Nutrient Intake of Wildland Firefighters During Arduous Wildfire Suppression

Macronutrient and Micronutrient Consumption

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Wildland firefighters (WLFFs) perform in adverse environments making rapid adjustments to dietary needs. The National Mobile Food Services (NMFS) contract details WLFF dietary provisions on wildfire incidents. **Objective:** Determine the nutrient content of food and drink provided to and consumed by WLFFs under the NMFS contract. **Methods:** Individual (n = 122) dietary provisions and consumption was recorded during 1 workday. Nutritional analysis of items provided was compared with consumption and the recommended dietary allowance (RDA). **Results:** WLFFs consumed significantly (P < 0.05) fewer macronutrients than provided for calories, protein, and fat. Provided and consumed micronutrients were below the RDA for vitamins D and E, magnesium, and manganese. **Conclusion:** Most dietary recommendations were met by NMFS provisions. Next steps include WLFF nutrition education to improve consumption and contract revisions to meet micronutrient recommendations. **Keywords:** dietary intake, macronutrients, micronutrients, wildland firefighters.
wildfire assignments. During a shift on a wildfire incident (12 to 16 hours) the shift provision items are essential tools for work performance when it comes to both nutrient intake and nutrient timing. Due to early breakfast consumption and late dinner consumption, WLFFs rely on shift provisions to sustain nutrient intake for an extended period of time when energy expenditure is greatest. Timing of food consumption, specifically protein and CHO, is crucial for WLFFs to meet the high energy demands.6 Inability to meet daily nutrient intake requirements may result in compromised health and safety of WLFFs and impaired recovery.

WLFFs participate in a variety of self-selected nutrient intake and physical activities during a wildfire assignment. WLFF nutrition sources while on a wildfire assignment include catered breakfast and dinner of suggested meal serving sizes and prepared shift provisions.6,10,21,22 The typical shift provisions during wildfire suppression contains 1506 to 2008 kcals.6,21,22 Furthermore, many WLFFs bring additional (supplemental) food items such as food bars, dried meats, or sports drinks to consume during the daily work shift.6,21,22 However, these items are not always available due to extraneous variables, including cost, policy, and fire location. Therefore, WLFFs may experience fatigue, decreased work rate, and ultimately compromised safety.6,10,21–23

Vitamins and minerals are critical components of many metabolic processes within the human body.24 Dietary references intakes (DRIs) refer to all vitamins and essential minerals required by the human body to support healthy function.25–27 DRIs encompass recommended daily allowance (RDA) and adequate intakes (AI). The RDA provides adequate micronutrients to support 98% of the US population’s health, whereas the AI is a speculated value used when an RDA cannot be determined. Previous literature suggests athletes require additional vitamins and minerals to support metabolic processes and rapid tissue growth and repair compared with sedentary individuals. Specifically, the intensity, duration, and frequency of activity may dictate the overall metabolic demands and necessity for increased amounts of specific vitamins and minerals.24,28 Electrolyte balance during wildfire suppression are critical to maintain work output and avoid health complications such as rhabdomyolysis, renal distress, hyponatremia, and heat exhaustion.6,29,30 When overall energy intakes are sufficient to support an individual’s activity level, most individuals’ micronutrient requirements may be met. However, if energy intakes are not adequate to support strenuous activity, micronutrient intakes may not be sufficient. Therefore, it is critical to determine if WLFFs consume the recommended amounts of micronutrients to support overall health and physical demands of wildfire suppression. However, a lack of knowledge on micronutrient intakes for WLFFs exists. Additional information is necessary regarding WLFF micronutrient intake and recommendations for micronutrient intake within this population.

The primary purpose of this study was to determine if following the NMFS contract provides adequate nutrients (macronutrients and micronutrients) to WLFFs during wildfire suppression. If sufficient nutrients are not provided, alterations to the catering contract may be warranted to ensure WLFFs have access to proper nutrients for wildfire suppression and overall health. The secondary purpose was to determine if WLFFs consume adequate nutrients to sustain high energy expenditure and meet micronutrient requirements during wildfire suppression. If WLFFs do not consume sufficient nutrients, nutrition education is necessary to teach and encourage WLFFs the importance of proper nutrient intake for wildfire suppression, health, and safety.

**RESULTS**

**Participants and Study Design**

Subjects included WLFFs (n = 122) deployed to 12 different wildfire incidents across six regions of the western United States during the 2018 fire season. A different subset of this dataset has described total energy intake, composition, nutrient timing, and activity counts during the work shift.22 The primary purpose of this analysis was to determine differences in nutrients provided by the NMFS versus consumed by WLFFs across a full day (breakfast, work shift, dinner). Additionally, WLFF consumption of micronutrients was compared with RDAs/AIs. Before participation, subjects provided informed consent and were briefed on study design and procedures. Each subject volunteered for one full work shift, including breakfast, shift food, and dinner. The University of Montana Institutional Review Board approved this study (IRB #121–18).

**Nutrient Intake**

Nutrient intake was classified as provided or consumed. Provided nutrient intake refers to the food offered by the caterers via the NMFS contract, whereas, consumed nutrient intake refers to what was ingested by WLFFs in one day both from caterer-provided food and any additional sources. Subjects were matched with field-going researchers on a 1:1 basis. Consumption of meals and shift provisions were recorded in real-time by the assigned researcher to minimize the potential for recall or self-report inaccuracies. Photographs were taken of breakfast and dinner plates provided to subjects and any additional supplemental items selected by subjects from the self-serve area (eg, salad, fruit). Finished plates were taken and any leftover food items were weighed using an Ohaus FD Series Food Service Scale (NTEP Certified, Ohaus Corporation, Parsippany, NJ). Unconsumed item weights were then compared with initial ounce-weights of a representative meal served to the research team by the caterer strictly for measurement purposes. Each representative meal consisted of all food items and serving sizes outlined by the NMFS contract and served to all fire personnel for that meal period. This representative meal was used to determine provided nutrient amounts. The difference between provided weights and uneaten weights on finished plates was used to determine the consumed dietary analysis. Ounce-weight measurements of provided and consumed meal items were recorded for nutrient analysis, as well as estimated waste. Prior to the work shift, an inventory of all shift provision items were measured by weight, photographed, and entered into mobile data collection devices to allow entries to be made in the field in real-time. The final log of consumed calories was entered into the Food Processor program (ESHA, 10.13.1, Salem, OR) at the end of the work shift along with provided calories for the subject by the NMFS contract.

**Statistical Analyses**

Average energy intake (calories), macronutrients (CHO, protein, and fat), and micronutrients (vitamins and minerals) by meal (breakfast, shift provisions, dinner) and workday total were reported for male and female WLFFs. Nutrient intake variables for the total day were not normally distributed; therefore, a log-transformation was performed. Paired t tests were used to determine differences between provided and consumed dietary analysis variables of log-transformed data among men and women. All tests were two-sided at the 0.05 significance level. Data are reported as mean or mean ± SD. Provided and consumed amounts for micronutrients are also were expressed as a percent of the RDA or AI. Descriptive statistics and data were analyzed using SPSS software version 24 (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY.)

**Subjects**

Subject (n = 122) demographic information is reported in Table 1 (M: n = 102; F: n = 20; BMI: 24.9 ± 3.3 kg/m²). Six subjects included in the study were on a fire with a Type 3 caterer who
TABLE 1. Participants Demographic Characteristics

| Sex          | N   |
|--------------|-----|
| Male         | 102 |
| Female       | 20  |
| Crew type    |     |
| Type 1       | 45  |
| Type 2       | 53  |
| Engine & Helitack | 24  |

| Characteristic | Sex | Male | Female |
|----------------|-----|------|--------|
| Age, yrs       |     | 27.6 | 26.7   |
| Height, m      |     | 1.80 | ± 0.1  |
| Weight, kg     |     | 79.8 | ± 14.5 |
| BMI, kg/m²     |     | 24.9 | ± 3.3  |

Descriptive statistics were used to determine mean ± SD of demographic characteristics.

BMI, body mass index; kg, kilograms; m, meters; yrs, years.

TABLE 2. Macronutrient Intake Outcomes

|                | Breakfast¹ | Shift Food | Dinner | Total¹ |
|----------------|------------|------------|--------|--------|
|                | Provided   | Consumed¹ | Provided| Consumed| Provided| Consumed |
| Calories, kcal | 979 ± 308  | 901 ± 334  | 2282 ± 354 | 1717 ± 793 | 1097 ± 337 | 1344 ± 540 | 4296 ± 688 | 3889 ± 116³ |
| Protein, g     | 37 ± 8     | 33 ± 12    | 75 ± 18 | 56 ± 27 | 67 ± 26 | 69 ± 34 | 184 ± 42 | 163 ± 6³ |
| Protein, g/kg   | 0.4 ± 0.2  | 0.7 ± 0.4  | NA     | NA     | NA     | NA     | NA     | NA     |
| Carbohydrate, g| 84 ± 36    | 100 ± 53   | 271 ± 67 | 212 ± 110 | 103.5 ± 40.3 | 141 ± 68 | 451 ± 95 | 440 ± 16³ |
| Carbohydrate, g/kg | 1 ± 0.7  | NA     | 2 ± 1 | NA     | NA     | NA     | NA     | NA     |
| Fiber, g       | 4 ± 2      | 6 ± 4      | 26 ± 6 | 18 ± 10 | 11.0 ± 4 | 11 ± 4 | 47 ± 4 | 45 ± 7³ |
| Fat, g         | 54 ± 19    | 42 ± 19    | 105 ± 23 | 74 ± 39 | 46.1 ± 26.2 | 57 ± 33 | 205 ± 35 | 172 ± 5⁶³ |
| Fat, kcal      | 487 ± 177  | 374 ± 169  | 944 ± 214 | 666 ± 356 | 415.3 ± 235.9 | 511 ± 295 | 1873 ± 356 | 1585 ± 604 |
| Omega 3, g     | 1 ± 0.6    | 1 ± 0.6    | 0.5 ± 0.5 | 0.3 ± 0.4 | 1 ± 0.5 | 1 ± 0.7 | 2 ± 1  | 2 ± 1  |
| Omega 6, g     | 8 ± 4      | 6 ± 3      | 8 ± 5  | 4 ± 4   | 5.8 ± 4.0 | 7 ± 5   | 22 ± 7 | 18 ± 8³ |

Female macronutrient intake (n = 20)

| Calories, kcal | 913 ± 240 | 754 ± 420 | 2223 ± 294 | 1555 ± 567 | 1106 ± 443 | 1115 ± 442 | 4165 ± 814 | 3429 ± 83³ |
| Protein, g     | 40 ± 7    | 26 ± 15    | 64 ± 14    | 44 ± 23    | 66 ± 28    | 51 ± 25    | 165 ± 39   | 122 ± 41³ |
| Protein, g/kg   | 0.4 ± 0.2 | 0.7 ± 0.4  | NA         | NA         | NA         | NA         | NA         | NA         |
| Carbohydrates, g| 72 ± 34    | 97 ± 60    | 284 ± 45   | 210 ± 73   | 126 ± 60   | 148 ± 78   | 479 ± 110  | 457 ± 114  |
| Carbohydrates, g/kg | 1.5 ± 0.8 | 3.3 ± 1.2 | NA    | NA    | NA    | NA    | NA    | NA    |
| Fiber, g       | 4 ± 2      | 8 ± 4      | 26 ± 5     | 22 ± 10   | 12 ± 4    | 12 ± 5    | 44 ± 8    | 42 ± 13    |
| Fat, g         | 51 ± 14    | 30 ± 22    | 96 ± 17    | 64 ± 32   | 38 ± 21   | 36 ± 21   | 182 ± 40  | 131 ± 51³ |
| Fat, kcal      | 461 ± 127  | 271 ± 202  | 870 ± 156  | 577 ± 293 | 344 ± 190 | 332 ± 196 | 1641 ± 364 | 1183 ± 46³ |
| Omega 3, g     | 0 ± 0.3    | 0.5 ± 0.3  | 0.5 ± 0.7  | 0.3 ± 0.3 | 0.7 ± 0.6 | 0.7 ± 0.6 | 2 ± 1     | 1.5 ± 0.8³ |
| Omega 6, g     | 7 ± 2      | 4 ± 2      | 8 ± 6      | 5 ± 4     | 6 ± 4     | 5 ± 4     | 21 ± 8    | 15 ± 6³    |

¹Breakfast and dinner, first and last meals consumed at fire camp, respectively; shift food, food items consumed during wildfire suppression, not at fire camp.

²Provided = food items given to or available for WLFFs for all meals. Consumed = food eaten by WLFFs.

³P < 0.05, total consumed significantly different from provided.

Micronutrient intake outcomes for men are reported in Table 3. Total provided micronutrient amounts were significantly greater than consumed for iron (mg; P = 0.008), potassium (mg; P = 0.032), sodium (mg; P = 0.039), copper (mg; P = 0.018), selenium (mg; P < 0.0001), choline (mg; P < 0.0001), vitamin B3 (mg NE; P < 0.0001), and folate (mcg DFE; P < 0.0001) for men. Consumed micronutrient amounts were significantly greater than provided for vitamin D (IU; P = 0.003), vitamin B12 (mcg; P = 0.011), and vitamin E (mg; P = 0.045) for males. No significant differences were observed between provided and consumed micronutrient amounts for zinc (mg; P = 0.407), calcium (mg; P = 0.194), magnesium (mg; P = 0.107), manganese (mg; P = 0.372), phosphorus (mg; P = 0.195), vitamin A (mcg RAE; P = 0.347), vitamin B1 (mg; P = 0.133), vitamin B2 (mg; P = 0.664), vitamin B6 (mg; P = 0.643), vitamin C (mg; P = 0.387), vitamin K (mg; P = 0.457), and pantothenic acid (mg; P = 0.752) for men. The total daily provided and consumed micronutrient amounts were above the RDA for zinc (mg; 119%; 115%), calcium (mg; 121%; 143%), iron (mg; 383%; 368%), potassium (mg; 117%, 111%), sodium (mg; 508%, 455%), copper (mg; 188%, 166%), phosphorus (mg; 273%, 258%), selenium (mcg; 423%, 377%), vitamin B1 (mg; 475%, 613%), vitamin B2 (mg; 207%, 230%), vitamin B3 (mg NE; 375%, 340%), vitamin B6 (mg; 253%, 330%),
TABLE 3. Male Micronutrient Intake Outcomes (n=102)

| Micronutrient Intake | Breakfast Provider | Shift Food Provided | Dinner Provided | Total Provider | % RDA or AI ▲ |
|----------------------|--------------------|--------------------|----------------|--------------|----------------|
|                      | Consumed           | Consumed           | Consumed       | Consumed      |                |
| Vitamin D, IU         | 90 ± 32            | 107 ± 85           | 36 ± 43        | 70 ± 341      | 25 ± 48        |
| Zinc, mg              | 4 ± 1              | 3 ± 2              | 5 ± 6          | 13 ± 8        | 7 ± 5          |
| Calcium, mg           | 261 ± 115          | 378 ± 276          | 709 ± 321      | 580 ± 399     | 275 ± 134      |
| Iron, mg              | 6 ± 5              | 9 ± 16             | 15 ± 5         | 11 ± 8        | 8 ± 3          |
| Magnesium, mg         | 72 ± 7             | 93 ± 54            | 198 ± 104      | 135 ± 65      | 117 ± 51       |
| Potassium, mg         | 1042 ± 412         | 1095 ± 494         | 1816 ± 605     | 1370 ± 798    | 1215 ± 556     |
| Sodium, mg            | 2123 ± 1351        | 1715 ± 1325        | 3515 ± 1020    | 2793 ± 1425   | 2111 ± 852     |
| Copper, mg            | 0.3 ± 0.1          | 0.3 ± 0.2          | 0.9 ± 0.6      | 0.6 ± 0.6     | 0.5 ± 0.2      |
| Manganese, mg         | 0.8 ± 0.9          | 1 ± 1              | 2 ± 2          | 2 ± 2         | 1 ± 0.6        |
| Phosphorous, mg       | 602 ± 218          | 578 ± 275          | 700 ± 304      | 516 ± 326     | 640 ± 294      |
| Selenium, mcg         | 59 ± 18            | 46 ± 22            | 52 ± 25        | 42 ± 41       | 80 ± 43        |
| Choline, mg           | 276 ± 125          | 201 ± 135          | 183 ± 135      | 88 ± 79       | 147 ± 116      |
| Vitamin A (mcg RAE)   | 274 ± 133          | 275 ± 229          | 341 ± 346      | 262 ± 356     | 145 ± 141      |
| Vitamin B1, mcg       | 0.7 ± 0.3          | 0.8 ± 0.8          | 1 ± 0.6        | 1 ± 1         | 1 ± 0.6        |
| Vitamin B2, mcg       | 1 ± 0.5            | 1 ± 0.6            | 0.9 ± 0.4      | 1 ± 1.5       | 1 ± 0.4        |
| Vitamin B3 (mg NE)    | 14 ± 5             | 12 ± 6             | 20 ± 10        | 17 ± 16       | 26 ± 16        |
| Vitamin B6, mcg       | 0.8 ± 0.5          | 0.7 ± 0.5          | 1 ± 0.4        | 2 ± 4         | 1 ± 0.7        |
| Vitamin B12, mcg      | 2 ± 1              | 2 ± 1.5            | 1 ± 1          | 6 ± 18        | 2 ± 2          |
| Vitamin C, mcg        | 16 ± 18            | 27 ± 31            | 87 ± 79        | 159 ± 333     | 37 ± 26        |
| Vitamin E-A-Toco, mcg | 2 ± 1              | 2 ± 3              | 6 ± 2          | 5 ± 10        | 2 ± 2          |
| Folate (mcg DFE)      | 137 ± 66           | 136 ± 135          | 191 ± 106      | 150 ± 224     | 169 ± 112      |
| Vitamin K, mcg        | 17 ± 15            | 15 ± 14            | 32 ± 28        | 32 ± 64       | 49 ± 44        |
| Panthenic acid, mg    | 3 ± 1              | 3 ± 1              | 3 ± 1          | 3 ± 4         | 2 ± 1          |

% RDA or AI ▲ percent recommended dietary allowance or adequate intake of total; DFE, dietary folate equivalents; IU, international units; mcg, micrograms; mg, milligrams; NE, macin equivalents, RAE, retinol activity equivalents.

1Breakfast and dinner = first and last meals consumed at fire camp, respectively. Shift food = food items consumed during wildfire suppression, not at fire camp.

2Provided = food items given to or available for WLFFs for all meals. Consumed = food eaten by WLFFs.

3Paired t tests were used to determine differences in provided versus consumed nutrient intakes.

4AI bolded.

5P < 0.05, total consumed significantly different from provided.

vitamin B12 (mcg; 225%, 441%), vitamin C (mg; 150%, 249%), and folate (mcg DFE; 118%, 111%), for men. The total daily provided and consumed pantothenic acid was above the AI for men (mg; 196%, 208%). The total daily provided and consumed micronutrient amounts were below the RDA for vitamin D (IU; 38%, 65%), magnesium (mg; 95%, 88%), manganese (mg; 2%, 2%), and vitamin E (mg; 70%, 71%). The total provided choline was above the AI for men (mg; 102%), whereas the total consumed choline was below the AI (mg; 78%). The total provided vitamin A (mcg RAE) and K (mcg) were below the RDA for vitamin A and AI for vitamin K (99%, 84%), whereas the total consumed vitamin A and K were above the RDA and AI, respectively (115%, 105%).

Female Micronutrient Intake

Micronutrient intake outcomes for women are reported in Table 4. Total provided micronutrient amounts were significantly greater than consumed for zinc (mg; P = 0.004), sodium (mg; P < 0.0001), phosphorous (mg; P = 0.001), selenium (mcg; P < 0.0001), choline (mg; P = 0.001), vitamin B1 (mg; P = 0.008), vitamin B2 (mg; P = 0.040), and vitamin B3 (mg NE; P < 0.0001) for women. No significant differences were observed between provided and consumed micronutrient amounts for vitamin D (IU; P = 0.208), calcium (mg; P = 0.256), iron (mg; 0.229), magnesium (mg; P = 0.738), potassium (mg; P = 0.174), copper (mg; P = 0.403), manganese (mg; P = 0.521), vitamin A (mcg RAE; P = 0.864), vitamin B6 (mg; P = 0.979), vitamin B12 (mcg; P = 0.261), vitamin C (mg; P = 0.634), vitamin E (mg; P = 0.111), folate (mcg DFE; P = 0.092), vitamin K (mcg; P = 0.340), and pantothenic acid (mg; P = 0.085) for women.

The total provided and consumed micronutrient amounts were above the RDA for zinc (mg; 155%, 155%), calcium (mg; 110%, 106%), iron (mg; 153%, 149%), magnesium (mg; 132%, 138%), potassium (mg; 119%, 113%), sodium (mg; 451%, 362%), copper (mg; 200%, 188%), manganese (mg; 255%, 311%), phosphorous (mg; 265%, 218%), selenium (mcg; 337%, 242%), vitamin B1 (mg; 236%, 200%), vitamin B2 (mg; 236%, 209%), vitamin B3 (mg NE; 400%, 319%), vitamin B6 (mg; 307%, 366%), vitamin B12 (mcg; 345%, 391%), vitamin C (mg; 421%, 554%), and folate (mcg DFE; 138%, 130%), for women. Additionally, total provided and consumed micronutrient amounts were above the AI for vitamin K (mcg; 118%, 154%), and pantothenic acid (mg; 156%, 140%) for women. The total daily provided and consumed micronutrient amounts were below the RDA for vitamin D (IU; 33% 28%) and vitamin E (mg; 80%, 68%). Furthermore, the total daily provided choline was above the AI (mg; 122%), whereas the consumed choline was below the AI (mg; 88%) for women. Conversely, provided vitamin A was below the RDA (mcg RAE; 97%), whereas the consumed vitamin A was above the RDA (mcg RAE; 103%).

DISCUSSION

This study compared the nutritional content of the provided dietary provisions for male and female WLFFs during wildfire suppression, as supplied by the National Mobile Food Service (NMFS) contract, to the actual dietary intake consumed by WLFFs. Both the provided and consumed values for micronutrients were then compared with existing dietary recommendations for overall health.13,17–19 To the authors’ knowledge, this is the first study to assess the difference between provided WLFF macronutrient and micronutrient intake in comparison to the actual consumption on a wildfire assignment and how this compares to the dietary reference intakes (DRI).

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TABLE 4. Female Micronutrient Intake Outcomes (n=20)

| Nutrient       | Breakfast† | Shift Food | Dinner | Total‡ | % RDA or AI§ |
|----------------|------------|------------|--------|--------|--------------|
|                | Provided¹  | Consumed   | Provided| Consumed| Provided      |
| Vitamin D, IU  | 93 ± 33    | 81 ± 70    | 11 ± 18| 7 ± 16  | 25 ± 52       |
| Zinc, mg       | 4 ± 1      | 3 ± 1      | 6 ± 7  | 4 ± 3   | 6 ± 3         |
| Calcium, mg    | 221 ± 188  | 210 ± 197  | 625 ± 278 | 439 ± 272 | 264 ± 178 |
| Iron, mg       | 6 ± 2      | 10 ± 17    | 13 ± 6 | 9 ± 4   | 7 ± 3         |
| Magnesium, mg  | 76 ± 32    | 95 ± 20    | 208 ± 75 | 204 ± 171 | 135 ± 62 |
| Potassium, mg  | 1034 ± 489 | 986 ± 501  | 1705 ± 487 | 1599 ± 801 | 1340 ± 607 |
| Sodium, mg     | 2183 ± 1521| 1327 ± 1513| 2836 ± 760 | 1970 ± 711 | 2038 ± 940 |
| Copper, mg     | 0.3 ± 0.2  | 0.4 ± 0.2  | 1 ± 0.4| 1 ± 0.5 | 0.5 ± 0.3    |
| Manganese, mg  | 1 ± 0.6    | 2 ± 1      | 2 ± 4  | 1 ± 1   | 4 ± 2         |
| Phosphorus, mg | 597 ± 128  | 468 ± 254  | 642 ± 149 | 496 ± 313 | 697 ± 371 |
| Selenium, mg   | 61 ± 16    | 39 ± 20    | 41 ± 21| 34 ± 30 | 91 ± 43       |
| Choline, mg    | 319 ± 96   | 267 ± 152  | 83 ± 53 | 69 ± 48 | 136 ± 108   |
| Vitamin A (mcg RAE) | 273 ± 103  | 223 ± 142  | 248 ± 252 | 244 ± 385 | 155 ± 121   |
| Vitamin B1, mg | 0.2 ± 0.1  | 0.4 ± 0.1  | 1 ± 0.5| 1 ± 0.5 | 1 ± 0.6      |
| Vitamin B2, mg | 0.2 ± 0.1  | 0.3 ± 0.1  | 1 ± 0.5| 1 ± 0.5 | 1 ± 0.6      |
| Vitamin B3 (mg NE) | 13 ± 7  | 9 ± 5     | 16 ± 8 | 15 ± 10 | 27 ± 17     |
| Vitamin B6, mg | 1 ± 0.4    | 1 ± 0.4    | 2 ± 0.7| 3 ± 6   | 1 ± 0.6      |
| Vitamin B12, mcg | 2 ± 1    | 1 ± 1     | 4 ± 18 | 7 ± 19 | 1 ± 1       |
| Vitamin C, mg  | 16 ± 12    | 19 ± 17    | 270 ± 733 | 347 ± 760 | 35 ± 26   |
| Vitamin E-Toco, mg | 2 ± 1 | 2 ± 1 | 7 ± 3 | 5 ± 6 | 2 ± 2 |
| Folate (mcg DFE) | 130 ± 53 | 141 ± 126 | 200 ± 107 | 164 ± 110 | 226 ± 167 |
| Vitamin K, mcg | 18 ± 16    | 16 ± 12    | 32 ± 4 | 36 ± 45 | 59 ± 57     |
| Panthenic acid, mg | 2 ± 0.4 | 2 ± 1 | 3 ± 2 | 2 ± 2 | 3 ± 2 |

¹% RDA or AI, percent recommended dietary allowance or adequate intake of total; DFE, dietary folate equivalents; IU, international units; mcg, micrograms; mg, milligrams; NE, niacin equivalents; RAE, retinol activity equivalents.
²Breakfast and dinner = first and last meals consumed at fire camp, respectively. Shift food = food items consumed during wildfire suppression, not at fire camp.
³Provided = food items given to or available for WLFFs for all meals. Consumed = food eaten by WLFFs.
⁴Paired t-tests were used to determine differences in provided versus consumed nutrient intakes.
⁵AI bolded.

Caloric and macronutrient requirements during wildfire suppression have been repeatedly observed in WLFFs. Ruby et al.¹⁰ previously reported total energy expenditure during wildfire suppression as a wide range of 4878 ± 716 and 3541 ± 718 kcal d⁻¹ for males and females, respectively, using doubly labeled water. Additionally, Cuddy et al.¹³ further demonstrated arduous wildfire suppression demands as a total energy expenditure of 4556 ± 943 kcal d⁻¹. In the current study, WLFFs consumed an average of 3889 ± 1162 and 3429 ± 836 kcal d⁻¹ for men and women, respectively. Compared with Cuddy (2015)¹⁵, WLFFs average caloric consumption does not meet the previously measured energetic demands for wildfire suppression. However, the provided caloric amount for WLFFs was significantly greater (P < 0.0001) than consumed for both men and women. The food items offered were provided to supply WLFFs with 4296 ± 688 kcal d⁻¹ for men and 4165 ± 814 kcal d⁻¹ for women. Therefore, if WLFFs consumed all provided food items, their energy intake would result in an additional 1000 kcal d⁻¹, bringing intake closer to the total energy expenditure previously identified during a representative workday.¹²¹³ The greatest amount of calories consumed was during the work shift, whereas the least calories consumed was during breakfast. Consuming a greater amount of calories at breakfast may be a strategy to increase WLFF overall caloric intake when a more strenuous shift is expected. Further describing the food items that WLFFs choose to consume and not consume may be important to better understand this difference between provided and consumed calories. Furthermore, better understanding the reasons why WLFFs do not consume all items provided may help to identify teachable moments for nutrition education.

CHO stores in the body are limited but can be manipulated by the daily intake of CHO rich foods. Subsequently, CHO store depletion results in fatigue, decreased work rate, and compromised concentration.³² A high CHO diet, containing 6 to 10 g kg⁻¹, is promoted to optimize work output for individuals engaging in intense training or physically demanding work, such as WLFFs. In the current study, CHO intake has been quantified as 5 and 7.2 g kg⁻¹ d⁻¹ for men and women, respectively. Compared with the 6 to 10 g kg⁻¹ reported in the previous studies as well as results from Ruby et al.¹⁰ of 6.9 g kg⁻¹ d⁻¹, men may be consuming inadequate CHO (5 g kg⁻¹ d⁻¹), whereas women may be consuming minimal CHO (7.2 g kg⁻¹) to maintain glycogen stores for 12 to 16 hours of wildfire suppression for 5 days.¹⁰ Our results demonstrate WLFFs consumed significantly more CHO during breakfast and dinner than provided, however less CHO than provided during the work shift. This higher consumption than was provided indicates that WLFF were supplementing with food outside of that provided by the NMFS contract. Therefore, providing additional CHO rich food items during breakfast and dinner may pose an opportunity to increase WLFFs overall CHO intake. Additionally, since adequate CHO was provided but not consumed during the work shift, nutrition education focused on CHO needs and nutrient timing may help to improve CHO intake during the work shift.

Protein requirements for arduous occupations (such as WLFF and military operations) often exceed the RDA (0.8 g kg⁻¹) for the average healthy population to avoid adverse health effects. Protein consumption at or below the RDA may lead to a negative nitrogen balance and reduced skeletal muscle protein synthesis.⁵³⁴
Occupational athletes, including WLFFs, who are regularly involved in endurance or resistance training, require additional protein in the diet. However, optimal protein intake for specific WLFF performance remains unknown. In the present study, protein consumption was 2.0 ± 1.0 and 1.9 ± 0.6 g·kg⁻¹·d⁻¹ for men and women, respectively. Therefore, the protein consumed in this study falls within the optimal level for exercising populations. Additionally, both male and female WLFFs consumed significantly less protein compared with what was provided (163 ± 67 g·d⁻¹ vs 184 ± 42 g·d⁻¹ and 122 ± 41 g·d⁻¹ vs 165 ± 39 g·d⁻¹, respectively). WLFFs consumed less protein than provided for breakfast and during the work shift, however greater than provided during dinner. From this data, WLFFs are successful at proper nutrient timing for optimal protein synthesis and skeletal muscle recovery by consuming a greater amount of protein after arduous work has been completed for the day.

Habitually, WLFF fat intake has been greater than recommended (more than 30% total kcal) for arduous work. This may be due to the increased reliance on pre-packaged and non-perishable food items during wildfire suppression. WLFFs have previously experienced unfavorable metabolic profiles associated with the wildfire season, including increased cholesterol, low-density lipoproteins, and negative implications on body composition (increased body fat and visceral fat). High dietary fat intakes during wildfire suppression efforts may contribute to these unfavorable metabolic health outcomes, although further research is necessary to determine possible correlations. In the present study, both male and female WLFFs consumed significantly less fat compared with what was provided (172 ± 56 g·d⁻¹ vs 205 ± 35 g·d⁻¹ and 131 ± 51 g·d⁻¹ vs 182 ± 40 g·d⁻¹, respectively). The greatest fat intake was during the work shift (provided and consumed values). This may be due to the work shift duration and the necessity for an increased amount of calories to sustain work and satiation.

Micronutrients (vitamins and minerals) are necessary to sustain growth and development and support metabolic, immune, and cognitive functions. Specifically, during periods of increased activity, micronutrients are responsible for energy and macronutrient metabolism, oxygen and nutrient delivery, as well as skeletal muscle repair. As such, nutrient requirements for periods of increased activity often exceed that of the DRI. The provided amount of many micronutrients was above the RDA for men and women. However, no micronutrient is close to the tolerable upper limit; thus, not warrant health concerns. Additionally, the provided amount of select micronutrients fell below the RDA, including vitamins D, A, and E for men and women. The provided amount of magnesium, manganese, and vitamin K fell below the RDA/AI for men. WLFFs consumption is primarily dictated by the nutrients provided through the NMFS. Therefore, if the provided amount of any nutrient is below the DRI, WLFFs consumption may only meet the DRI if they supplement their diet with food items outside of the NMFS contract. These supplemental items may be provided by the crew boss, food unit leader, caterer, or by the WLFF themselves.

Vitamin D is critical for protein synthesis, skeletal muscle regulation, immune function, and the inflammatory response. Specifically, a prevalent clinical symptom of vitamin D deficiency is skeletal muscle weakness. Therefore, physically active individuals may require higher doses of vitamin D beyond the RDA. The RDA for vitamin D is 600 IU d⁻¹; however, it is suggested that doses of more than or equal to 1000 to 2000 IU d⁻¹ are necessary for physically active populations to support skeletal muscle synthesis. Familiar food sources of vitamin D include fish (herring, salmon, halibut, cod), tuna, and eggs. Most individuals obtain dietary vitamin D from fortified foods such as tofu, milk products, orange juice, cereal, and yogurt. However, the predominant source of vitamin D for most individuals is most commonly through sunlight exposure. Many factors impact cutaneous vitamin D production, including latitude, season, sunblock usage, and the amount of clothing covering the body. Therefore, WLFFs may not acquire the RDA for vitamin D through sunlight exposure because their skin is typically covered throughout the work shift due to extensive personal protective equipment for wildfire suppression. In the present study, the provided and consumed amount of vitamin D was 153 ± 68 and 261 ± 347 IU, respectively, for male WLFFs. The provided and consumed amount of vitamin D for women were 132 ± 63 and 111 ± 82 IU, respectively. Male WLFFs consumed a significantly greater amount of vitamin D compared with provided amounts, with consumption greater than provided at all meals, indicating WLFF consumed supplemental foods. Previous literature suggests vitamin D may increase performance, specifically muscular strength, due to an increase in the size and number of type II muscle fibers. A study by Alimoradi et al. showed significant increases in leg press and sprint tests in athletes supplemented with 50,000 IU wk⁻¹ vitamin D. Therefore, the NMFS should focus on increasing the amount of vitamin D rich food items for WLFFs to meet their vitamin D nutrient needs as well as consider providing a more significant amount of nutrient-dense food options to increase the food quality provided to WLFFs.

In the present study, the provided and consumed intake of sodium was well above the RDA for men (mg; 508.2%, 455%), and women (mg; 451.3%, 361%), whereas magnesium (mg; 95.5%, 88.2%) was below the RDA for men and above the RDA for women (mg; 132.5%, 138.5%). Sodium intakes above the RDA may be necessary for individuals participating in strenuous activity. However, excessive sodium intake may lead to hypertension and cardiovascular irregularities. Pre-packaged and non-perishable food items provided during wildfire suppression are large contributing factors to WLFFs high sodium intakes. Contract revisions and WLFF education may be necessary to ensure WLFFs are not consuming excessive sodium resulting in adverse health consequences. Furthermore, magnesium plays a critical role in regulating oxidative stress following strenuous exercise. Inadequate magnesium intake may exacerbate oxidative damage during wildfire suppression.

Due to increased physical stress and compromised sanitary conditions during wildfire suppression, WLFFs may be at an increased risk for developing infections. Therefore, adequate doses of select micronutrients such as vitamins A, D, C, E, B₆, B₁₂, folate, and zinc, are necessary for individuals participating in strenuous activity. However, excessive sodium intake may lead to hypertension and cardiovascular irregularities. Pre-packaged and non-perishable food items provided during wildfire suppression are large contributing factors to WLFFs high sodium intakes. Contract revisions and WLFF education may be necessary to ensure WLFFs are not consuming excessive sodium resulting in adverse health consequences. Furthermore, magnesium plays a critical role in regulating oxidative stress following strenuous exercise. Inadequate intake of vitamin E may result in impaired immunity through diminished B and T cell function as well as reductions in T cell maturation.

While following the current NMFS contract specifications can meet most micronutrient needs, there is room for improvement. Additional micronutrient specifications or examples of nutrient dense food items that meet the current contract guidelines has the potential to significantly improve micronutrient content of NMFS provisions. Consumption of micronutrients below or above the RDA poses educational opportunities for WLFFs to ensure they are meeting the recommendations for everyday health as well as occupational demands.

Limitations

The present study was among the first to observe WLFFs eating behavior in a free-living condition. However, researchers following WLFFs throughout the work shift may have contributed...
to alterations in nutritional practices while being observed. Additionally, participants in the study volunteered, therefore the sample is not random and may not fully represent the normal distribution of WLFs. Another important limitation to address is the possible influence of environmental conditions on dietary behavior which may impact the difference between provided and consumed macronutrients.

CONCLUSION

The primary finding in the current study was that while the NMFS provides adequate daily calories and macronutrients, the spacing of these nutrients throughout the day (breakfast, shift provisions, dinner) could be improved in order to best meet WLF needs. Furthermore, while daily provisions were adequate, WLF did not consume all that was provided, resulting in calorie consumption and macronutrient distribution that may be insufficient to meet the demands of strenuous muscular strength and endurance activity. The NMFS provides adequate (at or above the DRI) amounts of most micronutrients, while select essential micronutrients remain below the DRI for provided and consumed amounts. In instances in which the provided nutrient amounts do not meet the DRI indicate an opportunity for revisions to the NMFS contract to ensure caterers are providing adequate nutrients to WLFs. Micro-nutrient specifications should be included in the NMFS contract to ensure WLFs receive sufficient nutrition to meet DRIs for overall health. Discrepancies in provided versus consumed dietary intakes can largely be attributed to WLFs' consumption of supplemental food items, where consumed intake is greater than provided. Additional research is necessary to determine what supplemental food items are frequently consumed by WLFs, as well as the nutritional content of said items. Lastly, instances in which the adequate nutrients are provided but consumed intake does not meet the DRI are aware of the importance of nutrient intake during wildfire suppression.

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Nutrient Intake Wildland Firefighters

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