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Natick, Massachusetts

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DATE December 2008

ADA

BLOOD BIOCHEMISTRIES FOLLOWING REPEATED DAYS OF FIRST STRIKE RATION OR MEAL, READY TO EAT CONSUMPTION

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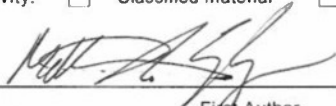
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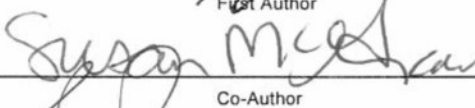
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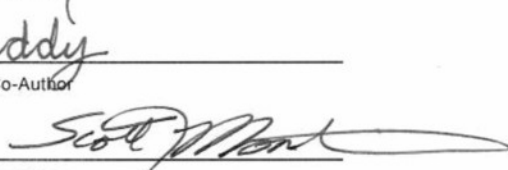
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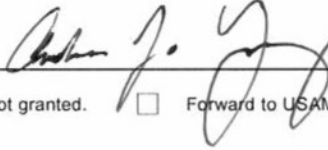


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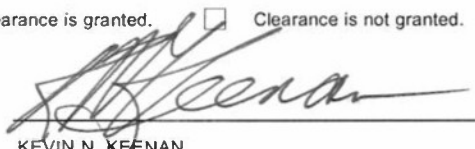
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14. ABSTRACT To determine if the First Strike Ration (FSR) sustains nutritional and metabolic status as effectively as the Meals, Ready to Eat (MRE), blood chemistries were compared between Soldiers who consumed 1 FSR (2864 Kcal, 377 g CHO, 91 g PRO, 109 g Fat) per day or 2 MRE (2620 Kcal, 348 g CHO, 84 g PRO, 102 g Fat) per day while performing 3 days of wildland fire suppression. Eighteen Soldiers were randomly assigned to one of two diet groups. Food intake was quantified from dietary logs and food wrapper waste. Daily activity was measured by accelerometry. While FSR group ate on average 300-400 additional kcal per day over first two days and exhibited a general pattern of more time spent in moderate activity and less time sedentary compared to the MRE group, these differences were not statistically significant. In both diet groups, blood glucose declined while β -Hb and FFA rose over time ($p < 0.05$) with no differences between diet groups. AST and preALB were unaffected by diet and stable over the 3 days. It was concluded that FSR sustained nutritional and metabolic markers as effectively as MRE over 3 days of arduous labor.					
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Blood biochemistries following repeated days of First Strike Ration or Meal, Ready to Eat consumption

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DISCLAIMERS

The opinions or assertions contained herein are the private views of the author(s) and are not to be construed as official or as reflecting the views of the Army or Department of Defense.

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRMC Regulation 70-25 on the use of volunteers in research.

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BACKGROUND

The Combat Feeding Directorate (CFD), Natick Research Engineering and Development Center, Natick, MA responded to Warrior desire to reduce load and the observation that Meals, Ready to Eat (MRE) are field stripped, to propose development of a small, lightweight ration consisting of components that would be easy to consume on-the-move. Initial positive feedback of prototype versions of this ration concept led to formal development efforts, and the ration was given the working name of First Strike Ration (FSR). In 2005, USARIEM and CFD established an Army Technical Objective (ATO) entitled Nutritionally Optimized First Strike Ration (MD.IV.2005.02) to continue spiral development of this new individual assault ration.

When developing a new ration, it is important to establish that it performs equally as well or better than the ration that preceded it. This report summarizes an investigation performed as part of the Nutritionally Optimized First Strike Ration effort to document that the FSR sustains blood biochemical and nutritional status markers as effectively as MRE over several days of consumption.

ACKNOWLEDGEMENTS

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The investigators have adhered to the policies for protection of human subjects as prescribed in Army Regulation 70-25, and the research was conducted in adherence with the provisions of 32 CFR Part 219.

EXECUTIVE SUMMARY

The purpose of this experiment was to determine if the First Strike Ration (FSR) sustains nutritional and metabolic status as effectively as the Meals, Ready to Eat (MRE). Metabolic status was assessed by comparing blood chemistries between Soldiers who consumed 1 FSR (2864 Kcal, 377 g CHO, 91 g PRO, 109 g Fat) per day or 2 MRE (2620 Kcal, 348 g CHO, 84 g PRO, 102 g Fat) per day while performing 3 days of wildland fire suppression. Eighteen Soldiers were randomly assigned to one of two diet groups. Food intake was quantified from dietary logs and food wrapper waste. Daily activity was measured by accelerometry. Blood and saliva samples were obtained before and after 3 days of fire suppression to examine nutritional and metabolic status. While FSR group ate on average 300-400 additional kcal per day over first two days and exhibited a general pattern of more time spent in moderate activity and less time sedentary compared to the MRE group, these differences were not statistically significant. In both diet groups, blood glucose declined while β -hydroxybutyrate and free fatty acids rose over time ($p < 0.05$) with no statistical differences between diet groups. AST and prealbumin were unaffected by diet and stable over the 3 days arduous labor. There was statistical interaction in the response of BUN and retinal binding protein to fire suppression between the diet groups, but meaningfulness is uncertain as the magnitude of change was within normal variability. It was concluded that FSR sustained nutritional and metabolic markers as effectively as MRE over 3 days of arduous labor.

INTRODUCTION

The FSR is a compact, eat-on-the-move ration designed to be consumed during short-term high-intensity missions of approximately 3 days. The FSR substantially reduces the size and weight burden on the Warfighter relative to current field ration, the MRE, and its eat-on-move capabilities are expected to enhance consumption, nutritional intake, and mobility. The FSR features include: solely eat-out-of-hand components, inclusion of caffeinated gum and a caffeinated carbohydrate bar, and inclusion of a food wrapper waste bag; all of which is packed as single whole-day ration pack. In contrast, the MRE contains many items that are not conducive to eating out-of-hand, there is limited supply of caffeine, and the ration packs are bundled as individual meals. The intent of the FSR design is to promote snacking and regular food intake while on-the-go. Prototype versions of the FSR have received high acceptability and desirability scores (Federici et al., 2003, 2004, 2004a; Montain et al., 2006), and the ration was accepted for accelerated procurement.

Prior to this investigation, USARIEM actively participated on two field studies that compared the FSR prototype to MRE. Initially, the acceptability of the FSR prototype was tested with 124 Warfighters performing patrol missions in Eastern Afghanistan (Montain et al., 2006). 68% of those who ate the FSR over a 3 day mission reported that they liked the FSR “moderately” or “extremely” (8 & 9 on 9 point scale), and 63% reported that they would prefer the FSR over the MRE for their next mission. Only 20% preferred the MRE over the FSR. More recently, USARIEM collaborated with the USDA

Forest Service and the University of Montana to perform the only performance-type test to date of the FSR compared to MRE. Montain et al. (2008), tested the efficacy of FSR for improving voluntary work productivity and cognitive performance capability of wildland firefighters while they performed 2 days of fire suppression activities. The wildland firefighters consuming the FSR had greater total activity counts per shift as they spent a greater percentage of their work shift with activity counts > 1000 counts/min ($21 \pm 8\%$ vs. $18 \pm 6\%$; $p = 0.01$) and less percent of work shift with activity counts < 50 counts/min (33 ± 10 vs. $38 \pm 10\%$; $p 0.01$). Additionally, total voluntary energy intake (5250 ± 580 vs. 4396 ± 599 kcal), carbohydrate intake (698 ± 76 vs 545 ± 82 g) and caffeine intake (347 ± 262 vs. 55 ± 65 mg) were greater ($p < 0.05$) when eating FSR compared to the MRE. Salivary cortisol and testosterone, two markers of metabolic stress, were not different between the MRE and FSR groups, 0.09 vs. 0.11 $\mu\text{g/dl}$ and 94 vs. 92 pg/ml , respectively.

Blood biochemistries are altered by several days of underfeeding and arduous work. In a recent field study (Nindl et al., 2007), Marines consuming approximately 1,600 kcal/day (from 1 Meal, Ready to Eat + supplemental drink and bar) while expending $\sim 3,800$ kcal/day for 4 days, presented with significantly decreased circulating blood glucose (5.2 to 4.6 mM) and increased glycerol (0.04 to 0.18 mmol/L), free fatty acid (0.10 to 1.29 mmol/L), and β -hydroxybutyrate (0.08 to 1.02 mg/dl). To a lesser extent underfeeding reduced blood prealbumin (29.4 to 26.9 mg/dl) and retinal binding protein (3.3 to 3 mg/dl), and increased BUN (15.3 to 17.5 mg/100ml). These changes in

the blood markers are indications of altered substrate metabolism and increased metabolic stress.

Modest improvements in energy intake and/or carbohydrate availability could have measurable effects on these variables during underfeeding situations. Cuddy et al., (2007) reported that wildland firefighters who regularly snack maintain a higher blood glucose level than those who do not. Associated with regular snacking there was an increase in voluntary work. Similarly, consumption of the FSR by wildland firefighters resulted in increased time spent performing physical activity and less time sedentary (Montain et al., 2008). Saliva samples taken after the 2 days of fire suppression revealed no differences between consumption of the FSR and MRE for salivary cortisol (0.09 vs. 0.11 $\mu\text{g/dl}$) or testosterone levels (94 vs. 92 pg/ml), both measures of internal stress. No blood samples were taken to compare nutritional or metabolic status consequent to consuming either diet.

The purpose of this investigation was to evaluate activity levels, voluntary food intake, and blood biochemistries in wildland firefighters supplied with either the FSR or MRE over several days of arduous work. Specific objectives were to compare volunteers' biochemical blood profile after consuming either 1 FSR/day or 2 MRE/day over the 3 days of work. It was hypothesized that 1) consumption of the FSR would be greater than consumption of the MRE, 2) FSR would be associated with greater self-paced work than the MRE, and 3) blood biochemical profiles would be similar between volunteers consuming the 1 FSR or 2 MRE during repeated days of arduous work.

METHODS

STUDY DESIGN

A cross-sectional design was used to address the experimental hypotheses. Volunteers were randomly assigned to consume either 2 MREs or 1 FSR per day for three consecutive days of arduous work. Food consumption was assessed by having the volunteers maintain daily food logs and by collecting all food wrappers from consumed food and all other uneaten food items. Blood sampling was performed before and after 3 days of eating the rations. Baseline measurements included measurement of height, weight, and a completion of a background questionnaire. Figure 1 depicts the study timeline. Data collection was conducted at the Tripod Complex Fire near Winthrop, WA September 2007.

Figure 1. Data collection timeline

Group	Day 1	Day 2	Day 3
A	FSR	FSR	FSR
B	2 MREs	2 MREs	2 MREs

Saliva	↑	↑	↑	
Blood	↑			↑
Wrappers		↑	↑	↑
Meal Cards		↑	↑	↑
Actical	▬	▬	▬	

Eighteen Soldiers whose unit's were assigned to assist with fire suppression volunteered to participate in the study. All volunteers were verbally briefed about the nature, purpose, and requirements for participation in the study. A witness other than

one of the investigators was present during the verbal briefing and during signing of the consent form to confirm that consent was voluntary and that the volunteers were aware of what the study was investigating, what participation entailed, and medical risks associated with participation. The investigators adhered to Army Regulation 70-25 and the U.S. Army Research Institute of Environmental Medicine memorandum 70-25 on the Use of Volunteers in Research. The volunteers were randomly assigned to either the FSR or MRE groups, the demographics of the two groups are presented in Table 1.

Table 1. Demographic profile of the two diet groups

Diet	Age, years	Weight, kg	Height, cm
FSR	23 ± 5	86.9 ± 14.9	178 ± 7
MRE	22 ± 2	86.0 ± 12.6	181 ± 9

Data mean ± sd and n=9 per group.

The FSR and MRE composition are summarized in Table 2. Volunteers were verbally instructed to only eat the food that was provided them. Ration consumption (when, what, and how much) was at the subjects' discretion. The participants had unrestricted access to potable water.

Table 2. Average Macronutrient Content of the FSR and MRE menus

	FSR	MRE
Total Kcal	2864	2620
Total Protein (g)	91	84
Total Carbohydrate (g)	377	348
Total Fat (g)	109	102

Ration intake was assessed using a food log and intake verified by collecting eaten and uneaten food wrappers. The food log included all of the FSR or MRE components, and each volunteer recorded the approximate amount of the item consumed (25%, 50%, 75% or 100%), the approximate time of day the item was consumed (early morning, mid-morning, early afternoon, mid-afternoon, early evening, late evening), and how much they liked each component (9 point Likert scale). Nutrient intakes were calculated from the dietary intakes using a food composition database compiled from existing laboratory determinations made by the ration developers, from calculations of the product formulation using Genesis (ESHA, version 7.6), from manufacturer-provided data, from the U.S. Department of Agriculture Nutrient Data Base for Standard Reference (release 17), and the USDA Nutrient Data Base for Individual Food Intake Surveys (1998).

Work-shift activity was quantified by actimetry using Actical sensors (Mini Mitter Co., Bend, OR) attached to a hard card and inserted into the chest pocket of each volunteer's Nomex shirt. Activity counts were read and processed using Actical software (Mini Mitter Co., Inc., Bend OR).

Body weight was measured each morning of testing using a calibrated electronic battery-powered scale accurate to 0.1 kg. Subjects were weighed in shorts, t-shirt, and without shoes. To crudely assess hydration state, daily morning urine samples were obtained and urine specific gravity measured using a refractometer.

Blood samples were obtained by venepuncture from a superficial forearm vein. 7 ml of blood were collected into a red-top tube, allowed to clot for 30 min, centrifuged and frozen until analysis. The initial blood sample was obtained in the morning after an overnight fast prior to beginning the day's work shift. The second blood sample was obtained when volunteer's returned to base camp upon completion of day 3 work shift. Biochemical analysis was performed at the Pennington Biomedical Research Center (PBRC, Baton Rouge, LA). Glucose, free fatty acid, glycerol, β -hydroxybutyrate, BUN and AST were processed on a DXC 600 Pro (Beckman Coulter, Brea, CA) analyzer, while retinol binding protein and prealbumin were assayed on an Array 360 CE (Beckman Coulter, Brea, CA) analyzer.

STATISTICAL ANALYSIS

Data were analyzed using Statistica statistical software (Statsoft Tulsa Ok.). Anthropometric, energy and nutrient intake, activity and biochemistry data were analyzed using descriptive statistics to derive measures of central tendency and variance. Group demographics and total dietary intake parameters were compared using a t-test. A mixed model ANOVA (diet group x time) was used to test for statistical differences between FSR and MRE on blood chemistry variables, dietary intake, activity, body mass changes, and urine specific gravity. Where a significant main effect or interaction (F-ratio) occurred post-hoc comparisons were made using Tukey's HSD. Significance was accepted when $p < 0.05$.

RESULTS

Body weight fell progressively day over day independent of diet group (Table 3); presumably due to mismatch between energy intake and energy expenditure. Within a work shift, the volunteers maintained post-shift body mass within 2% of their pre-shift mass.

Table 3. Body mass changes in response to three days of arduous labor when fed MRE or FSR

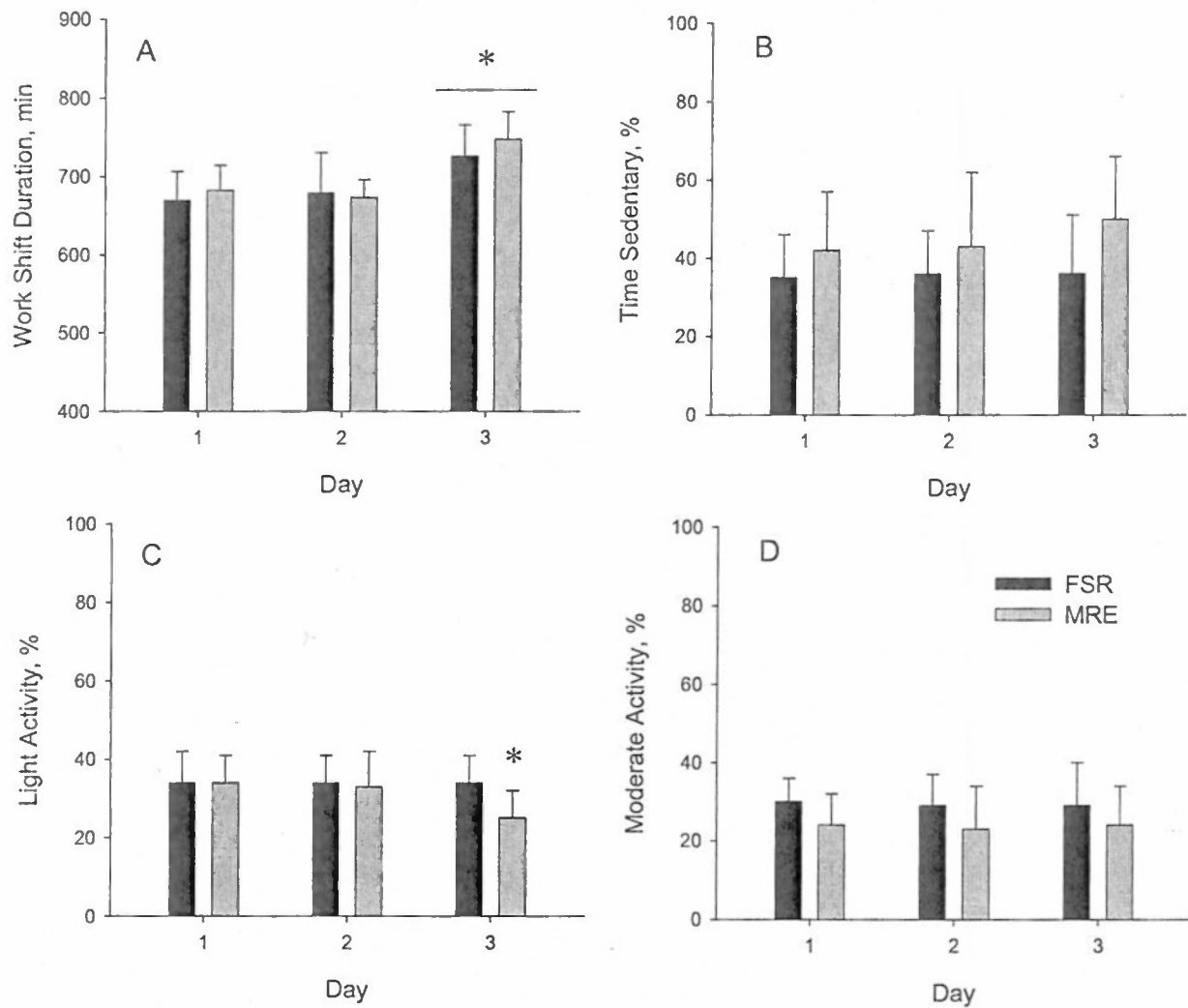
	MRE		FSR		Diet	Time	D x T
	Pre	Post	Pre	Post			
Day 1	86.0 ± 12.6	85.9 ± 12.5	86.9 ± 14.9	86.6 ± 15.1	NS	P<0.01	NS
Day 2 *	85.0 ± 12.5	85.1 ± 12.1	86.0 ± 15.1	85.9 ± 14.8			
Day 3 *†	84.6 ± 12.2	84.7 ± 11.9	85.5 ± 14.9	85.8 ± 15.0			

Data are mean ± sd for 9 subjects per diet group. * Different from day 1, $p < 0.05$. † Different from day 2, $p < 0.05$.

Work shift duration varied day-to-day; day 3 was longer than day 1 or day 2 ($p < 0.01$), but was similar within-day for the two diet groups. The shift durations were 669 ± 11 , 679 ± 13 , and 726 ± 13 minutes for FSR on day 1, 2 and 3, respectively, and 682 ± 11 , 673 ± 13 , and 745 ± 13 minutes for the MRE group (Figure 2). While there appeared to be trend for the MRE group to spend greater time sedentary (expressed as either absolute min or % of work shift) there were no statistical differences between groups ($p = 0.13$ and $p = 0.16$, respectively) and no interaction between diet and day. Time spent in light activity changed over time, but was dependent on diet group ($p < 0.01$), as % of work shift time in light activity remained stable day over day in FSR,

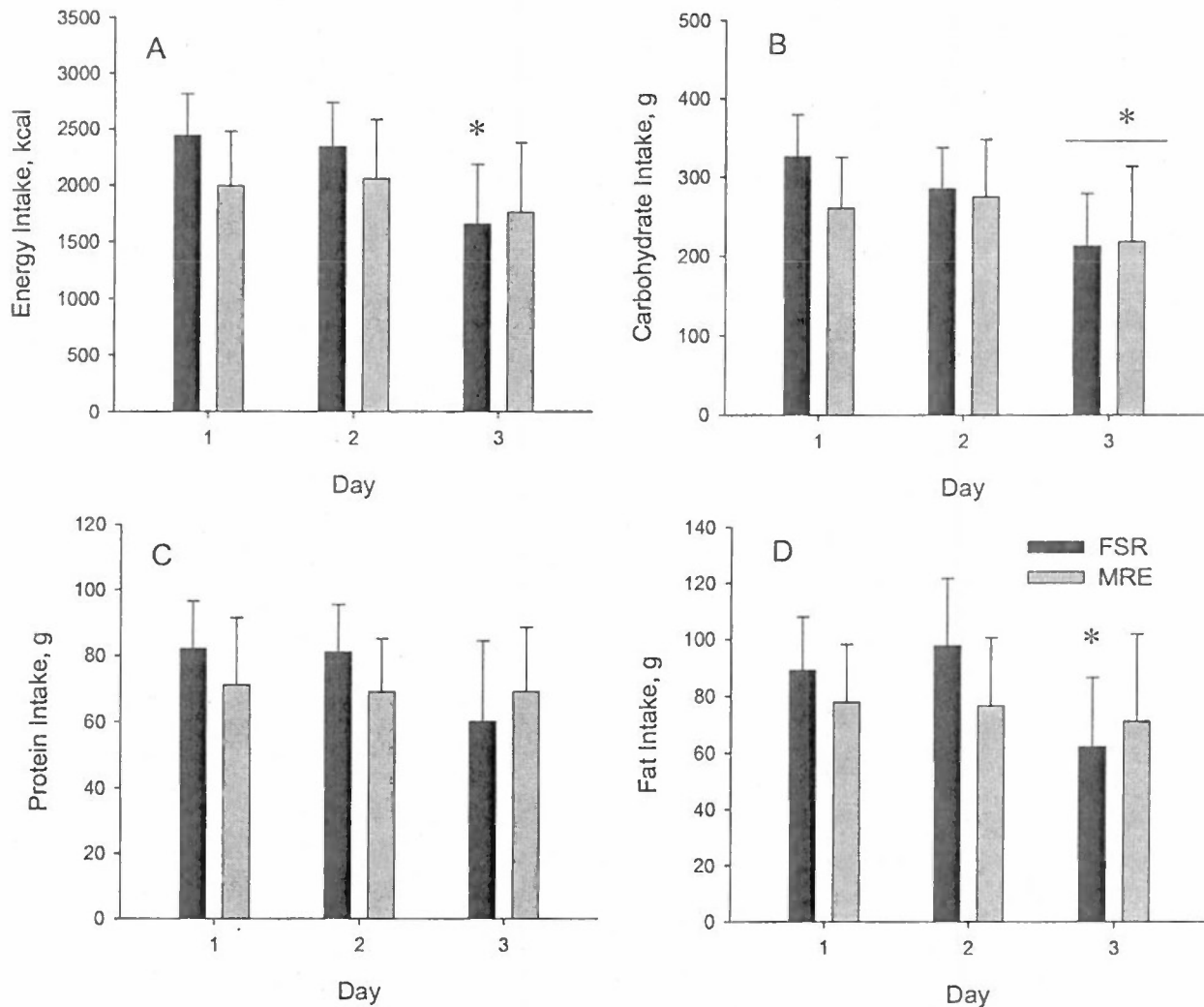
but fell on day 3 in those consuming the MRE. Percent of time performing moderate activity was similar across the three days and similar between the diet groups. Total activity counts across the 3 work shifts were similar between groups averaging $815,650 \pm 231,496$ counts and $764,706 \pm 307,369$ for FSR and MRE, respectively.

Figure 2. Activity profile of the FSR and MRE diet groups



There were no statistical differences in the total energy (FSR= $6,436 \pm 1,086$; MRE= $5,806 \pm 1,421$ kcal, $p=0.3$), carbohydrate (FSR= 823 ± 139 ; MRE= 753 ± 198 g, $p=0.4$) protein (FSR= 223 ± 33 ; MRE= 210 ± 38 g, $p=0.5$) or fat intake (FSR= 249 ± 51 ; MRE= 226 ± 64 g; $p=0.4$) over the three day observation period between the diet groups. Dietary intake did vary over time, however, and the interactions between diet group and time are illustrated in Figure 3. Energy intake declined over time and this change was dependent on diet group ($p=0.04$). The caloric intake of FSR group was approximately equal on Day 1 ($2,439 \pm 145$ kcal: mean $\pm$ SE) and Day 2 ($2,342 \pm 155$ kcal) but fell on Day 3 to ($1,655 \pm 192$ kcal), whereas the caloric intake of the MRE group was approximately equal on day 1 ($1,994 \pm 145$ kcal) and on day 2 ($2,056 \pm 156$ kcal) but did not decline significantly on day 3 ($1,757 \pm 192$). Fat intake showed a similar pattern of response over time and same interaction effect, whereas carbohydrate intake was lower on day 3, with no interaction with diet group. There were no statistical differences in dietary protein intake between diet groups or across days.

Figure 3. Dietary intake of the FSR and MRE diet groups.



Three days of arduous work impacted blood chemistry as plasma glucose declined, while β -hydroxybutyrate and free fatty acids increased (Table 4). In general, there were no differences in blood chemistries between diet groups, however, there was a main effect of diet on BUN, but this was dependent on day, as BUN increased more over time in the group consuming MRE than FSR. In addition, the decline in retinal binding protein over time was also dependent on diet; with FSR exhibiting a greater

decline than MRE. For both variables, the absolute values before and after the dietary intervention were within normal variability of the measure.

Table 4. Blood biochemistry responses to three days of arduous labor when fed MRE or FSR

	MRE		FSR		Diet	Time	D x T
	Pre	Post	Pre	Post			
Glucose, mg/dl	4.9 ± 0.3	4.3 ± 0.4	5.1 ± 0.6	4.3 ± 0.8	NS	p<0.05	NS
β-HB, mM	0.02 ± 0.01	0.23 ± 0.18	0.05 ± 0.02	0.19 ± 0.33	NS	p<0.05	NS
Glycerol, mM	0.02 ± 0.01	0.04 ± 0.04	0.03 ± 0.02	0.04 ± 0.04	NS	NS	NS
FFA, mM	0.31 ± 0.24	0.62 ± 0.36	0.29 ± 0.12	0.45 ± 0.38	NS	p<0.05	NS
AST, IU/L	22 ± 8	26 ± 8	20 ± 6	22 ± 7	NS	NS	NS
Prealb, mg/dl	29 ± 5	28 ± 6	32 ± 5	31 ± 5	NS	NS	NS
BUN, mg/dl	14 ± 3	17 ± 2	14 ± 3	13 ± 3	p<0.05	NS	p<0.05
RBP, mg/dl	4.4 ± 0.8	4.2 ± 0.9	4.7 ± 0.9	4.2 ± 0.8	NS	p<0.05	p<0.05

Data are mean ± sd for 9 subjects per diet group. β-HB, beta hydroxybutyrate; FFA, free fatty acids; Prealb, prealbumin, RBP, retinal binding protein.

DISCUSSION

The outcomes of this investigation support the hypothesis that FSR is equally effective at sustaining nutritional and metabolic status as MRE over repeated days of arduous labor. Blood metabolic status indicators such as glucose, free fatty acids and β-hydroxybutyrate responded similarly to the stress applied independent of diet group. Similarly, prealbumin and AST levels were not different between diet groups. Equally

important, both diets were sufficient to create only marginal changes in any of the nutritional and metabolic status indicators measured.

The experiment was conducted using the Wildland Firefighter model as these occupational laborers typically work in teams that perform approximately the same duties and the nature of their physical labor produces energy expenditures approximately equal to values observed in warriors conducting dismounted operations (Ruby et al, 2002; Tharion et al., 2005). In the group studied, the work shifts were ~12 hours in duration with ~60% of shift spent in light, moderate or vigorous activities. The terrain was quite rugged; with most fire suppression activities performed on mountainside terrain. Energy expenditures were likely more modest than expected, and probably less than some dismounted military operations, as 1-2 hours of each work shift was spent traveling from base camp to fire site, and the nature of the labor (mop up activities) was less physically demanding than digging fire line, etc.

Based on previous studies with the FSR (Montain et al., 2006; Montain et al., 2008), it was anticipated that volunteers would consume more of the FSR than MRE. While a similar pattern appeared to be present on day 1 and day 2 of the dietary intervention, there were not statistical differences in the total amount of energy, carbohydrate and protein consumed by volunteers consuming FSR vs. the MRE. This may be due to the relatively smaller sample size used in the current investigation, but is contrary to our a priori hypothesis. Regardless, the data clearly indicate that FSR is

equally effective at sustaining nutritional and metabolic status as MRE when energy and nutrient intakes are similar between the two rations.

In a previous investigation (Montain et al., 2008) it was observed that fire fighters consuming the FSR performed greater amount of self-paced work than when consuming the MRE. Differences in self-paced activity were not statistically significant in the present investigation. A reasonable explanation is that the use of a cross-sectional design and much smaller sample size did not possess the statistical power to detect modest (but meaningful) differences in self-paced activity. There was a pattern in the data that suggests that a more robust design may have been able to reproduce the earlier observation that FSR better sustains self-paced work than MRE. It was observed that the FSR group spent a similar percentage of time performing light activities day over day, whereas the MRE group spent less time in light activities on day 3 and this was accompanied by a trend indicating more shift time spent sedentary.

There were modest effects of diet on both BUN and retinal binding protein. In the case of BUN, the diet effect appeared to be largely attributable to a modest increase in BUN when consuming MRE whereas this increase did not occur when consuming FSR. That said, the magnitude of change (14 to 17 mg/dl) is well within normal clinical limits. Similarly, there was a reduction in retinal binding protein from day 1 to day 3 of the diet intervention, and this was dependent on diet group. The reduction in retinal binding protein appeared largely attributable to a marginally higher retinal binding protein at study onset in FSR and a decline to same post values for the two diets. Again,

however, the magnitude of difference between diet groups was within clinical norms and the magnitude of the observed change over time was relatively small compared to what can be induced by energy deficit and nutritionally inadequate diets. Our interpretation is that these observed differences are unlikely to have clinical significance.

CONCLUSIONS

The FSR was as effective at sustaining biological indicators of nutrition and metabolic status as MRE over 3-days of feeding during arduous labor.

RECOMMENDATIONS

Continue development of FSR for operational forces that would benefit from smaller, lighter operational rations that are easy to consume on-the-move.

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