

# 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

The National Mobile Food Services (NMFS) contract consists of dietary specifications for the use of multiple Mobile Food

Service Units (MFSU) for deployment on wildfires. The NMFS aims to outline specifications for meals, shift provisions (sack lunches), hot and cold menu items, and supplemental items. Specifically, the MFSU must provide three meals per day (breakfast, shift provisions, and dinner) unless arrangements have been made with the Food Unit Leader for Meals Ready to Eat (MRE) or other substitutions.<sup>1</sup> Prior to 2020, a self-serve salad bar and breakfast bar could also be provided by the NMFS contract. Wildland firefighters (WLFFs) on a large fire incident rely on MFSUs to supply nutritional and appetizing meals to sustain their energy needs for arduous wildfire suppression and support overall health during fire season. Therefore, evaluations of the NMFS and additional insight into WLFF dietary requirements and behaviors can support improvements for future NMFS contacts.

Wildland firefighting is an arduous occupation in which a combination of muscular strength and endurance activities are sustained for long durations in strenuous conditions.<sup>2</sup> WLFFs face many physical demands including long workdays (12 to 16 hours) in hazardous environments, compromised sleeping conditions, and environmental conditions including heat and moderate to high altitude.<sup>3–6</sup> Various types of WLFF resources exist, including Type 1, Type 2, engine, and helitack crews. Interagency hotshot crews (IHCs) are an organized Type 1 team of approximately 20 individuals with stringent qualifications and experience for engaging in initial and extended wildfire management activities. Comparatively, Type 2 resources can still have a diverse range of capabilities and expertise but have fewer requirements for certification and may also consist of staffing less than 20 people, such as engine crews.<sup>7</sup> Though duties can vary by resource type, during wildfire suppression, typical duties include hiking with a load, conducting fireline operations to create breaks between burned and unburned areas, and working with aviation resources.<sup>8</sup> Additional stressors include the number of days a WLFF is on a fire assignment and the severity of the fire.<sup>9</sup> Each fire assignment poses unique challenges and exhibits specific stressors that depend on the fire location, size, and ambient conditions.<sup>6</sup> Therefore, WLFFs must make rapid nutrient intake adjustments in response to multiple variables (ambient temperature, altitude, activity) to meet the demands of the job for consecutive days of work (14 to 21 days).<sup>5</sup>

Nutrient intake requirements for physically demanding occupations, including WLFFs, exceed those of average healthy individuals.<sup>10,11</sup> Therefore, it is necessary to support the additional energy spent during extended bouts of muscular strength and endurance activities.<sup>12–15</sup> Previously reported 24-hour WLFF energy demands are  $229 \pm 56 \text{ kcal h}^{-1}$  ( $5496 \pm 1344 \text{ kcal d}^{-1}$ ).<sup>5,10</sup> Additionally, the average kilocalorie intake during the work shift has been quantified as  $2195 \pm 699 \text{ kcal d}^{-1}$ .<sup>16</sup> WLFF macronutrient recommendations include 6 to  $10 \text{ g kg}^{-1}$  body weight of carbohydrate (CHO), 1.2 to  $1.7 \text{ g kg}^{-1}$  body weight of protein, and 20% to 35% of total kilocalorie intake from fat.<sup>13,17–19</sup> Ruby et al<sup>10</sup> demonstrated nutrient intake among Type 1 crews is low in carbohydrates (CHO;  $53 \pm 9\%$ ) and high in fat intake ( $32 \pm 7\%$ ) during

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Clinical Significance: Findings from this study indicate necessary alterations to the NMFS catering contract to ensure WLFFs are provided adequate nutrients to support the energy demands of wildfire suppression. Additionally, WLFF nutrition education is imperative to ensure they are aware of the importance of proper nutrient intake.

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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.<sup>6</sup> 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.<sup>6,10,11,20,21</sup> WLFF nutrition sources while on a wildfire assignment include catered breakfast and dinner of suggested meal serving sizes and prepared shift provisions.<sup>6,10,21,22</sup> The typical shift provisions during wildfire suppression contains 1506 to 2008 kcals.<sup>6,21,22</sup> Furthermore, many WLFFs bring additional (supplemental) food items such as food bars, dried meats, or sports drinks to consume during the daily work shift.<sup>6,21,22</sup> 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.<sup>6,10,21–23</sup>

Vitamins and minerals are critical components of many metabolic processes within the human body.<sup>24</sup> Dietary references intakes (DRIs) refer to all vitamins and essential minerals required by the human body to support healthy function.<sup>25–27</sup> 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.<sup>24,28</sup> Electrolyte balance during wildfire suppression are critical to maintain work output and avoid health complications such as rhabdomyolysis, renal distress, hyponatremia, and heat exhaustion.<sup>6,29,30</sup> 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.

## MATERIALS AND METHODS

### 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.<sup>22</sup> 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  $\pm$  SD. Provided and consumed amounts for micronutrients are also 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).

## RESULTS

### Subjects

Subject ( $n = 122$ ) demographic information is reported in Table 1 (M:  $n = 102$ , F:  $n = 20$ ; BMI:  $24.9 \pm 3.3$  kg/m<sup>2</sup>). Six subjects included in the study were on a fire with a Type 3 caterer who

**TABLE 1.** Participants Demographic Characteristics

Demographic Information		N
Sex		
Male		102
Female		20
Crew type		
Type 1		45
Type 2		53
Engine & Helitack		24
		Mean ± SD
Age, yrs		27 ± 6
Height, m		1.8 ± 0.1
Weight, kg		79.8 ± 14.5
BMI, kg/m <sup>2</sup>		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.

provides meals in the same format as a national caterer but is not held to the NMFS contract. Various resource types were represented in the sample including Type 1 (n = 45), Type 2 (n = 53), Engine and Helitack (n = 24).

**Macronutrient Intake**

Macronutrient intake results are reported in Table 2. Provided macronutrient amounts were significantly greater than consumed for calories (kcal d<sup>-1</sup>; P < 0.0001), protein (g d<sup>-1</sup>; P < 0.0001), fiber (g d<sup>-1</sup>; P = 0.0001), fat (g d<sup>-1</sup>; P < 0.0001; kcal d<sup>-1</sup>;

P < 0.0001), Omega 3 (P = 0.031), and Omega 6 (P < 0.0001) for men. No significant differences were observed between provided and consumed CHO (g d<sup>-1</sup>; P = 0.142) for men. Provided macronutrient amounts were significantly greater than consumed for calories (kcal d<sup>-1</sup>; P < 0.0001), protein (g d<sup>-1</sup>; P < 0.0001), fat (g d<sup>-1</sup>; P = 0.001; kcal d<sup>-1</sup>; P = 0.001), Omega 3 (g d<sup>-1</sup>; P = 0.036), and Omega 6 (g d<sup>-1</sup>; P = 0.018) for females. No significant differences were observed between provided and consumed CHO (g d<sup>-1</sup>; P = 0.392) and fiber (g d<sup>-1</sup>; P = 0.382) for women.

**Male Micronutrient Intake**

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 (mcg; 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), phosphorous (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 (mcg; 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%), phosphorous (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 2.** Macronutrient Intake Outcomes

	Breakfast*		Shift Food		Dinner		Total†	
	Provided	Consumed‡	Provided	Consumed	Provided	Consumed	Provided	Consumed
Male macronutrient intake (n = 102)								
Calories, kcal	979 ± 308	901 ± 334	2282 ± 354	1717 ± 793	1097 ± 337	1344 ± 540	4296 ± 688	3889 ± 1162§
Protein, g	37 ± 8	33 ± 12	75 ± 18	56 ± 27	67 ± 26	69 ± 34	184 ± 42	163 ± 67§
Protein, g kg <sup>-1</sup>	NA	0.4 ± 0.2	NA	0.7 ± 0.4	NA	0.8 ± 0.4	NA	2 ± 1
Carbohydrate, g	84 ± 36	100 ± 53	271 ± 67	212 ± 110	103.5 ± 40.3	141 ± 68	451 ± 95	440 ± 163
Carbohydrate, g kg <sup>-1</sup>	NA	1 ± 0.7	NA	2 ± 1	NA	2 ± 1	NA	5 ± 2
Fiber, g	4 ± 2	6 ± 4	26 ± 6	18 ± 10	11.0 ± 4.0	11 ± 4	47 ± 42	45 ± 76§
Fat, g	54 ± 19	42 ± 19	105 ± 23	74 ± 39	46.1 ± 26.2	57 ± 33	205 ± 35	172 ± 56§
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 ± 8§
Female macronutrient intake (n = 20)								
Calories, kcal	913 ± 240	754 ± 420	2223 ± 294	1555 ± 567	1106 ± 443	1115 ± 442	4165 ± 814	3429 ± 836§
Protein, g	40 ± 7	26 ± 15	64 ± 14	44 ± 23	66 ± 28	51 ± 25	165 ± 39	122 ± 41§
Protein, g kg <sup>-1</sup>	NA	0.4 ± 0.2	NA	0.7 ± 0.4	NA	0.8 ± 0.4	NA	1.9 ± 0.6
Carbohydrates, g	72 ± 34	97 ± 60	284 ± 45	210 ± 73	126 ± 60	148 ± 78	479 ± 110	457 ± 114
Carbohydrates, g kg <sup>-1</sup>	NA	1.5 ± 0.8	NA	3.3 ± 1.2	NA	2 ± 1	NA	7.2 ± 1.6
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 ± 51§
Fat, kcal	461 ± 127	271 ± 202	870 ± 156	577 ± 293	344 ± 190	332 ± 196	1641 ± 364	1183 ± 462§
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 ± 0.8§
Omega 6, g	7 ± 2	4 ± 2	8 ± 6	5 ± 4	6 ± 4	5 ± 4	21 ± 8	15 ± 6§

g, grams; kcal, calories; kg, kilograms of body mass.

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

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

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

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

TABLE 3. Male Micronutrient Intake Outcomes (n=102)

	Breakfast*		Shift Food		Dinner		Total <sup>†</sup>		% RDA or AI <sup>§</sup>	
	Provided <sup>‡</sup>	Consumed	Provided	Consumed	Provided	Consumed	Provided	Consumed	Provided	Consumed
Micronutrient intake										
Vitamin D, IU	90 ± 32	107 ± 85	36 ± 43	70 ± 341	25 ± 48	88 ± 93	153 ± 68	261 ± 347 <sup>  </sup>	38	65
Zinc, mg	4 ± 1	3 ± 2	5 ± 2	5 ± 6	7 ± 5	7 ± 5	13 ± 8	12 ± 7	119	115
Calcium, mg	261 ± 115	378 ± 276	709 ± 321	580 ± 399	275 ± 134	524 ± 318	1218 ± 406	1436 ± 625	121	143
Iron, mg	6 ± 5	9 ± 16	15 ± 5	11 ± 8	8 ± 3	8 ± 3	30 ± 10	29 ± 20 <sup>  </sup>	383	368
Magnesium, mg	72 ± 7	93 ± 54	198 ± 104	135 ± 85	117 ± 51	134 ± 64	382 ± 123	352 ± 131	95	88
Potassium, mg	1042 ± 412	1095 ± 494	1816 ± 605	1370 ± 798	1215 ± 556	1442 ± 708	4005 ± 806	3803 ± 1284 <sup>  </sup>	117	111
Sodium, mg	2123 ± 1351	1715 ± 1325	3515 ± 1020	2793 ± 1425	2111 ± 852	2508 ± 1040	7623 ± 2278	6824 ± 2731 <sup>  </sup>	508	455
Copper, mg	0.3 ± 0.1	0.3 ± 0.2	0.9 ± 0.6	0.6 ± 0.6	0.5 ± 0.2	0.5 ± 0.3	2 ± 0.6	2 ± 1 <sup>  </sup>	188	166
Manganese, mg	0.8 ± 0.9	1 ± 1	2 ± 2	2 ± 2	1 ± 0.6	2 ± 5	8 ± 26	8 ± 29	2	2
Phosphorous, mg	602 ± 218	579 ± 275	700 ± 304	516 ± 326	640 ± 294	771 ± 401	1913 ± 495	1810 ± 688	273	258
Selenium, mcg	59 ± 18	46 ± 22	52 ± 25	42 ± 41	80 ± 43	76 ± 45	233 ± 301	207 ± 336 <sup>  </sup>	423	377
Choline, mg	276 ± 125	201 ± 135	183 ± 135	88 ± 79	147 ± 116	158 ± 117	560 ± 200	430 ± 199 <sup>  </sup>	<b>102</b>	<b>78</b>
Vitamin A (mcg RAE)	274 ± 133	275 ± 229	341 ± 346	262 ± 356	145 ± 141	362 ± 229	894 ± 1005	1036 ± 1167	99	115
Vitamin B1, mg	0.7 ± 0.3	0.8 ± 0.8	1 ± 0.6	1 ± 1	1 ± 0.6	1 ± 0.5	5 ± 28	9 ± 56	475	613
Vitamin B2, mg	1 ± 0.5	1 ± 0.6	0.9 ± 0.4	1 ± 1.5	1 ± 0.4	1 ± 0.6	3 ± 1	3 ± 2	207	230
Vitamin B3 (mg NE)	14 ± 5	12 ± 6	20 ± 10	17 ± 16	26 ± 16	25 ± 18	60 ± 19	54 ± 21 <sup>  </sup>	375	340
Vitamin B6, mg	0.8 ± 0.5	0.7 ± 0.5	1 ± 0.4	2 ± 4	1 ± 0.7	1 ± 1	3 ± 3	4 ± 5	253	330
Vitamin B12, mcg	2 ± 1	2 ± 1.5	1 ± 1	6 ± 18	2 ± 2	2 ± 2	5 ± 2	10 ± 18 <sup>  </sup>	225	441
Vitamin C, mg	16 ± 18	27 ± 31	87 ± 79	159 ± 333	37 ± 26	43 ± 33	135 ± 88	224 ± 341	150	249
Vitamin E-a-Toco, mg	2 ± 1	2 ± 2	6 ± 3	5 ± 10	2 ± 1	2 ± 2	10 ± 4	10 ± 11 <sup>  </sup>	70	71
Folate (mcg DFE)	137 ± 66	136 ± 135	196 ± 113	150 ± 224	169 ± 112	170 ± 113	473 ± 198	446 ± 336 <sup>  </sup>	118	111
Vitamin K, mcg	17 ± 15	15 ± 14	32 ± 28	32 ± 64	49 ± 44	78 ± 95	101 ± 66	126 ± 122	<b>84</b>	<b>105</b>
Panthenic acid, mg	3 ± 1	3 ± 1	3 ± 1	3 ± 4	2 ± 1	3 ± 2	10 ± 15	10 ± 17	<b>196</b>	<b>208</b>

% 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.

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

<sup>†</sup>Provided = food items given to or available for WLFFs for all meals. Consumed = food eaten by WLFFs.

<sup>‡</sup>Paired *t* tests were used to determine differences in provided versus consumed nutrient intakes.

<sup>§</sup>AI bolded.

<sup>||</sup>*P* < 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 (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%, 346%), 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.<sup>13,17-19</sup> 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).

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

	Breakfast <sup>†</sup>		Shift Food		Dinner		Total <sup>‡</sup>		% RDA or AI <sup>§</sup>	
	Provided <sup>†</sup>	Consumed	Provided	Consumed	Provided	Consumed	Provided	Consumed	Provided	Consumed
Micronutrient intake										
Vitamin D, IU	93 ± 33	81 ± 70	11 ± 18	7 ± 16	25 ± 52	22 ± 36	132 ± 63	111 ± 82	33	28
Zinc, mg	4 ± 1	3 ± 1	6 ± 7	4 ± 3	6 ± 3	4 ± 2	16 ± 7	12 ± 4 <sup>  </sup>	206	155
Calcium, mg	221 ± 68	259 ± 197	651 ± 278	438 ± 272	264 ± 178	370 ± 238	1104 ± 357	1068 ± 495	110	106
Iron, mg	6 ± 2	10 ± 17	13 ± 6	9 ± 4	7 ± 3	6 ± 3	27 ± 7	26 ± 18	153	149
Magnesium, mg	76 ± 32	95 ± 50	208 ± 75	204 ± 171	135 ± 62	128 ± 65	410 ± 107	429 ± 190	132	138
Potassium, mg	1034 ± 489	986 ± 501	1705 ± 487	1599 ± 801	1340 ± 607	1238 ± 621	4054 ± 750	3839 ± 1049	119	113
Sodium, mg	2183 ± 1512	1527 ± 1513	2836 ± 760	1970 ± 711	2038 ± 940	1927 ± 825	6770 ± 2512	5427 ± 2027 <sup>  </sup>	451	362
Copper, mg	0.3 ± 0.2	0.4 ± 0.2	1 ± 0.4	1 ± 0.5	0.5 ± 0.3	0.5 ± 0.3	2 ± 0.6	2 ± 0.6	200	188
Manganese, mg	1 ± 0.6	2 ± 1	2 ± 1	2 ± 4	1 ± 1	1 ± 1	4 ± 2	5 ± 4	255	311
Phosphorous, mg	597 ± 128	468 ± 254	642 ± 149	496 ± 313	697 ± 371	558 ± 357	1855 ± 503	1526 ± 586 <sup>  </sup>	265	218
Selenium, mcg	61 ± 16	39 ± 20	41 ± 21	34 ± 30	91 ± 43	61 ± 42	185 ± 61	133 ± 60 <sup>  </sup>	337	242
Choline, mg	319 ± 96	267 ± 152	83 ± 53	69 ± 48	136 ± 108	99 ± 71	521 ± 158	376 ± 126 <sup>  </sup>	<b>122</b>	<b>88</b>
Vitamin A (mcg RAE)	273 ± 103	222 ± 142	248 ± 232	244 ± 385	155 ± 121	256 ± 203	680 ± 287	723 ± 470	97	103
Vitamin B1, mg	1 ± 0.2	0.7 ± 1	1 ± 0.4	1 ± 0.5	1 ± 1	1 ± 0.6	2 ± 1	2 ± 1 <sup>  </sup>	236	200
Vitamin B2, mg	1 ± 0.2	1 ± 0.5	1 ± 0.3	1 ± 1	1 ± 0.6	1 ± 0.6	2 ± 1	2 ± 1 <sup>  </sup>	236	209
Vitamin B3 (mg NE)	13 ± 3	9 ± 5	18 ± 5	15 ± 10	27 ± 17	19 ± 14	56 ± 18	44 ± 17 <sup>  </sup>	400	319
Vitamin B6, mg	1 ± 0.4	1 ± 0.4	2 ± 7	3 ± 6	1 ± 0.6	1 ± 0.5	4 ± 7	4 ± 6	307	346
Vitamin B12, mcg	2 ± 1	1 ± 1	4 ± 18	7 ± 19	1 ± 1	1 ± 1	8 ± 17	9 ± 19	345	391
Vitamin C, mg	16 ± 12	19 ± 17	270 ± 733	347 ± 760	35 ± 26	48 ± 37	316 ± 714	415 ± 771	421	554
Vitamin E-a-Toco, mg	2 ± 1	2 ± 2	7 ± 3	5 ± 6	2 ± 2	2 ± 2	12 ± 5	10 ± 6	80	68
Folate (mcg DFE)	130 ± 53	141 ± 126	200 ± 107	164 ± 110	228 ± 167	216 ± 168	554 ± 187	522 ± 249	138	130
Vitamin K, mcg	18 ± 16	16 ± 12	32 ± 41	36 ± 45	59 ± 57	87 ± 100	106 ± 62	139 ± 111	<b>118</b>	<b>154</b>
Panothenic acid, mg	2 ± 0.4	2 ± 1	3 ± 2	2 ± 2	3 ± 2	2 ± 1	7 ± 2	7 ± 3	<b>156</b>	<b>140</b>

% 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.

<sup>†</sup>Breakfast and dinner = first and last meals consumed at fire camp, respectively. Shift food = food items consumed during wildfire suppression, not at fire camp.

<sup>‡</sup>Provided = food items given to or available for WLFFs for all meals. Consumed = food eaten by WLFFs.

<sup>§</sup>Paired *t* tests were used to determine differences in provided versus consumed nutrient intakes.

<sup>||</sup>AI bolded.

<sup>||</sup>*P* < 0.05, total consumed significantly different from provided.

Caloric and macronutrient requirements during wildfire suppression have been repeatedly observed in WLFFs. Ruby et al<sup>10</sup> previously reported total energy expenditure during wildfire suppression as a wide range of 4878 ± 716 and 3541 ± 718 kcal d<sup>-1</sup> for males and females, respectively, using doubly labeled water. Additionally, Cuddy et al<sup>31</sup> further demonstrated arduous wildfire suppression's physical demands as a total energy expenditure of 4556 ± 943 kcal d<sup>-1</sup>. In the current study, WLFFs consumed an average of 3889 ± 1162 and 3429 ± 836 kcal d<sup>-1</sup> for men and women, respectively. Compared with Cuddy (2015)<sup>31</sup>, 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<sup>-1</sup> for men and 4165 ± 814 kcal d<sup>-1</sup> for women. Therefore, if WLFFs consumed all provided food items, their energy intake would result in an additional 1000 kcal d<sup>-1</sup>, bringing intake closer to the total energy expenditure previously identified during a representative workday.<sup>9,30</sup> 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.<sup>32</sup> A high CHO diet, containing 6 to 10 g kg<sup>-1</sup>, is promoted to optimize work output for individuals engaging in intense training or physically demanding work, such as WLFFs.<sup>18,19,33</sup> In the current study, CHO intake has been quantified as 5 and 7.2 g kg<sup>-1</sup> d<sup>-1</sup> for men and women, respectively. Compared with the 6 to 10 g kg<sup>-1</sup> reported in the previous studies as well as results from Ruby et al<sup>10</sup> of 6.9 g kg<sup>-1</sup> d<sup>-1</sup>, men may be consuming inadequate CHO (5 g kg<sup>-1</sup> d<sup>-1</sup>), whereas women may be consuming minimal CHO (7.2 g kg<sup>-1</sup>) to maintain glycogen stores for 12 to 16 hours of wildfire suppression for 5 days.<sup>10</sup> 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<sup>-1</sup>) for the average healthy population to avoid adverse health effects. Protein consumption at or below the RDA may lead to a negative nitrogen protein balance and reduced skeletal muscle protein synthesis.<sup>15,34</sup>

Occupational athletes, including WLFFs, who are regularly involved in endurance or resistance training, require additional protein in the diet.<sup>35</sup> However, optimal protein intake for specific WLFF performance remains unknown. In the present study, protein consumption was  $2.0 \pm 1.0$  and  $1.9 \pm 0.6 \text{ g kg}^{-1} \text{ d}^{-1}$  for men and women, respectively. Therefore, the protein consumed in this study falls within the optimal level for exercising populations.<sup>36</sup> Additionally, both male and female WLFFs consumed significantly less protein compared with what was provided ( $163 \pm 67 \text{ g d}^{-1}$  vs  $184 \pm 42 \text{ g d}^{-1}$  and  $122 \pm 41 \text{ g d}^{-1}$  vs  $165 \pm 39 \text{ g d}^{-1}$ , 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.<sup>10</sup> 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).<sup>37</sup> 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 ( $172 \pm 56 \text{ g d}^{-1}$  vs  $205 \pm 35 \text{ g d}^{-1}$  and  $131 \pm 51 \text{ g d}^{-1}$  vs  $182 \pm 40 \text{ g d}^{-1}$ , 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.<sup>38</sup> 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 and does 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.<sup>39–42</sup> 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  $600 \text{ IU d}^{-1}$ ; however, it is suggested that doses of more than or equal to  $1000$  to  $2000 \text{ IU d}^{-1}$  are necessary for physically active populations to support skeletal muscle synthesis.<sup>43</sup> 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.<sup>44</sup> 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.<sup>44,45</sup> 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 were  $153 \pm 68$  and  $261 \pm 347 \text{ IU}$ , respectively, for male WLFFs. The provided and consumed amount of vitamin D for women were  $132 \pm 63$  and  $111 \pm 82 \text{ IU}$ , 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.<sup>46</sup> A study by Alimoradi et al<sup>47</sup> showed significant increases in leg press and sprint tests in athletes supplemented with  $50,000 \text{ IU wk}^{-1}$  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.<sup>48,49</sup> 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.<sup>50</sup> 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, zinc, copper, and selenium are necessary for immune system support.<sup>58</sup> In the present study, the provided and consumed intake of vitamin E was below the RDA for males (mg; 70%, 71%) and females (mg; 80%, 68.7%), respectively. Vitamin E is a critical fat-soluble vitamin that protects against free radicals and supports antioxidant defense, specifically when exposed to pollutants and toxins.<sup>51,52</sup> 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.<sup>53</sup>

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.<sup>22</sup> 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 WLFFs. Another important limitation to address is the possible influence of environmental conditions on dietary behavior which may impact the difference between provided and consumed macro- and micronutrients.

## 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 WLFF needs. Furthermore, while daily provisions were adequate, WLFF 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. 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 WLFFs. Micro-nutrient specifications should be included in the NMFS contract to ensure WLFFs receive sufficient nutrition to meet DRIs for overall health. Discrepancies in provided versus consumed dietary intakes can largely be attributed to WLFFs' 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 WLFFs, 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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