOVA was used to determine differences in RPE. A 2 x 7 ANOVA was used to determine differences in blood glucose concentrations. Statistical significance was established using an alpha level of $p<0.05$.

RESULTS

Paragraph Number 17 **L CHO Trials.** *Hourly Activity.* To collect the data for the L CHO trial, CSA Monitors were used. The day by time interaction was not significant. The main effect of activity over time was significant. Hours 2-5 post breakfast (PB) and 1-6 post lunch (PL), were significantly higher than hour 1 PB ($p<0.05$, Fig. 1). The main effect for day was also significant. CHO demonstrated significantly higher mean counts·hr^{-1} over the entire day compared to the PLA, [50,262 ± 36560 and 40,159 ± 35969 counts·hr^{-1}·12hr^{-1} for the CHO and PLA, respectively; $p<0.05$, Fig. 1]. There were no significant differences for AD LIB versus CHO or PLA.

Paragraph Number 18 Blood Glucose. The trial by time interaction for BG was significant ($p<0.05$). During the CHO trial blood glucose was significantly elevated from pre-breakfast values at all time points throughout the day. In contrast, the blood glucose response was similar during the AD LIB and PLA trials, showing a significant increase at hours 2 and 4 PB and hours 2 and 4 PL compared to pre-breakfast values. BG was significantly higher during the CHO trial than PLA at hours 6 PB and hours 4 and 6 PL compared to both the AD LIB and PLA trials. However, there were no significant differences between the AD LIB and PLA trials (Fig. 2a).

Paragraph Number 19 **L+S CHO Trials.** *Total and Hourly Activity.* To collect data for the L+S CHO trials, ActiCal® Monitors were used. Total daily work output expressed in average counts/min over the entire work shift was higher for the CHO group compared to PLA, [551 ± 185 and 451 ± 133 counts·min^{-1}, respectively; $p<0.05$]. For hourly activity, the day by time interaction for activity was statistically significant. Average counts·min^{-1} were significantly higher for CHO during hours 4-6, 8-10, and 10-12 compared to PLA

($p<0.05$, Fig. 3). Additionally, PLA demonstrated a significant decrease across the work shift for hours 4-6, 6-8, 8-10, and 10-12 compared to the average counts·min^{-1} during hours 2-4.

Paragraph Number 20 Intensity. The day by time interaction was not significant for the sedentary and light intensities. However, there was a significant main effect for day for both intensities ($p<0.05$). CHO spent significantly less time in the sedentary activity range compared to PLA (74.2 ± 21.6 and 79.1 ± 21.1 minutes·2hr^{-1} for the CHO and PLA groups, respectively; $p<0.05$). Similarly, CHO spent significantly more time in the light activity range compared to PLA (45.7 ± 21.6 and 40.8 ± 21.0 minutes·2hr^{-1} for the CHO and PLA groups, respectively; $p<0.05$).

Paragraph Number 21 Blood Glucose. The trial by time interaction was significant ($p<0.05$). Blood glucose concentration during the CHO trial was significantly elevated from pre-breakfast values at hour 2 post-breakfast and 2, 4 and 6 post-lunch. In contrast, during the PLA trial, blood glucose demonstrated a significant increase at hour 2 post-lunch. Blood glucose was significantly higher during the CHO trial at hours 6 post-breakfast and hours 4 and 6 post-lunch (Fig. 2b).

Paragraph Number 22 Rating of Perceived Exertion. The trial by time interaction was significant for RPE ($p<0.05$). Both CHO and PLA trials demonstrated significantly higher values for RPE at all time points compared to hour 1. Subjects reported significantly higher RPE for the PLA trial at hours 2 and 12 compared to CHO. However, at hour 9, subjects reported higher values for RPE for the CHO trial compared to PLA (Fig 4a).

Paragraph Number 23 **Sack Lunch and Snack Food.** *Total Activity.* Total daily work output was not significantly different between diets, [352 ± 252 and 317 ± 183 counts·min^{-1}·$10hr^{-1}$] for the SNA and SL days, respectively.

Paragraph Number 24 *Hourly Activity.* The day by time interaction was significant ($p<0.05$). Within the SNA group, average counts·min^{-1} during hours 8-10 were significantly lower than hours 2-4 of the work shift, [209 ± 116 and 378 ± 435, respectively; $p<0.05$, Fig. 5]. In contrast, average counts·min^{-1} during hours 10-12 were significantly higher than hours 2-4, [521 ± 421 and 378 ± 435, respectively; $p<0.05$, Fig. 5]. Within the SL group, average counts·min^{-1} during hours 8-10 were significantly lower than hours 2-4, [292 ± 381 and 415 ± 358, respectively; $p<0.05$, Fig. 5]. In addition, average counts·min^{-1} were significantly higher for the SNA during hours 10-12 compared to SL, [521 ± 421 and 366 ± 249, respectively; $p<0.05$, Fig. 5].

Paragraph Number 25 *Intensity.* The day by time interaction for the sedentary, light, and moderate/vigorous range of intensities was not significant. For the sedentary range there was a significant main effect for time, demonstrating an increase in time spent in the sedentary range between hours 2-4 and 8-10 of the work shift ($p<0.05$). The mean time spent in the sedentary range was 70.5 ± 24.4 and 79.5 ± 20.9 minutes·$2hr^{-1}$ for hours 2-4 and 8-10, respectively ($p<0.05$, Fig. 6a). For the moderate/vigorous range there was a significant main effect for time, demonstrating a decrease in time spent in the moderate/vigorous range between hours 2-4 and 8-10 of the work shift ($p<0.05$). The mean time spent in the moderate/vigorous category was 8.3 ± 10.4 and 3.2 ± 5.6 minutes·$2hr^{-1}$ for hours 2-4 and 8-10, respectively ($p<0.05$, Fig. 6b).

Paragraph Number 26 *Rating of Perceived Exertion.* The day by time interaction was not significant. The main effect for time was significant, demonstrating a difference between hour 1 and hours 2-10 of the work shift ($p<0.05$, Fig. 4b).

DISCUSSION

***Paragraph Number 27** Li CHO Trials.* Over the past few fire seasons, our laboratory has completed a series of studies evaluating the effects of supplemental CHO feeding on self-selected work rates in WLFF. When compared to AD LIB (normal) feeding, CHO supplementation provided no additional benefit for completing work (Fig. 1). However, compared to PLA, regular CHO feeding resulted in subjects performing approximately 20% more work over the entire day. During the 12 hour shift, subjects consuming regular CHO supplements completed the equivalent of approximately 2.4 more hours of work versus PLA. In a study by Coyle et al., subjects consuming liquid CHO cycled for an hour more than those consuming PLA[6]. While the intensity in Coyle's study was considerably higher than that of the WLFF, it demonstrates a considerable improvement in work completed when fed CHO. In several other studies using time to exhaustion or time to complete a standard amount of work as the measure of performance, CHO feedings have been clearly shown to extend the time to exhaustion[1,4,6,7,9,12,22,24,30]. While the current data does not suggest an improvement in time to exhaustion, when subjects were provided with regular CHO, they self-selected a higher work rate during the day compared to PLA.

Paragraph Number 28 The AD LIB day was incorporated into the study to get a baseline for typical work output of WLFF without any experimental intervention. Treating the AD LIB group as the baseline, Fig. 7 demonstrates the impact of CHO and PLA on work output relative to normal feeding habits. In the hours post-breakfast, CHO resulted in an average of 24% more total work compared to PLA, with the final 3 hours showing an increase of 24%, 48%, and 48%, respectively. In the hours PL, subjects consuming CHO completed 17% more work, with the final 3 hours being 29%, 40%, and 19%, respectively. There was no significant difference between either experimental group (CHO and PLA) and the AD LIB group. This suggests that WLFF are able to consume appropriate amounts of food and fluid to sustain work output independent of dietary intervention. However, the effect of CHO to increase work output versus PLA is clearly demonstrated.

Paragraph Number 29 Despite no interaction effect among the three trials in activity, an interaction effect was seen in BG concentration during the three trials. The CHO trial had elevated BG levels compared to PLA at hours 6 PB, 4 PL, and 6 PL (Fig. 2a). It is interesting that no differences were found between CHO and AD LIB in BG, and that the BG findings parallel the main effect for trial seen between the CHO and PLA trials. However, in neither group was hypoglycemia present, with all values ~5 $mmol \cdot l^{-1}$ and above. Thus, the difference in work output cannot be attributed to hypoglycemia. Possible explanations for these differences will be discussed below.

Paragraph Number 30 L+S CHO Trials. Compared to PLA, CHO feedings allowed WLFF to maintain a steady work output throughout the work shift (Fig. 3). When subjects did not consume CHO, the activity declined steadily throughout the work shift. During the last 2 hours of the shift, PLA subjects completed 47% less work than they did during hours 2-4. In contrast, when CHO was consumed at regular intervals, there was no drop in work output at hours 8-10 and only a slight (3%) drop during hours 10-12. CHO feedings resulted in significantly more work completed between CHO and PLA during hours 4-6, 8-10, and 10-12 of the work shift (Fig. 3). It is important to recognize that while hours 4-6 appear to be early in the shift, they are the last 2 hours prior to lunch.

During this time, PLA had not fed since breakfast. Following lunch, the activity from both CHO and PLA was similar during hours 6-8 but then separated again at hours 8-10 and 10-12. Accompanying the significant difference in work output at hours 8-10 and 10-12 between CHO and PLA trials was a significant difference in BG at the same time points (Figs. 3, 2b). The CHO group had an elevated BG compared to the PLA, despite both groups having relatively normal BG levels (6.4 and 5.7 $mmol \cdot l^{-1}$ at hour 10 and 6.2 and 5.1 $mmol \cdot l^{-1}$ at hour 12 for the CHO and PLA groups, respectively). Thus, it is difficult to suggest that the reason for a decline in work output is a consequence of hypoglycemia. Rather, it would be more appropriate to suggest that an elevated BG response contributes to an increase in work output. The present findings mirror those of Carter et al., who found an improvement in time to fatigue during cycling at 60 and 73% VO_2 max despite a lack of hypoglycemia in either trial[4]. In numerous studies, a decline in performance is associated with a decline in BG, even if subjects do not reach a state of hypoglycemia[1, 9, 12, 22, 24, 30]. Our findings contradict those of Madsen et al, where a significant difference in BG was found between the placebo trial and both the glucose and glucose plus branched chained amino acids trials, but no difference was found in time to complete a 100 km cycling trial[20].

Paragraph Number 31 Our data suggest an ergogenic effect of CHO, demonstrated by significantly more work completed by the CHO groups compared to PLA both overall and later in the work shift. Several mechanisms have been proposed as to why CHO contributes to an improvement in performance: maintaining blood glucose and high levels of CHO oxidation, sparing endogenous glycogen, synthesizing glycogen during low-intensity exercise, or a central effect of CHO[15]. The most probable explanation for our differences might be the resynthesis of glycogen during low-intensity exercise and/or a central effect of CHO. The effect of exogenous CHO intake on CHO oxidation has been demonstrated in numerous studies[13, 14, 16, 17]. It appears that the maximum rate of CHO oxidation from exogenous sources is ~1.0 to 1.75 $g \cdot min^{-1}$ and supplemental feeding can delay liver glycogenolysis[13, 15, 18]. The majority of the work intensity for the WLFF is primarily sedentary (~61-66%) and low intensity (using established accelerometer cut points), with some intermittent bouts of moderate to high intensity. Therefore, the possibility of resynthesis of supplemental CHO is very likely. Another possible reason for the increase in work output in the CHO group compared to PLA is a central effect. Jeukendrup suggests that the presence of CHO in the oral cavity may trigger a series of events that results in stimulation of the reward and/or pleasure centers in the brain[15]. It is possible that in our study the presence of CHO does indeed stimulate these portions of the brain and allows subjects to work harder. Our RPE findings are somewhat mixed when comparing CHO and PLA (Fig. 4a). It appears that there is no consistent subjective difference in subjects' perception of work effort, despite differences in work output. Thus, perhaps CHO may stimulate the brain in such a way that one is able to perform more work than when under PLA conditions, despite similar perceptions of effort. As seen in our data, work output increases in the CHO group later in the shift. However, since WLFF were able to sustain work output with AD LIB feeding, it is possible that the deprivation of energy with the PLA trials causes work output to decline because adequate exogenous energy sources were unavailable. In short, we are unable to fully elucidate the mechanisms behind why subjects completed more work during CHO.

Paragraph Number 32 SL+SNA Trials. Since CHO supplementation increased work output compared to PLA during the L CHO and L+S CHO trials, we were curious to see whether regular feedings, under isocaloric conditions, would impact self-selected work activity. During the SNA+SL trial, an interaction effect was observed between the SNA and SL groups. The SL group maintained a relatively constant amount of work throughout the course of the day, with a slight decrease during hours 8-10. Additionally, the SNA group had a slight decrease during this time period. The reason for this, as mentioned earlier, was probably task assignments for the crews. During hours 10-12 the SNA group completed significantly more work (25%) than the SL group. This finding parallels our earlier findings where CHO supplementation increased work output later in the shift. The SL group had not eaten for ~4-5 hours, so it is difficult to attribute this effect to CHO directly. In contrast, the SNA group was fed shortly prior to this spike in activity (at ~hr 9), and this feeding alone could have contributed to this increase in work activity. Nonetheless, the SNA foods were high in CHO (55%), so it is possible that CHO contributed to the increase in work output. Febbraio et al. found similar results during 2 hours of cycling at ~63% of peak power output[8]. In this study, endurance performance was only increased when CHO feedings were consumed throughout exercise. Likewise, McConell et al. demonstrated that regular CHO ingestion (every 15 minutes) during exercise increased total work during a 15 minute performance ride following 2 hours of cycling at 70% VO_2 peak[21]. However, when an isocaloric amount of CHO was consumed in a 21% solution during the last 30 minutes of exercise, no significant improvement in total work during the 15 minute performance ride over the control group was observed.

Thus, it can be suggested from our data that the feeding at ~hr 9 contributed to the increase in work output during hours 10-12 for the SNA trial compared to the SL trial.

Paragraph Number 33 Intensity. While the previous data demonstrate greater activity with CHO supplementation, our next question was whether the CHO feedings assisted in subjects performing more intense work. In a paper by Panter-Brick regarding work intensity, pace, and sustainability, she discusses time intensity work versus energy intensity work in subsistence communities[26]. Briefly, time intensity deals with heavy workloads being the result of very long hours spent completing light to moderate habitual tasks. Conversely, energy intensity work would be high levels of energy expenditure from short bursts of intensive activity throughout the work day. The nature of the WLFF's job is both time and energy intensive, with a stronger demand for endurance over time rather than intensive effort per unit time. Thus, it was anticipated that the bulk of the time during a work shift would range between the sedentary and light categories. As expected, this was the case for both our hypercaloric (L+S CHO) and isocaloric (SL+SNA) protocols.

Paragraph Number 34 In the L+S CHO protocol, there was a significant main effect of total activity for the work shift. Subjects consuming CHO spent significantly less time (4.9 $min \cdot 2hr^{-1}$) in the sedentary range and significantly more time in the light range (4.9 $min \cdot 2hr^{-1}$) than did PLA. While 4.9 $min \cdot 2hr^{-1}$ seems small, it amounts to 29.4 $min \cdot 12hr^{-1}$ over the course of the work shift for a single WLFF. For a typical hot shot crew of 20 members, this amounts to 9.8 total person hours more work for a single day. Thus, while the individual effect in a 2 hour window seems small, it has great consequences when considered in light of a crew's performance during an entire shift.

Paragraph Number 35 It may seem surprising that the bulk of time (62% and 66% for the CHO and PLA groups, respectively) is spent in the sedentary category during the L+S CHO protocol. However, many duties of the WLFF, primarily holding the line and lookout, are activities that require little activity. Also, a crew may spend considerable time standing and waiting for spot fires to break out or waiting to see what shifts the weather brings to the fire. Interestingly, no time was spent in the moderate/vigorous category during these two days of work. Most likely this was a result of the assignments the crews were provided, but nonetheless underscores the necessity of time-intense work rather than energy intense work.

Paragraph Number 36 Contrary to the L+S CHO trial, there was no main effect for day but there was a main effect for time for the sedentary and moderate/vigorous intensity range during the SL+SNA trial (Fig. 6). Again, subjects spent the majority of their time (61%) in the sedentary category. For the light intensity category no interaction or main effect for either time or day was observed, so the data were not included. Differing from the L+S CHO trial, subjects during the SL+SNA trial spent an average of 6.7 $min \cdot 2hr^{-1}$ in the moderate/vigorous category, or 5.6% of their time. During hours 8-10, subjects spent significantly more time in the sedentary category compared to hours 2-4; significantly less time was spent in the moderate/vigorous category for hours 8-10 versus hours 2-4 (Fig. 6). The significant difference between hours 2-4 and 8-10 for both the sedentary and moderate/vigorous categories during the SL+SNA protocol most likely reflects the work demands for each crew rather than a feeding effect.

Paragraph Number 37 The implications of no main effect for day during the SL+SNA protocol must be considered. Whereas the L CHO and L+S CHO trials provided subjects an additional 669 $kj \cdot hr^{-1}$, the SL+SNA trial resulted in similar $kj \cdot hr^{-1}$. Thus, regular feeding under isocaloric conditions yielded no differences in the intensity of work completed (Fig. 6). The main effect for day with the L+S CHO protocol suggests an impact of supplemental CHO on work output, since the CHO group spent significantly less time in the sedentary category and significantly more time in the light category. This suggests that CHO supplementation might be responsible for an increase in the intensity of activity, particularly a shift from sedentary to light activity. Several studies have shown an enhanced sprint performance following long duration exercise in the group consuming CHO[9, 11], and another study shows that soldiers consuming a CHO-electrolyte drink were able to maintain uphill run performance and marksmanship following 3 days of arduous training[24]. It is difficult to compare our intensity findings to these studies because subjects in these trials completed high intensity work as best as possible following long duration exercise and/or training. However, they nonetheless demonstrate the impact of CHO to improve performance on intensity tasks following long duration exercise.

Paragraph Number 38 RPE. During the L+S CHO trial, a significant interaction existed for RPE. RPE was higher for all time points beyond hour 1 of the work shift for both the CHO and PLA trials. PLA was significantly higher during hours 2 and 5, while CHO was significantly higher during hour 9 (Fig. 4a). During the SL+SNA trial, there was a significant main effect for time for RPE (Fig. 4b). RPE rose gradually throughout the work shift up to hour 6 and then remained steady until the end of the shift. It appears that despite differences in work output, WLFF select an RPE from 9-12 for most of the work shift. Interestingly, this coincides with the intensity data discussed earlier. According to

Borg's 6-20 point-scale, subjects selected intensities between very light and fairly light, which parallels the actual activity counts.

Paragraph Number 39 Experienced WLFF have learned how hard they are capable of working for extended durations and are able to self-regulate their activity habits with great proficiency. Collectively, the different protocols completed over several fire seasons demonstrate the ability of CHO and regular feedings to increase self-selected work rates in WLFF, particularly during the latter hours of a shift. In short, liquid and/or solid supplemental CHO and regular feedings increased self-selected work rates during wildland fire suppression, particularly during the latter hours of a shift.

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LEGENDS FOR FIGURES

Figure 1. Activity for the Liquid CHO versus Liquid PLA trials using the CSA monitors. Mean counts·hr^{-1} for the CHO, PLA, and AD LIB trials are displayed. *$p<0.05$ between CHO and PLA, main effect for day. †$p<0.05$ versus hour 1, main effect for time.

Figure 2. (a) Blood glucose concentration for the Liquid CHO and Liquid PLA trial. *$p<0.05$ between CHO versus both PLA and AD LIB, interaction effect. †$p<0.05$ versus Pre Breakfast for each trial, interaction effect. (b) Blood glucose concentration for the Liquid CHO + Solid CHO trial versus PLA. *$p<0.05$ between CHO and PLA, interaction effect. †$p<0.05$ versus Pre Breakfast for each trial, interaction effect.

Figure 3. Mean counts·min^{-1} for the Liquid CHO + Solid CHO versus PLA trial using the Actical® monitors. *$p<0.05$ between CHO and PLA, interaction effect. †$p<0.05$ versus hours 2-4 for PLA, interaction effect.

Figure 4. (a) RPE for the Liquid CHO + Solid CHO versus PLA trial. *$p<0.05$ between CHO and PLA, interaction effect. †$p<0.05$ versus Hour 1 for each trial, interaction effect. (b) RPE for the SNA and SL trials. †$p<0.05$ versus hour 1, main effect for time.

Figure 5. Mean counts·min^{-1} for the SNA and SL groups using the Actical® monitors. *$p<0.05$ between SNA and SL, interaction effect. †$p<0.05$ versus hours 2-4, interaction effect.

Figure 6. The min·$2hr^{-1}$ spent in the sedentary category (a) and the min·$2hr^{-1}$ spent in the moderate/vigorous category (b) for the SNA and SL trials. $^{\dagger}p<0.05$ versus hours 2-4, main effect for time.

Figure 7. Percent work of AD LIB treatment for the Liquid CHO versus Liquid PLA trials. AD LIB trial treated as 100% and work during the CHO and PLA trials were calculated as percentages of the AD LIB trial.

Figure 1

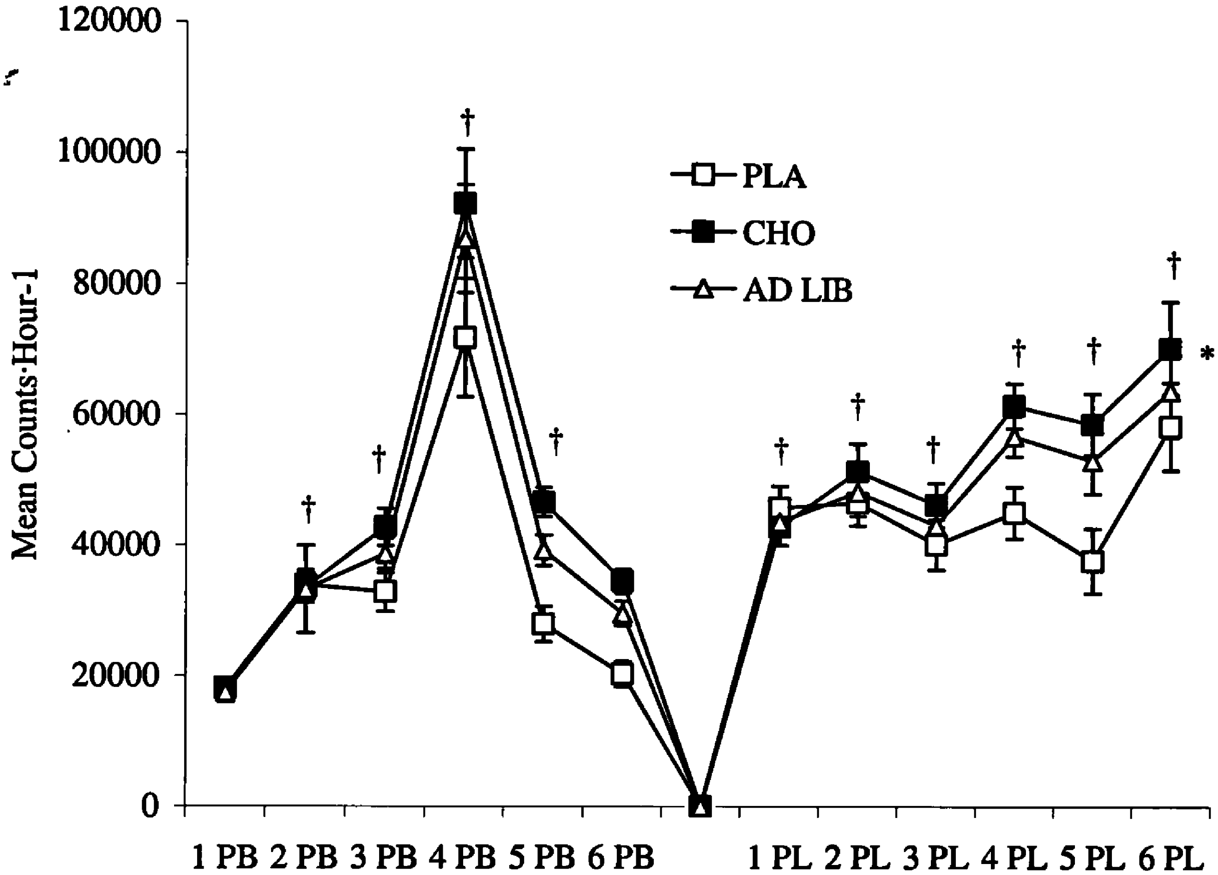

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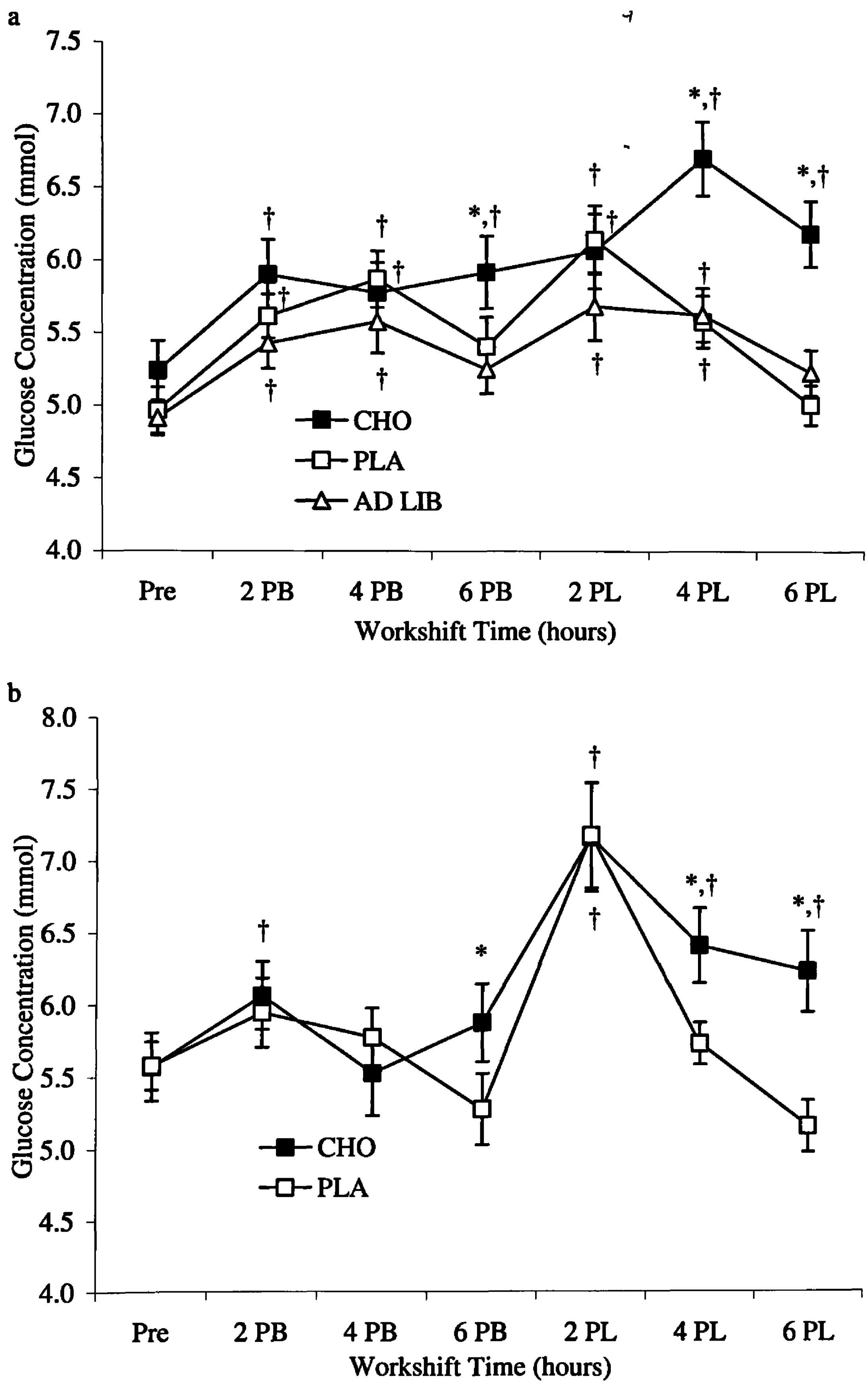
Figure 2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Workshift Time (hours)
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Glucose Concentration (mmol)
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Workshift Time (hours)

Figure 3

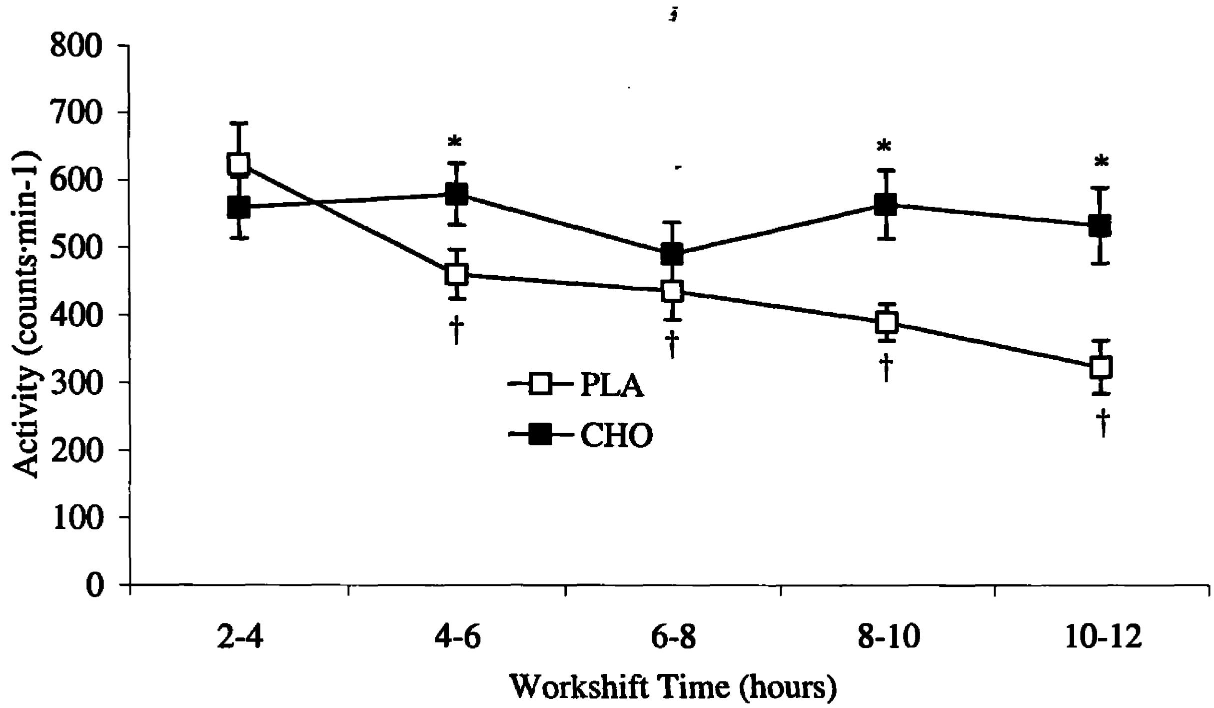

800
700
600
500
400
300
200
100
0
Activity (counts·min-1)
*
*
*
†
†
†
†
PLA
CHO
2-4
4-6
6-8
8-10
10-12
Workshift Time (hours)

Figure 4

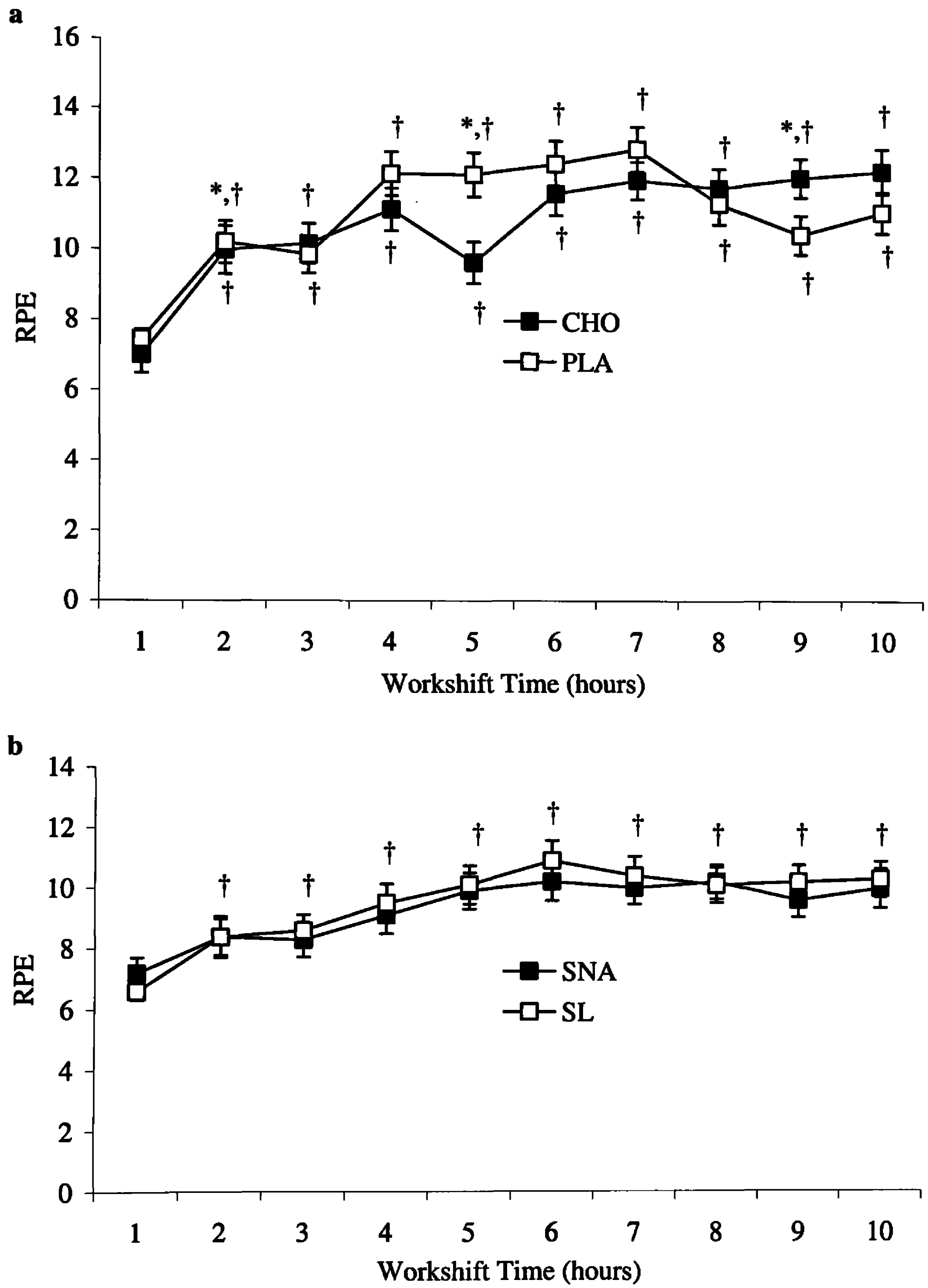

a
RPE
16
14
12
10
8
6
4
2
0
*,†
†
*,†
*,†
CHO
PLA
1
2
3
4
5
6
7
8
9
10
Workshift Time (hours)
b
RPE
14
12
10
8
6
4
2
0
SNA
SL
1
2
3
4
5
6
7
8
9
10
Workshift Time (hours)

Figure 5

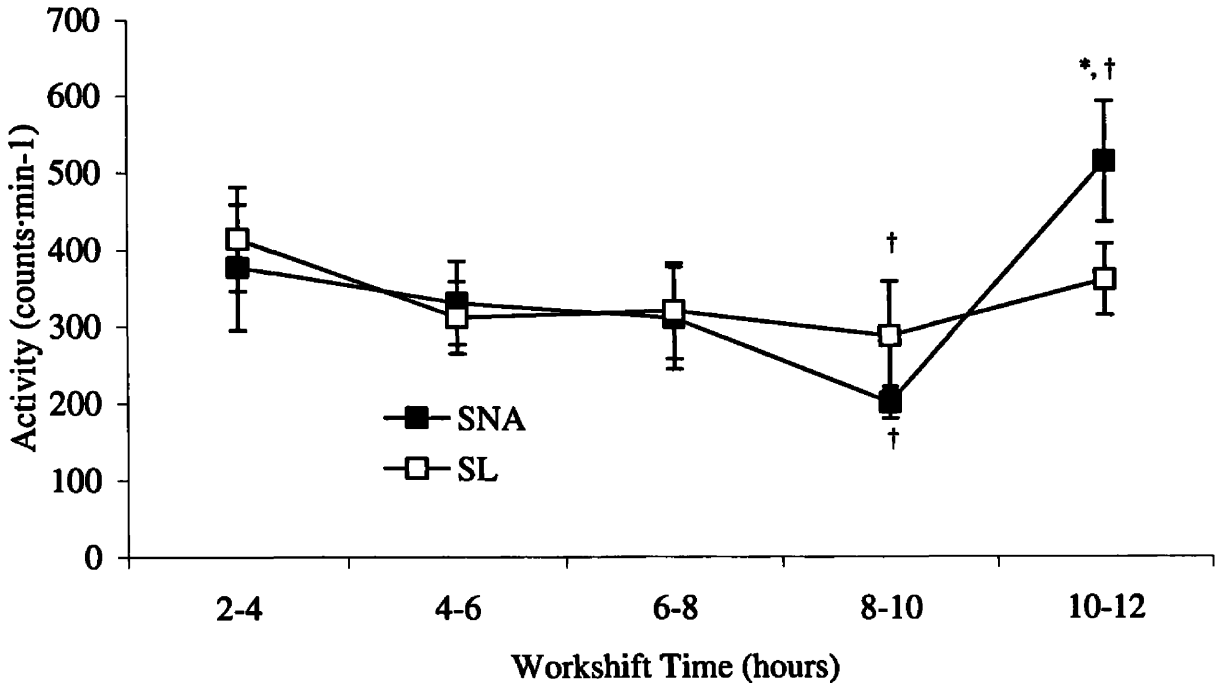

700
600
500
400
300
200
100
0
Activity (counts·min-1)
*, †
†
†
SNA
SL
2-4
4-6
6-8
8-10
10-12
Workshift Time (hours)

Figure 6

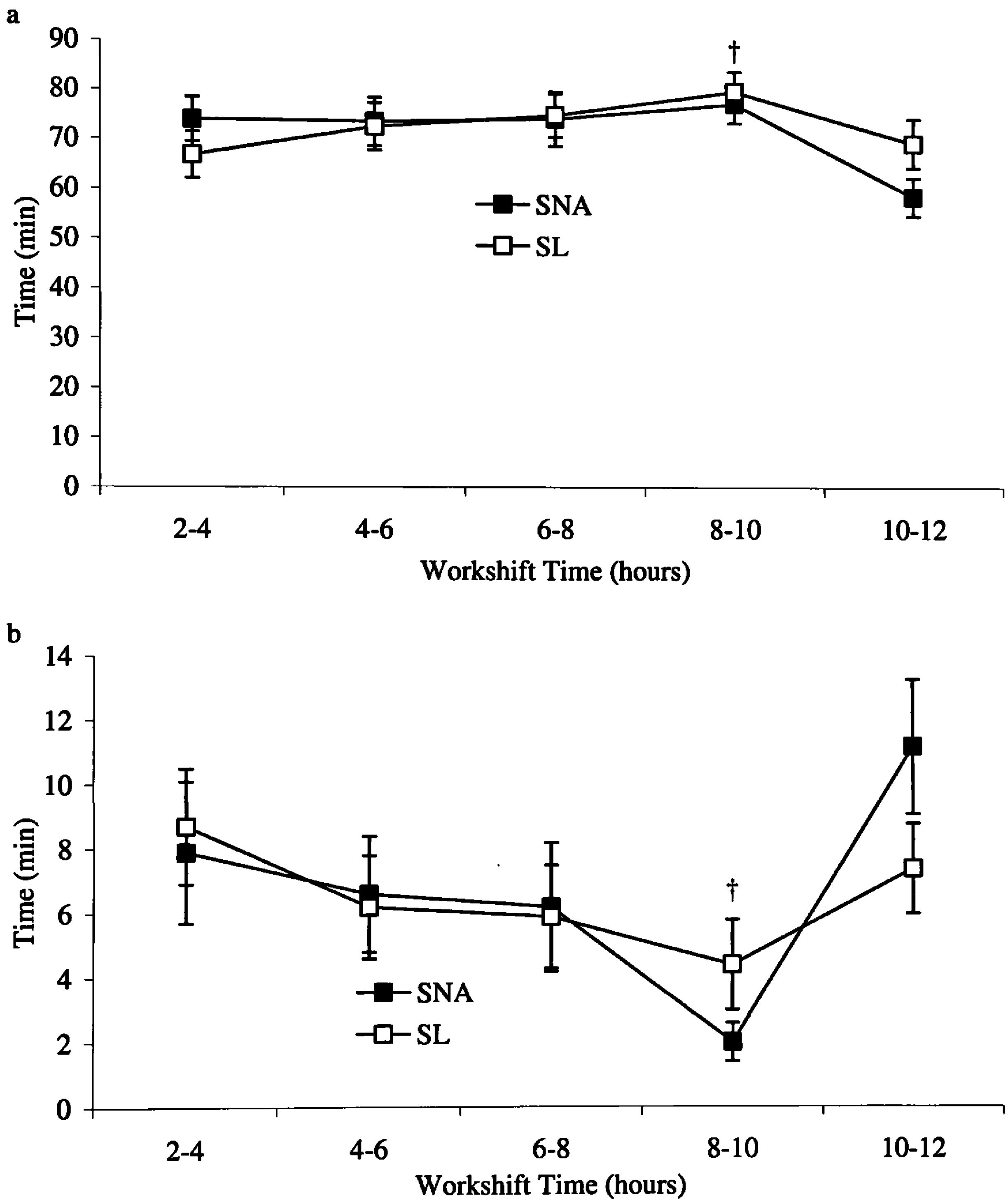
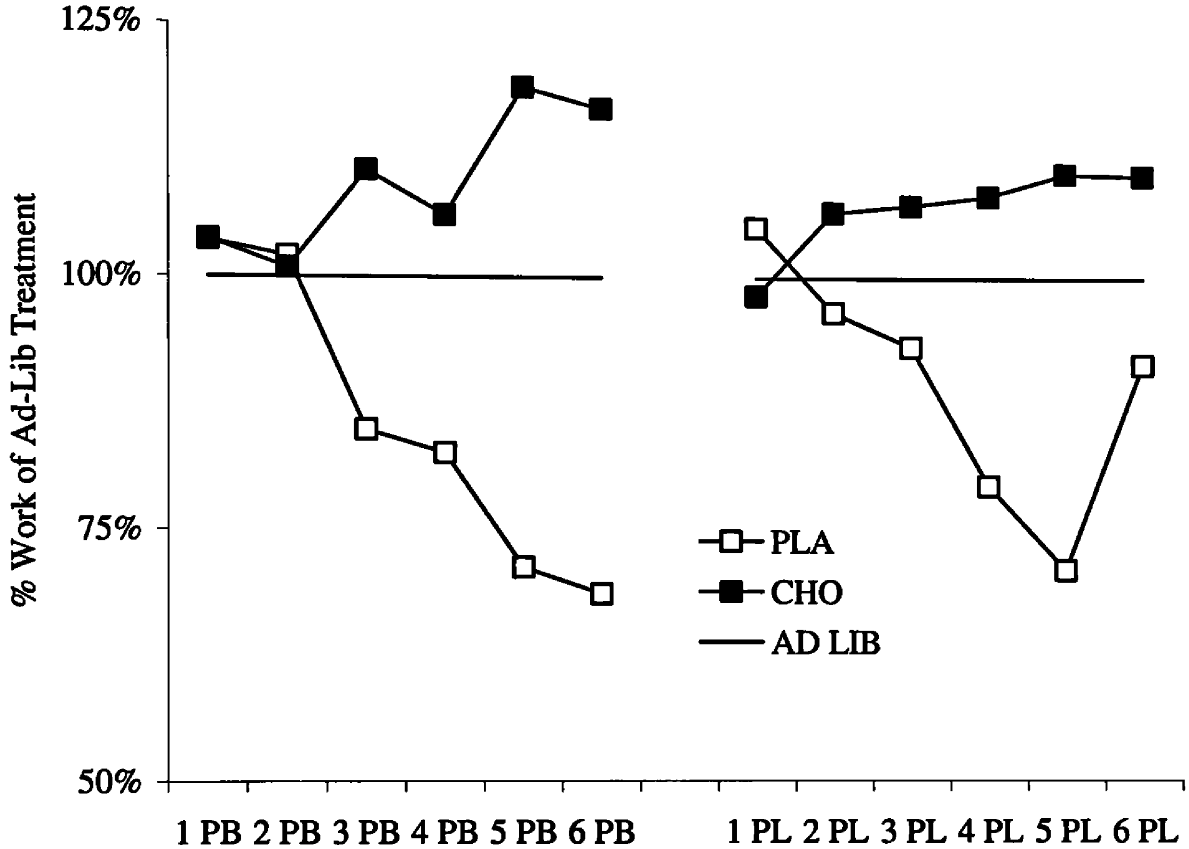

a
90
80
70
60
50
40
30
20
10
0
Time (min)
†
SNA
SL
2-4
4-6
6-8
8-10
10-12
Workshift Time (hours)
b
14
12
10
8
6
4
2
0
Time (min)
†
SNA
SL
2-4
4-6
6-8
8-10
10-12
Workshift Time (hours)

Figure 7


125%
100%
75%
50%
% Work of Ad-Lib Treatment
PLA
CHO
AD LIB
1 PB 2 PB 3 PB 4 PB 5 PB 6 PB
1 PL 2 PL 3 PL 4 PL 5 PL 6 PL

Appendices

Anthropometrics				
Subject	**Age (yrs)**	**Height (cm)**	**Sex**	**Wt (kg)**
102	30	167.64	F	69.68
104	23	182.88	M	74.27
105	24	185.42	M	92.32
106	20	182.88	M	95.45
108	25	182.88	M	83.50
110	25	177.80	M	79.77
112	22	177.80	M	84.50
113	27	177.80	M	90.86
201	33	175.26	M	91.73
203	26	182.88	M	86.50
205	28	195.58	M	83.95
206	27	187.96	M	99.77
207	31	187.96	M	98.36
209	26	177.80	M	90.18
210	24	187.96	M	87.00
211	27	175.26	M	78.77
213	24	165.10	F	72.27
214	32	165.10	F	71.18
302	21	172.72	M	96.36
303	19	177.80	M	76.82
304	46	177.80	M	80.91
306	24	193.04	M	105.91
307	23	180.34	M	87.73
308	31	175.26	M	66.36
310	27	180.34	M	79.55
313	23	187.96	M	96.82
314	26	177.80	M	91.36
317	21	177.80	M	91.82
Mean	26.3	179.9		85.8
Stdev	5.3	7.4		10.0

Total Activity Counts		
Subject	SNA	SL
102	207.12	109.25
104	363.89	416.43
105	134.83	187.41
106	391.44	143.45
108	244.68	158.10
110	233.99	226.13
112	459.69	308.72
113	184.15	297.23
201	215.86	276.67
203	355.78	282.77
205	268.58	366.01
206	386.80	275.17
207	912.73	970.38
209	197.11	465.43
210	328.05	322.09
211	395.34	573.23
213	238.77	250.33
214	231.70	117.21
302	257.90	257.32
303	505.08	337.17
304	230.19	240.29
306	263.97	307.53
307	1395.01	711.14
308	232.05	267.43
310	354.57	322.40
313	288.65	166.52
314	209.55	333.58
317	364.93	192.80
Mean	351.87	317.22
Stdev	251.78	183.18
SEM	47.58	34.62
p-value		0.30
****units are counts/min***		

Hourly Activity Counts (counts/min)										
	SNA					SL				
Subject	2:00-3:59	4:00-5:59	6:00-7:59	8:00-9:59	10:00-12:00	2:00-3:59	4:00-5:59	6:00-7:59	8:00-9:59	10:00-12:00
102	120	82	5	208	266	208	5	347	522	577
104	143	53	29	183	693	612	260	75	41	227
105	195	54	92	87	47	182	106	37	51	110
106	299	200	106	469	459	263	64	105	139	134
108	145	51	22	133	477	228	20	20	39	76
110	194	93	83	195	314	649	63	136	173	435
112	285	151	162	197	835	449	209	86	185	416
113	317	105	50	202	171	175	137	431	235	540
201	53	353	334	25	339	159	285	376	335	102
203	2	522	972	62	514	425	444	676	194	584
205	99	527	228	87	526	183	540	376	238	405
206	359	383	492	169	665	118	375	1741	2069	1013
207	1137	1032	1031	461	1771	103	806	581	261	394
209	27	394	218	81	345	333	837	510	197	511
210	255	467	413	291	523	78	445	621	355	788
211	78	600	348	208	469	516	574	499	330	107
213	86	535	186	131	375	116	447	85	25	144
214	149	424	240	122	446	14	369	343	104	158
302	296	243	216	140	293	626	207	148	401	495
303	771	258	520	387	907	774	138	136	43	524
304	475	145	230	229	206	464	167	113	215	675
306	574	308	142	189	310	458	258	171	589	437
307	2178	1301	1619	398	1893	1883	1018	250	239	16
308	228	82	295	247	140	682	243	299	150	595
310	589	205	350	267	256	497	271	177	45	152
313	492	272	211	82	515	318	168	240	558	86
314	497	205	50	160	260	583	291	179	152	173
317	545	282	166	299	581	524	73	313	284	366
Mean	378.1	333.1	314.5	415.0	314.9	203.8	521.3	324.0	291.7	365.7
Stdev	434.7	288.9	356.1	357.7	253.8	116.4	420.8	332.9	381.3	249.4

Sedentary (min/2hr)										
	SNA					SL				
Subject	2:00-3:59	4:00-5:59	6:00-7:59	8:00-9:59	10:00-11:59	2:00-3:59	4:00-5:59	6:00-7:59	8:00-9:59	10:00-11:59
102	91	106	119	85	46	88	120	114	104	107
104	89	104	109	73	57	31	61	44	36	37
105	90	105	97	99	105	85	92	94	107	80
106	35	65	80	26	52	85	105	113	105	102
108	87	106	115	82	38	87	115	91	95	90
110	88	97	104	77	59	29	102	115	109	99
112	58	81	100	69	22	68	51	87	83	60
113	85	91	104	69	93	82	98	93	86	53
201	98	93	97	114	98	56	87	36	79	42
203	120	85	63	108	65	30	45	73	57	93
205	87	79	77	98	58	68	52	38	63	35
206	35	71	27	89	44	104	83	78	91	82
207	40	17	15	64	34	109	77	58	59	82
209	109	85	90	108	73	38	9	65	75	14
210	67	9	30	60	30	97	93	72	94	80
211	98	69	76	80	69	35	48	55	59	45
213	106	86	89	103	76	90	51	46	59	88
214	77	60	54	83	48	115	90	92	111	79
302	67	60	79	77	52	63	63	43	85	101
303	46	58	48	46	46	47	79	75	36	37
304	72	86	66	45	81	75	78	87	109	66
306	69	57	88	74	54	61	66	88	82	44
307	25	22	33	77	60	30	33	104	57	51
308	77	94	41	94	95	55	61	55	74	115
310	66	77	38	60	61	66	59	73	87	41
313	62	52	76	92	40	50	59	71	105	69
314	71	89	100	73	51	66	71	66	66	101
317	61	67	81	65	55	62	96	91	87	75
Mean	74.14	73.96	74.86	78.21	59.36	66.86	73.00	75.61	80.71	70.29
Stdev	23.66	25.88	29.11	20.45	20.84	25.11	25.65	23.07	21.69	26.71

Light (min/2hr)										
	SNA					SL				
Subject	2:00-3:59	4:00-5:59	6:00-7:59	8:00-9:59	10:00-11:59	2:00-3:59	4:00-5:59	6:00-7:59	8:00-9:59	10:00-11:59
102	25	9	1	33	71	26	0	6	16	13
104	30	16	11	47	39	72	59	75	79	74
105	27	15	23	21	15	34	28	26	13	40
106	84	55	40	91	58	29	15	7	15	15
108	33	14	5	38	75	28	5	29	23	29
110	30	23	16	43	55	82	18	5	11	20
112	57	38	15	51	74	37	65	31	35	53
113	24	29	16	49	22	36	17	26	33	58
201	20	15	10	5	10	64	25	75	36	68
203	0	23	21	12	45	86	67	41	55	27
205	33	26	36	20	53	50	55	64	57	79
206	79	39	91	31	65	15	26	31	19	25
207	44	74	76	46	39	7	20	24	28	22
209	11	22	25	10	39	78	103	53	45	96
210	49	108	90	59	77	22	14	35	20	23
211	22	39	32	35	42	82	57	43	58	52
213	11	20	27	13	37	29	60	65	61	32
214	43	51	66	37	61	5	19	28	9	41
302	51	57	37	42	64	42	50	71	35	15
303	57	61	61	70	47	52	41	44	80	76
304	38	34	54	75	37	30	42	33	11	34
306	37	61	31	45	64	48	54	30	33	54
307	45	59	47	33	26	47	51	11	47	58
308	42	26	79	20	23	50	57	63	44	5
310	37	40	81	60	59	41	60	39	32	64
313	44	68	40	28	68	70	61	49	15	51
314	38	29	20	47	68	38	43	50	37	16
317	44	48	39	50	48	43	24	24	30	44
Mean	37.68	39.25	38.93	39.68	49.32	44.39	40.57	38.50	34.89	42.29
Stdev	18.41	22.72	26.39	20.29	18.90	22.38	23.53	20.43	19.78	23.59

Moderate/Vigorous (min/2hr)										
	SNA					SL				
Subject	2:00-3:59	4:00-5:59	6:00-7:59	8:00-9:59	10:00-11:59	2:00-3:59	4:00-5:59	6:00-7:59	8:00-9:59	10:00-11:59
102	2	3	0	2	3	6	0	0	0	0
104	1	0	0	0	24	17	0	1	5	9
105	3	0	0	0	0	1	0	0	0	0
106	1	0	0	3	10	6	0	0	0	3
108	0	0	0	0	7	5	0	0	2	1
110	2	0	0	0	6	9	0	0	0	1
112	3	0	4	0	22	13	2	2	2	6
113	11	0	0	2	5	2	5	1	1	9
201	0	11	13	0	12	0	8	9	5	10
203	0	12	36	0	10	4	8	6	8	0
205	0	15	7	2	9	2	13	18	0	6
206	6	10	2	0	11	1	11	11	10	13
207	36	29	29	10	47	4	23	38	33	16
209	0	13	5	2	8	4	8	2	0	10
210	4	3	0	1	13	1	13	13	6	17
211	0	12	12	5	9	3	15	22	3	23
213	3	14	4	4	7	1	9	9	0	0
214	0	9	0	0	11	0	11	0	0	0
302	1	1	4	0	3	15	2	5	0	4
303	17	1	11	4	27	21	0	1	4	7
304	10	0	0	0	2	15	0	0	0	20
306	14	2	1	1	2	11	0	2	5	22
307	50	39	40	10	34	43	36	5	16	11
308	1	0	0	6	2	15	2	2	2	0
310	17	3	1	0	0	13	1	8	1	15
313	14	0	4	0	12	0	0	0	0	0
314	11	2	0	0	1	16	6	4	17	3
317	15	5	0	5	17	15	0	5	3	1
Mean	7.93	6.57	6.18	2.04	11.21	8.68	6.18	5.86	4.39	7.39
Stdev	11.65	9.42	10.96	2.91	10.95	9.29	8.41	8.51	7.24	7.36

Average RPE for Each Hour										
Hour	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
SL Mean	6.6	8.8	8.8	9.6	10.3	11.1	10.6	10.2	10.3	10.5
SL Stdev	1.4	3.5	2.7	3.2	3.2	3.3	3.2	3.0	2.9	3.0
SNA Mean	7.4	8.7	8.3	9.1	9.9	10.1	10.0	10.1	9.8	10.4
SNA Stdev	2.8	3.6	2.9	3.1	3.0	3.2	2.8	2.9	2.8	3.4
Mean Diff	0.74	0.15	0.52	0.57	0.44	0.93	0.59	0.07	0.52	0.11
p-value	0.35	1.00	0.28	0.48	0.62	0.34	0.42	0.93	0.52	0.76

Satisfaction Surveys									
	Convenience Carrying	**Convenience Eating**	**Ability to Work**	**Variety**	**Taste**	**Appearance**	**Energized**	**Quantity**	**Overall Satisfaction**
Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
SNA Mean	7.41	6.62	4.76	5.21	4.93	4.52	4.31	4.09	5.31
SNA Stdev	2.18	1.95	2.13	1.88	2.65	2.23	2.44	2.73	2.63
SL Mean	4.48	5.28	4.64	4.31	4.45	4.07	3.82	3.50	4.14
SL Stdev	1.94	1.62	2.08	2.17	2.13	1.85	2.23	2.86	1.81
Mean Diff	2.93	1.34	0.12	0.90	0.48	0.45	0.49	0.59	1.17
p-value	0.00	0.00	0.71	0.11	0.32	0.42	0.48	0.15	0.10

Sack Lunch Survey

*The **SACK LUNCH** was convenient to carry with me on the fireline.*

Strongly disagree Somewhat agree Strongly agree

1 2 3 4 5 6 7 8 9 10

*The **SACK LUNCH** was convenient to eat.*

Strongly disagree Somewhat agree Strongly agree

1 2 3 4 5 6 7 8 9 10

*The **SACK LUNCH** made me feel like I was able to work better.*

Strongly disagree Somewhat agree Strongly agree

1 2 3 4 5 6 7 8 9 10

*The **SACK LUNCH** provided a variety of foods.*

Strongly disagree Somewhat agree Strongly agree

1 2 3 4 5 6 7 8 9 10

*The **SACK LUNCH** provided satisfaction in taste of foods.*

Strongly disagree Somewhat agree Strongly agree

1 2 3 4 5 6 7 8 9 10

*The **SACK LUNCH** had an appealing appearance.*

Strongly disagree Somewhat agree Strongly agree

1 2 3 4 5 6 7 8 9 10

*The **SACK LUNCH** provided enough food to keep me energized throughout the day.*

Strongly disagree Somewhat agree Strongly agree

1 2 3 4 5 6 7 8 9 10

*If the **SACK LUNCH** didn't provide you with enough food, how many more food items would you like to have?*

1 2 3 4 5 6 7 8 9 10

*My overall satisfaction with the **SACK LUNCH** was:*

Very low Pretty good Very high

1 2 3 4 5 6 7 8 9 10

Snack Food Survey

The SHIFT FOOD was convenient to carry with me on the fireline.

Strongly disagree			Somewhat agree				Strongly agree		
1	2	3	4	5	6	7	8	9	10

The SHIFT FOOD was convenient to eat.

Strongly disagree			Somewhat agree				Strongly agree		
1	2	3	4	5	6	7	8	9	10

The SHIFT FOOD made me feel like I was able to work better.

Strongly disagree			Somewhat agree				Strongly agree		
1	2	3	4	5	6	7	8	9	10

The SHIFT FOOD provided a variety of foods.

Strongly disagree			Somewhat agree				Strongly agree		
1	2	3	4	5	6	7	8	9	10

The SHIFT FOOD provided satisfaction in taste of foods.

Strongly disagree			Somewhat agree				Strongly agree		
1	2	3	4	5	6	7	8	9	10

The SHIFT FOOD had an appealing appearance.

Strongly disagree			Somewhat agree				Strongly agree		
1	2	3	4	5	6	7	8	9	10

The SHIFT FOOD provided enough food to keep me energized throughout the day.

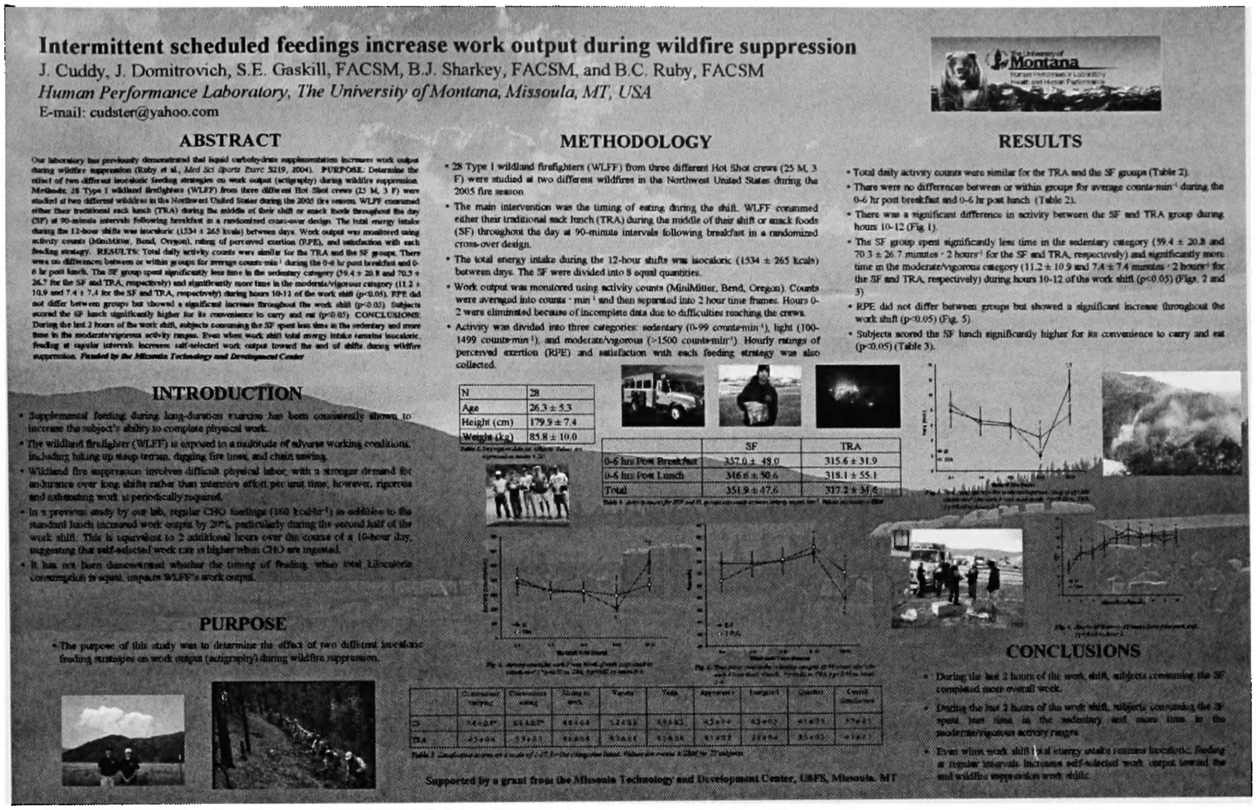
Strongly disagree			Somewhat agree				Strongly agree		
1	2	3	4	5	6	7	8	9	10

If the SHIFT FOOD didn't provide you with enough food, how many more food items would you like to have?

1	2	3	4	5	6	7	8	9	10

My overall satisfaction with the SHIFT FOOD was:

Very low				Pretty good					Very high
1	2	3	4	5	6	7	8	9	10


Intermittent scheduled feedings increase work output during wildfire suppression
J. Cuddy, J. Domitrovich, S.E. Gaskill, FACSM, B.J. Sharkey, FACSM, and B.C. Ruby, FACSM
Human Performance Laboratory, The University of Montana, Missoula, MT, USA
E-mail: cudster@yahoo.com
ABSTRACT
METHODOLOGY
• 28 Type I wildland firefighters (WLFF) from three different Hot Shot crews (25 M, 3 F) were studied at two different wildfires in the Northwest United States during the 2005 fire season.
• The main intervention was the timing of eating during the shift. WLFF consumed either their traditional sack lunch (TRA) during the middle of their shift or snack foods (SF) throughout the day at 90-minute intervals following breakfast in a randomized cross-over design.
• The total energy intake during the 12-hour shifts was isocaloric (1534 ± 265 kcals) between days. The SF were divided into 8 equal quantities.
• Work output was monitored using activity counts (MiniMitter, Bend, Oregon). Counts were averaged into counts · min⁻¹ and then separated into 2 hour time frames. Hours 0-2 were eliminated because of incomplete data due to difficulties reaching the crews.
• Activity was divided into three categories: sedentary (0-99 counts·min⁻¹), light (100-1499 counts·min⁻¹), and moderate/vigorous (>1500 counts·min⁻¹). Hourly ratings of perceived exertion (RPE) and satisfaction with each feeding strategy was also collected.
RESULTS
• Total daily activity counts were similar for the TRA and the SF groups (Table 2).
• There were no differences between or within groups for average counts·min⁻¹ during the 0-6 hr post breakfast and 0-6 hr post lunch (Table 2).
• There was a significant difference in activity between the SF and TRA group during hours 10-12 (Fig 1).
• The SF group spent significantly less time in the sedentary category (59.4 ± 20.8 and 70.3 ± 26.7 minutes · 2 hours⁻¹ for the SF and TRA, respectively) and significantly more time in the moderate/vigorous category (11.2 ± 10.9 and 7.4 ± 7.4 minutes · 2 hours⁻¹ for the SF and TRA, respectively) during hours 10-12 of the work shift (p<0.05) (Figs. 2 and 3).
• RPE did not differ between groups but showed a significant increase throughout the work shift (p<0.05) (Fig. 5).
• Subjects scored the SF lunch significantly higher for its convenience to carry and eat (p<0.05) (Table 3).
INTRODUCTION
PURPOSE
N | 28
Age | 26.3 ± 5.3
Height (cm) | 179.9 ± 7.4
Weight (kg) | 85.8 ± 10.0
SF | TRA
0-6 hrs Post Breakfast | 357.0 ± 48.0 | 315.6 ± 31.9
0-6 hrs Post Lunch | 346.6 ± 50.6 | 318.1 ± 55.1
Total | 351.9 ± 47.6 | 317.2 ± 31.6
CONCLUSIONS
Supported by a grant from the Missoula Technology and Development Center, USFS, Missoula, MT