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Energy Intake, Weight, and Body Composition of Canadian Soldiers Participating in an Arctic Training[1]

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Introduction

The Canadian Armed Forces (CAF) are responsible for protecting and defending our country as well as supporting international military and humanitarian operations. Military members are expected to maintain a good health and fitness status in order to carry out missions and meet physical demands.[2] It has been reported that a suboptimal

[1] Acknowledgements: The authors wish to thank the soldiers who participated in this study, the Canadian Armed Forces Strat J4 Foodservices for their support and contribution with data collection, especially LCdr Lynda Hinch, RD, as well as research assistants, especially Mylène Rosa, RD, MA(Ed).

[2] W.J. Tharion, H.R. Lieberman, S. J. Montain, et al, "Energy Requirements of Military Personnel," *Appetite* 44, 1 (2005): pp. 47-65. doi:10.1016/j.appet.2003.11.010.

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health and fitness status can impede soldier performance.[3] Keeping in mind military personnel generally have higher energy needs during training and deployments than the general population, meeting energy requirements is crucial for optimal performance.[4] These energy requirements are influenced by the environment in which military members work. From a physiological standpoint, extreme climates are more demanding.[5] In fact, in cold environments, the energy requirements are elevated due to heavy clothing and equipment, difficulty to move around and travel on snow-covered terrain, and additional energy spent to maintain body temperature.[6]

Indeed, the CAF is present across Canada, including the Arctic. Their responsibilities in northern Canada revolve around defending sovereignty and ensuring the security of the region.[7] Thus, military training takes place every year in the Arctic to familiarize soldiers and train them adequately to conduct cold-weather operations.[7]

However, working in extreme environments comes with its set of challenges, and they differ from other, more temperate, regions. In the High-Arctic (above the Arctic Circle, 66.5° north latitude), where the mean winter temperature is below -30°C,

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[3] B.M. Marriott, S.J. Carlson, eds., *Nutritional Needs in Cold and in High-Altitude Environments : Applications for Military Personnel in Field Operations*, Committee on Military Nutrition Research, Institute of Medicine (Washington, D.C. : National Academy Press, 1996); J.S.A. Edwards, W.E. Askew, N. King, "Rations in Cold Arctic Environments : Recent American Military Experiences," *Wilderness & Environmental Medicine* 6, 4 (1995): pp. 407-422. doi: 10.1580/1080-6032(1995)006[0407:RICAER]2.3.CO;2; S.J. Montain, A.J. Young, "Diet and Physical Performance," *Appetite* 40, 3 (2003): pp. 255-267. doi:10.1016/S0195-6663(03)00011-4.

[4] Tharion, et al., "Energy Requirements;" B.M. Marriott, ed., *Not Eating Enough: Overcoming Under-consumption of Military Operational Rations*, Committee on Military Nutrition Research, Institute of Medicine (Washington, D.C.: National Academy Press, 1995), https://www.ncbi.nlm.nih.gov/pubmed/25121269. Accessed 11 July 2019.

[5] L.M. Margolis, N.E. Murphy, S. Martini et al., "Effects of Winter Military Training on Energy Balance, Whole-Body Protein Balance, Muscle Damage, Soreness, and Physical Performance," *Applied Physiology, Nutrition and Metabolism* 39, 12 (2014): pp. 1395-1401. doi:10.1139/apnm-2014-0212.

[6] Tharion et al., "Energy Requirements."

[7] A. Lajeunesse, *The Canadian Armed Forces in the Arctic: Purpose, Capabilities and Requirements* (Calgary: The Canadian Defence and Foreign Affairs Institute, 1995), http://www.deslibris.ca/ID/247838. Accessed 11 July 2019; L. Goodman, W. Sullivan-Kwantes, A-R. Blais, *Observations and Survey Results of Army Field Feeding in the Arctic: Arctic Field Feeding logistics and Effectiveness* (Toronto: Defence Research and Development Canada, 2015, https://www.researchgate.net/publication/318276583_Observations_and_Survey_Results_of_Army_Field_Feeding_in_the_Arctic_Arctic_Field_Feeding_Logistics_and_Effectiveness. Accessed 30 June 2019.

travelling, communication, and the overall equipment require special attention.[8] Additional precautions for all activities need to be taken in these extreme conditions in order to minimize the risk of incidents and injury.[9]

As for feeding in the military, three combat rations (Individual Meal Pack; IMP) are provided by the CAF to soldiers each day when fresh feeding is not feasible. These meals are pre-packed and ready-to-use, each providing an average of 1600 kcal, for a daily total of at least 4800 kcal.[10] Each IMP mainly contains the following: main entrée, fruit or dessert, coffee, sports drink, meal replacement drink, bread, condiments, and a chocolate bar. Meals are designed to provide about 50 percent of the calories from carbohydrates, 15 percent from proteins, and a maximum of 35 percent coming from fats.[11] Occasionally, the CAF also gives additional daily snacks (including jerky, energy bar, fruit bar, nut mix, coffee, meal replacement drink), called Light Meal Combat rations (LMC, 1000 kcal). Soldiers are therefore offered a daily total of approximately 5800 kcal in rations, meals, and snacks combined. However, underconsumption of combat rations is very common in the military population, for various reasons including lack of time to eat, limited variety of meals, personal food preferences, operational anorexia, and logistics.[12] Consequently, soldiers may not meet their energy needs.[13] Over a prolonged period of time, this can lead to weight loss and an increased

[8] "Daily Data Report for January 2019," *Environment and Climate Change Canada*, http://climate.weather.gc.ca/climate_data/daily_data_e.html?StationID=53060&timeframe=2&StartYear=1840&EndYear=2019&Day=10&Year=2019&Month=1#. Published 11 June 2019. Accessed 13 July 2019; P.W. Lackenbauer, A. Lajeunesse, "The Canadian Armed Forces in the Arctic: Building Appropriate Capabilities," *Journal of Military and Strategic Studies* 16, 4 (2016): p. 60.

[9] W. Sullivan-Kwantes, J. Fung, *Health Protection Factors During Arctic Operations: Key Findings to Date* (Toronto: Defence Research and Development, 2018), p. 18.

[10] L. Mandic, I. Jacobs, *Field-Feeding for CF Land Military Operations: Basis of Guidelines for Standard and Incremental Allowances for Food Service Providers* (Toronto: Defence Research and Development Canada, 2013), p. 89.

[11] Ibid.

[12] Marriott, *Not Eating Enough*; *Nutrition Science and Food Standards for Military Operations* (NATO Research and Technology, 2010), https://apps.dtic.mil/dtic/tr/fulltext/u2/a526318.pdf. Accessed 11 July 2019; F.V. Lavergne, D. Prud'homme, I. Giroux, "Soldiers' Perception of Combat Ration Use During Arctic Training: A Qualitative Study," *Military Medicine* 186, 1-2 (January-February 2021): pp. 127–136, Published online 2 November 2020. doi:10.1093/milmed/usaa254.

[13] Goodman, et al., *Observations and Survey Results*; L.M. Margolis, N.E. Murphy, S. Martini, et al., "Effects of Supplemental Energy on Protein Balance during 4-d Arctic Military Training," *Medicine and Science in Sports and Exercise* 48, 8 (2016): pp. 1604-1612. doi:10.1249/MSS.0000000000000944.

risk of physical and cognitive performance decrements.[14] Few Canadian studies have examined combat ration consumption and energy needs of soldiers in the past decade, even less so in the Arctic. In addition, studies in cold environments – typically defined as <0°C – likely do not capture the complexity of the Arctic environment with its extremely low temperatures. Thus, documenting the energy intake and tracking physical changes, such as body weight and composition, of soldiers during training in the Arctic are key to formulating appropriate nutritional recommendations for this population.

The aim of this study was to assess the energy intake and energy requirements of CAF soldiers consuming combat rations during an 8-week military training in the Arctic and to document the impacts on weight and body composition.

Materials and methods

Study participants and setting

With permission from the CAF, we recruited military members participating in an 8-week Arctic Operations Advisor (AOA) training course between January and March 2019. Using G*Power software (version 3.1.9.4: Faul, Erdfelder, Buchner & Lang, 2019), a power analysis was performed for sample size estimation on the main outcome of energy intake, based on data from Margolis et al.[15] (n=21), comparing energy intake to expenditure during a military winter training for which they reported a significant difference. Based on this study, the effect size was calculated at 0.73, considered to be *large*. Power analysis revealed a sample size of 27 is required (power = 0.95, alpha = 0.05) to detect a difference between two independent means. We, therefore, aimed to recruit between 21-27 participants. The 2019 AOA training cohort had 24 attendees, all initially enrolled in this study.

All trainees and training instructors were eligible to participate; the inclusion criteria was to participate in the AOA training. There were no exclusion criteria. This training aimed to equip individuals with the necessary knowledge and training to

[14] P.C. Henning, B-S. Park, J-S. Kim, "Physiological Decrements during Sustained Military Operational Stress," *Military Medicine* 176, 9 (2011): pp 991-997. doi:10.7205/MILMED-D-11-00053.
[15] Margolis et al., "Effects of Winter Military Training."

advise their commander about the organization, planning, and coordination of operations in cold-weather environments. The AOA training started in Yellowknife (Northwest Territories) for three weeks of introductory activities, and preparation for the remainder of the training (Figure 1).

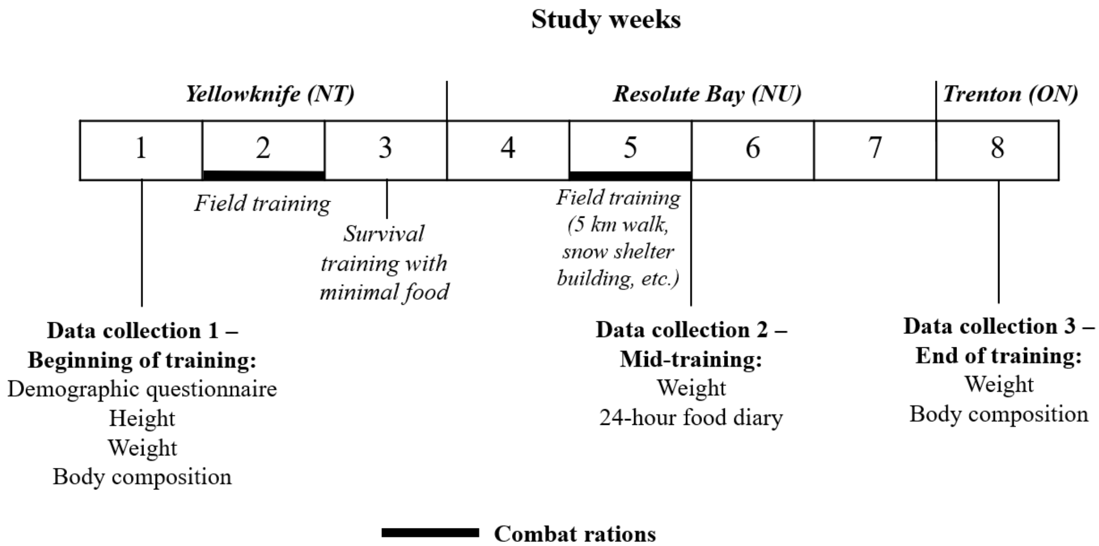

Figure 1. Study design for the 8-week military Arctic training. NT, Northwest Territories; NU, Nunavut; ON, Ontario.

The following four weeks were in the High-Arctic, mainly at the CAF Arctic Training Centre in Resolute Bay (Nunavut), as well as smaller surrounding communities (low -39°C to high -22°C, without windchill). The training provided familiarization with the Arctic environment and conditions through teaching on the use of communication technology, acquaintance with equipment and clothing, mobility skills, and field training including survival without a tent. The final few days of the AOA training were in Trenton (Ontario). This study did not alter the AOA programming as it was an observational study of participants in their natural setting, without intervention or modification to their scheduled activities and feeding plan.

During the training, the group of participants either consumed combat rations (three IMPs and one LMC per day) or ad libitum meals at the military dining facility or some locally purchased food. The training started in Yellowknife and included one week of field training with combat rations (week 2), then survival with minimal food for 3 days (week 3). Another similar week-long field training happened near Resolute Bay where participants relied on combat rations as an energy source (week 5).

Daily activities scheduled during week 5 included a 5 km walk to the training site and back, wearing Arctic-appropriate clothing and equipment (~13 kg), carrying rucksacks (~35 kg), and pulling heavy toboggans (~100 kg). On-site activities included building various snow shelters (i.e. igloos, snow caves) during 6-8 hours/day in which they slept. Soldiers had to cut, carry and place large ice blocks (1-2 m across by 0.3m thick) to build some shelters.

Anthropometrics and body composition

Data were collected at three different points of the training: at the beginning (during week 1), mid-training (end of week 5), and the end (during week 8). Two research dietitians travelled to Yellowknife for the start of the training to recruit study participants. Participants completed a short questionnaire collecting demographic information. Height was measured in duplicates to the nearest 0.1 cm using a stadiometer (PortStad), and body weight (clothed, no shoes) was measured to the nearest 0.1 kg with a calibrated scale (Platform Digital Scale Camry EB7009). Weight was measured in the same fashion at all measurement intervals. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Weight was measured at the beginning, middle, and end of the training by dietitians and/or a trained CAF researcher. Hydration status (i.e. total body water) and body composition (i.e. fat mass (FM) and fat-free mass (FFM)) were measured using hand-to-foot bioelectrical impedance analysis (Tanita BC-418). FM and FFM were measured at the beginning and end of the training for different body compartments (left and right arms, left and right legs, and torso), and for the total body. The "athlete" setting on the body composition analyzer was selected for body composition measurements, corresponding to individuals who do at least 10 hours/week of intense physical activity or individuals who have been fit for years but currently exercise less than 10 hours/week.[16]

[16] *Body Composition Analyzer BC-418: Instruction Manual* (Tanita Corporation: 2018). Accessed 9 July 2019.

After completion of the military training, participants who completed the study received a copy of their individual measurements and a nutrition education booklet developed by the CAF Strategic J4 Food Services (nutritional services office within the CAF).

Energy intake

Energy intake was estimated using a 24-hour food diary, completed at the end of week 5 of the training, for one typical day of intake. Bilingual food diary forms were created, adapted from others made by the CAF Strat J4 Food Services, or used in a previous study.[17] Food diaries had a designated section for each IMP meal and LMC. A list of combat ration components per meal (e.g. main entrée, bread, dessert, condiments) was given in each section to facilitate data entry for participants by limiting risks of participants' forgetting items. Furthermore, participants were instructed to write specific items eaten next to the pre-established categories. They were also asked to add any items they consumed that were not listed (i.e. food brought from home). Next to each item, participants wrote the percentage that represented the amount consumed. Food diaries were completed in Resolute Bay then verified by a dietitian along with participants during a post-training interview. Minor adjustments were made when necessary, to accurately reflect intake (ex: specify amount eaten if participants omitted this information, specify the type of snacks brought from home, add drinks and beverages if not already included).

Once verified, the dietitians analyzed the 24-hour food diaries using the nutritional information for Canadian combat rations provided by the CAF Strat J4 Food Services and based on manufacturers' nutritional analyses, to obtain each participant's estimated energy intake.

[17] Kullen C.J. Carins, *Field Acceptability and Consumption of CRIM and Potential New Food Items during the Hot Weather Ration Trial* (Australia: Defence Science and Technology Organisation, Australian Government, 2011), p. 29.

Energy requirements

Despite the paucity of use in the literature, total daily energy requirements were estimated using a predictive equation recently developed by Barringer et al.[18] specifically for military personnel which states that daily energy requirements (kcal) is equal to "[61.99 × FFM (kg)] + [716.49 × PAF] – 721.30". FFM at baseline was used, with a physical activity factor (PAF) of 2.41 (lower end of the "moderate-high" category) after comparing the reported daily activity schedule of the training to physical activity levels described in the Barringer et al. study.[19]

Statistical analysis

Paired *t*-tests were used to determine differences in weight and body composition (beginning vs. end of training). Repeated measures ANOVA and Sidak posthoc test were used to measure changes over time in weight (beginning vs middle vs end of training). Statistical significance was reached at $p<0.05$, and data are presented as means ± standard deviation (SD) and ranges. Data were compiled, verified, and analyzed in Microsoft Excel (Office 2010, Microsoft inc., Redmond, Washington) and IBM SPSS Statistics (version 25.0. IBM Corp., Armonk, NY, USA).

Ethics approval

This study was approved by the CAF and the Research Ethics Board of the University of Ottawa. Informed written consent was obtained from all participants.

[18] N.D. Barranger, S.M. Pasiakos, H.L. McClung, A.P. Crombie, L.M. Margolis, "Prediction Equation for Estimating Total Daily Energy Requirements of Special Operations Personnel," *Journal of the International Society of Sports Nutrition* 15, 1 (2018). doi:10.1186/s12970-018-0219-x.
[19] Ibid.

Results

Study participants

Twenty-four participants initially started the study. Ten dropped out due to staying in Resolute Bay after the training or not completing the training. Fourteen CAF military members based out of 6 provinces completed all parts of the study (males; 31.3 ± 5.5 years, range: 24-43). Although instructors were eligible, only training attendees participated. On average, participants had 10.5 ± 2.8 (range: 7-16) years of experience in the CAF. Half of the participants had previous experience in the Arctic, having gone one to three times. No differences were noted between both subgroups. All participants had previously used combat rations and were thus familiar with preparing and consuming them.

Anthropometrics and body composition

The average height of participants was 175.5 ± 6.9 cm. At the beginning of the training, the average weight was 96.4 ± 22.4 (range: 70.2-130.7) kg and their BMI was 30.8 ± 6.8 kg/m^2. The mid-point weight measurement in Resolute Bay was 93.2 ± 19.6 (range: 68.4-122.8) kg, resulting in an average decrease of 3.2 ± 3.3 kg, or 2.8 percent (range: weight gain of 2.0 percent to weight loss of 7.7 percent) for all participants (p=0.003). Figure 2 shows the individual weight changes throughout the training. Twelve participants lost weight: 3.9 ± 3.0 (range: 0.6-9.5) kg, p=0.001, equivalent to 3.5 (range: 0.8-7.7) percent. Participants with the heaviest body weight lost the most weight. Two participants gained weight (0.3 and 1.8 kg). At the end of the training, in Trenton, the average weight of participants was 95.8 ± 19.7 (range: 69.1-125.0) kg. This weight was significantly different from the mid-point weight (p<0.001), resulting in a weight gain for all participants after they returned to fresh feeding (2.6 ± 1.4; range: 0.3-4.9 kg). However, when comparing weights at the beginning and end of the training, no change was observed (p=0.61).

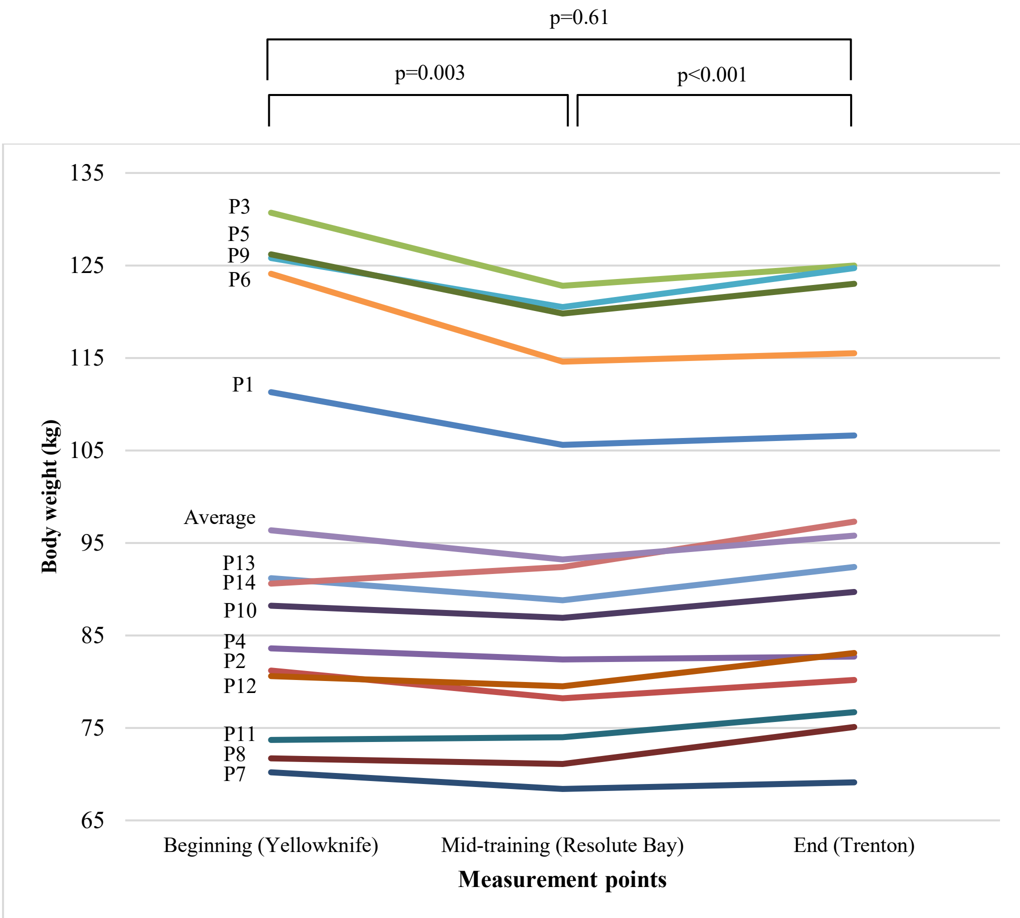

Figure 2. Changes in body weight of Canadian Armed Forces soldiers at different time points during the Arctic training (n=14), *participants = P*

Hydration status was measured at the beginning and end of the training, with an average total body water of 58 percent at both time points.

No significant difference was found for FM and FFM between the beginning and end of the training for total body and each body compartment (Table 1). Interestingly, the five participants with the highest total body fat mass were also the ones with the highest total body fat-free mass.

Table 1. Total and compartment fat mass and fat-free mass of Canadian Armed Forces soldiers at the beginning and end of the Arctic training (n=14)

	FM (kg)		FFM (kg)	
	Beginning	End	Beginning	End
Limbs	2.2 ± 1.9	2.1 ± 1.7	9.0 ± 4.6	9.0 ± 4.5
Trunk	12.4 ± 6.7	11.8 ± 6.3	37.9 ± 4.3	38.3 ± 4.1
Total body	21.2 ± 11.7	20.3 ± 10.8	73.8 ± 11.0	74.3 ± 9.8

Data are presented as mean ± SD; FM = Fat mass; FFM = Fat-free mass.
Measurements for limbs include right and left arms and legs.
*Statistically different from beginning values ($p < 0.05$)

Energy Intake

On average, CAF members consumed 2799 ± 835 kcal/day, ranging from 1866 to 4890 kcal/d (Figure 3).

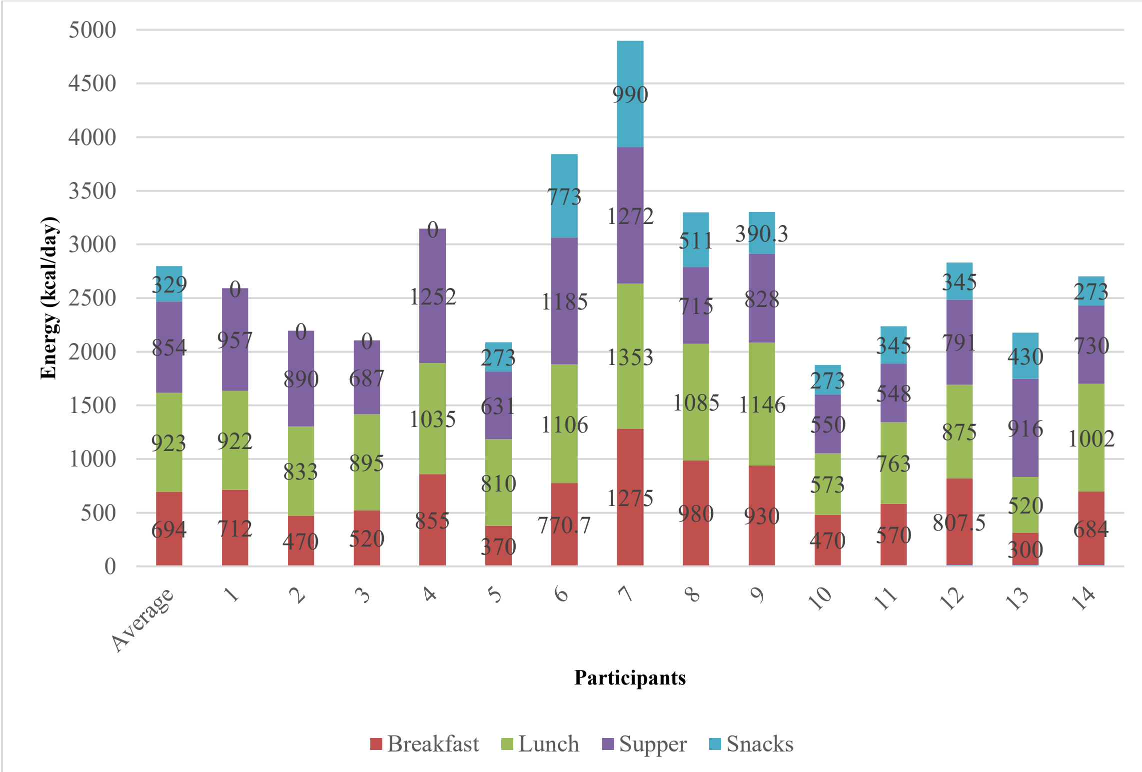

Figure 3. Distribution of estimated energy intake (from one 24-hour food diary) within meals of each Canadian Armed Forces soldier during the Arctic training, as well as the average of all participants (n=14)

Energy intake was distributed throughout the day: 25 ± 5 percent at breakfast, 33 ± 5 percent at lunch, 30 ± 6 percent at supper, and 12 ± 8 percent from snacks. The snacks were foods eaten outside of mealtimes, thus including LMCs and other items brought from home. Most CAF members (n=10) consumed LMCs. Five participants brought food with them from home, increasing their intake by 8 to 530 kcal/day.

Results from this study show that only the main entrée was consumed by every CAF member of the group at all meals. From the other categories available, the chocolate bars were the most frequently consumed, with 93 percent of participants eating this item at lunch and 86 percent eating one at supper. The chocolate bar was not available in the breakfast menu IMPs. The next most frequently consumed item was sports drinks, with 71 percent, 64 percent, and 43 percent of participants consuming it at breakfast, lunch, and supper, respectively. As for snacks, fruit bars were the most popular item from the LMCs, with 71 percent of participants eating it, followed by beef jerky (43 percent) and coffee (36 percent).

Energy requirements

Total daily energy requirements were estimated at 5577 ± 681 (range: 4557-6671) kcal/day, thus resulting in an average energy deficit of 2778 kcal/day (range: energy surplus of 333 to energy deficit of 4408 kcal/day), representing 49.8 ± 19.2 (range: -7 - 68) percent. The participant with the lowest estimated energy requirements was the only individual whose intake exceeded his requirements (participant 7, Figure 4). There was a tendency for a positive correlation between energy deficit and weight loss (R^2=0.264, p=0.06).

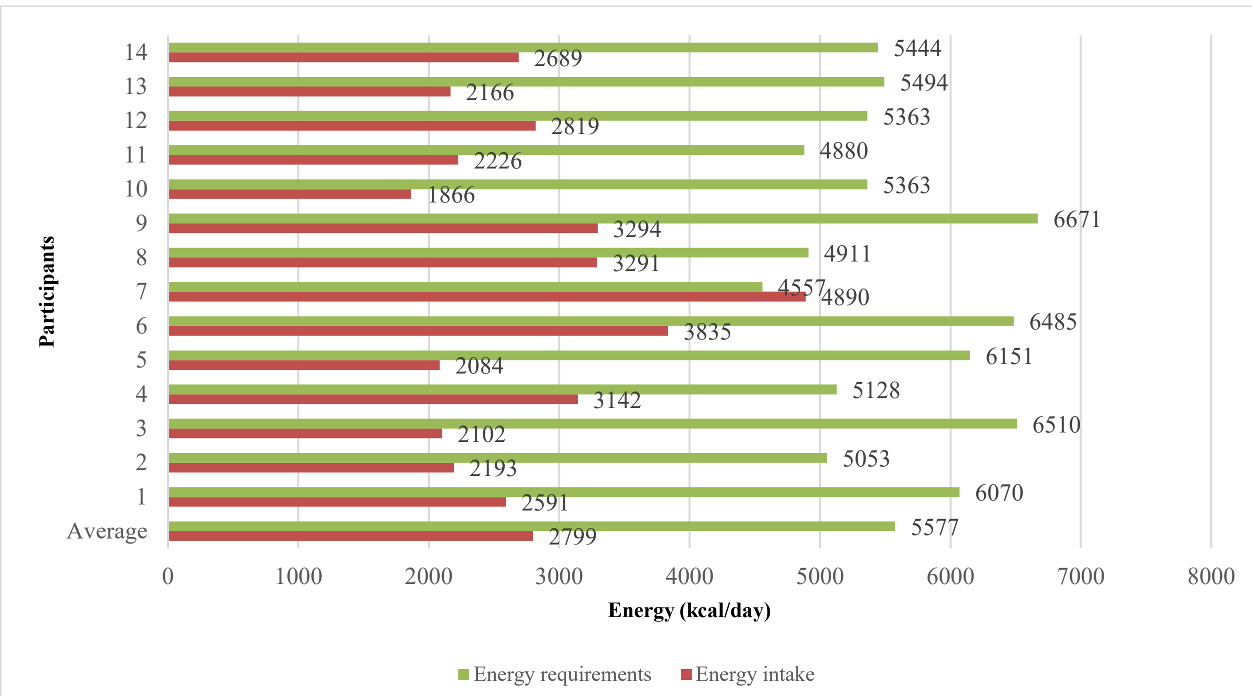

Figure 4. Estimated energy intake in comparison to estimated daily energy requirements of Canadian Armed Forces soldiers during the Arctic training (n=14)

Discussion

An important finding of this longitudinal observational study is a significant weight loss of 2.8 percent for all participants including 3.5 percent observed in 86 percent (n=12) of participants at mid-training, right after participants consumed combat rations during a week of field training (week 5) where they worked continuously for several hours per day in very cold temperatures, and after survival training (week 3) with minimal food. They also had combat rations during week 2 in Yellowknife. It is worth noting that a weight loss of <3 percent over 7-30 days has minimal health effects, and that one 3-10 percent is unlikely to affect performance. [20] However, some participants lost as much as 7.7 percent of their body weight which could lead-to health and/or performance decrements, such as the increased risk of fatigue, confusion, and injury, and decreased immune function, as seen in athlete and military populations.[21] Dehydration may also have played a role in this weight loss. A systematic review on body weight and composition changes of military personnel consuming combat rations stated that the most pronounced weight losses were seen during cold-weather training: 5.6 percent over 20 days, and 6.3 percent over 30 days.[222] It is suspected, although not confirmed, that the majority of the suboptimal intake and subsequent weight loss occurred during weeks with combat rations and minimal food (weeks 2, 3, and 5) since individuals had a limited amount and variety of food in a more austere climate (Figure 1). A weight decrease as seen in this study could become problematic, especially if continued over a longer period of time. In fact, soldiers can be on rations for extended periods, particularly during deployments. In future studies, it would be beneficial to

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[20] Barringer et al., "Prediction Equation."; E.C. Tassone, B.A. Baker, "Body Weight and Body Composition Changes during Military Training and Deployment Involving the Use of Combat Rations: A Systematic Literature Review," *British Journal of Nutrition* 117, 6 (2017): pp. 897-910. doi:10.1017/S0007114517000630; A.D. Weinberg, "Dehydration: Evaluation and Management in Older Adults," *JAMA* 274, 19 (1995): p. 1552. doi:10.1001/jama.1995.03530190066035; G.M. Fogelholm, R. Koskinen, J. Laakso, T. Rankinen, I. Ruokonen, "Gradual and Rapid Weight Loss: Effects on Nutrition and Performance in Male Athletes," *Medicine and Science in Sports and Exercise* 25, 3 (1993): pp. 371-377.

[21] Marriott, *Not Eating Enough*; Henning, "Physiological Decrements."; Tassonne et al., "Body Weight."; E. Franchini, E. Brito, G.G. Artioli, "Weight Loss in Combat Sports: Physiological, Psychological and Performance Effects," *Journal of the International Society of Sports Nutrition* 9, 1 (2012). doi:10.1186/1550-2783-9-52.

[22] Tassone et al., "Body Weight."

measure the impact of weight loss on various health parameters and military task performance indicators.

Once the part of the training that required utilization of combat ration feeding was completed, all participants gained weight in the remaining three weeks, during which they had access to the military dining facility and commercial foods. Comparison of body weights at the beginning and end of the training were similar, indicating participants were able to regain the weight lost while on combat rations. Likewise, their FM and FFM were comparable at the beginning and end of the training, similar to results obtained by Jones et al.[23] Weight loss is therefore not merely associated with the working environment, but also with the feeding regimen; the risk of weight loss is accentuated when consuming combat rations. Needless to say, it is encouraging that participants were able to regain the lost weight, but soldiers may not be able to recover as easily over a prolonged period of time and/or with a more severe weight loss.

When comparing energy intake and requirements, we estimated a substantial daily energy deficit of 2778 kcal (49.8 percent) for soldiers while on combat rations during field training in the Arctic, likely contributing to the weight loss measured from beginning to mid-training. A study by Margolis et al.[24] with 21 Norwegian male soldiers participating in a 1-week winter training obtained similar results, where energy deficit was 2382 kcal (43.5 percent) and 3390 kcal (49.5 percent), measured at two time-points. In that study, energy intake was measured with a waste collection method and food logs, whereas energy expenditure was measured using doubly labelled water. In addition, a recent study by Ahmed et al.,[25] using the same type of energy intake and expenditure measurement methods as Margolis et al., also observed similar results: during a cold-weather field training in southern Canada, they measured an energy deficit of 2539 kcal/day (51.6 percent). An older Canadian study from 1993[26] also noticed a significant discrepancy between energy intake and expenditure, although their results indicate that food intake was underreported which could also influence results if this

[23] P.J. Jones, I. Jacobs, A. Morris, M.B. Ducharme, "Adequacy of Food Rations in Soldiers during an Arctic Exercise Measured by Doubly Labeled Water," *Journal of Applied Physiology* 75, 4 (1993); pp. 1790-1797. doi:10.1152/jappl.1993.75.4.1790.
[24] Margolis et al., "Effects of Winter Military Training."
[25] M. Ahmed, I. Mandic, E. Desilets et al., "Energy Balance of Canadian Armed Forces Personnel during an Arctic-Like Field Training Exercise," *Nutrients* 12, 6 (2020): p. 1638. doi:10.3390/nu12061638.
[26] P.J. Jones et al., "Adequacy of Food Rations."

phenomenon occurred in the present study. Furthermore, Mandic, et al.,[27] estimated energy expenditure over four hours at -10°C in a thermally controlled chamber and their calculated estimated energy deficit aligns with our findings. Our findings, therefore, confirm there is indeed a problematic discrepancy between estimated energy intake and expenditure in Canadian soldiers during cold-weather training in the Arctic. Mandic et al.[28] also pointed to a possible change in appetite-regulating hormones with exposure to cold.

In terms of nutritional risk, unintended weight loss and reduced dietary intake are the two key indicators used to screen for malnutrition in Canada.[29]. Therefore, some participants may have been at risk of malnutrition. This indicates that further necessary precautions should be taken to prevent soldiers from facing negative health effects from inadequate feeding during prolonged training or work in the Arctic.

In fact, Goodman et al.[30] reported that 74 percent of soldiers indicated skipping lunch during an Arctic training. On the contrary, in the present study, the meal providing the most energy was lunch (31 percent). This suggests that mid-day mealtime may not have been skipped and might reflect the ability to consume food during the dedicated time for lunch in this Arctic training. Also, during the AOA training, soldiers were offered LMCs, providing up to 1000 kcal/d. Not all training offers LMCs in addition to IMPs; this is done when it is suspected energy needs might not be reached with IMPs alone and/or when they are requested and ordered. Considering energy intake was below energy requirements in all but one participant, it reinforces the need to offer LMCs since they provided 16 percent of daily energy intake and were consumed by the majority of participants. In another study, additional snacks (~1000 kcal) were also provided to soldiers, and once again, their intake was below requirements but higher than the control group not provided with snacks.[31] With the LMCs, only select items were eaten, suggesting different choices could be offered in the

[27] I. Mandic, M. Ahmed, S. Rhind, L. Goodman, M. L'Abbe, I. Jacobs, "The Effects of Exercise and Ambient Temperature on Dietary Intake, Appetite Sensation, and Appetite Regulating Hormone Concentrations," *Nutrition and Metabolism* 16, 1 (2019): p. 29. doi:10.1186/s12986-019-0348-5.
[28] Mandic et al., "The Effects of Exercise."
[29] *Canadian Nutrition Society: Canadian Nutrition Screen Tool,* Canadian Malnutrition Task Force, 2014, http://www.nutritioncareincanada.ca/sites/default/uploads/files/CNST.pdf. Accessed 14 July 2019.
[30] Goodman et al., *Observations and Survey Results.*
[31] Margolis et al., "Effects of Supplemental Energy."

hopes of increasing soldiers' intake with snacks that are more acceptable to them and operationally suitable. Indeed, previous research has demonstrated that some foods are not eaten and/or discarded because they are not adapted to extreme cold conditions (for example, frozen rations in the Arctic), which consequently decreases the available energy content.[32] Furthermore, if soldiers in the present study ate everything provided each day (three IMPs ≈ 4800 kcal, and one LMC ≈ 1000 kcal), they would have reached the estimated total daily energy requirements (5577 kcal/day). The low energy intake thus does not stem from an inadequate provision of food, but rather the suboptimal consumption.

Although weight was measured at mid-point, we were unable to measure body composition at that time due to logistical constraints in bringing the equipment to the Resolute Bay training site. As such, we cannot indicate which body compartment was most affected by weight loss from the beginning to mid-training, while on combat rations. Although measuring body composition via bioelectrical impedance analysis has its limits, consistent hydration status was maintained at both measurement points (58 percent), falling within an acceptable range of 50-65 percent of body weight for men, thus increasing measure reliability.[33] Other studies have identified the need for further research measuring body composition changes over time with the use of rations.[34] Another limitation was that energy expenditure was not measured. Although the equation used to estimate total daily energy requirements was developed in ambient temperature, it was specifically developed for a military population and generated results comparable to energy expenditure measured using doubly labelled water.[35] Also, participants did not specify if they were intentionally trying to lose weight.

Another limitation was that no food intake records were collected when soldiers were eating at the military dining facility. More frequent (i.e. weekly) measurements of

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[32] Lavergne et al., "Soldiers' Perception."; K. Charlot, D. Chapelot, P. Colin, C. Bourrilon, "Daily Energy Balance and Eating Behaviour during a 14-day Cold Weather Expedition in Greenland," *Applied Physiology, Nutrition and Metabolism* 45, 9 (2020): pp. 968-977. doi:10.1139/apnm-2019-0677.
[33] *Body Composition Analyzer;* A. Aandstad, K. Holtberger, R. Hagenberg, I. Holme, S.A. Anderssen, "Validity and Reliability of Bioelectrical Impedance Analysis and Skinfold Thickness in Predicting Body Fat in Military Personnel," *Military Medicine* 179, 2 (2014): pp. 208-217. doi:10.7205/MILMED-D-12-00545.
[34] Margolis et al., "Effects of Winter Military Training."
[35] Margolis et al., "Effects of Winter Military Training"; Barringer et al., "Prediction Equation"; Ahmed et al., "Energy Balance."

body weight and composition would have helped document more clearly the effect of rations on these measurements. Also, results were obtained from a smaller sample of participants than anticipated because of a change in schedule requiring some individuals to stay in the Arctic for a longer period of time, after the training was completed. Of note, several similar types of studies had between 10-21 participants.[36] This study involved a convenient sample that may not be representative of the CAF population, including its female population. Since the AOA training is offered once per year for a small group and given the sparsity of Canadian data on this topic, we opted for this sampling method. Therefore, future research with a larger sample size would be necessary to confirm these findings and further investigate the energy intake and body weight changes of soldiers on rations in the Arctic.

By measuring energy intake with food diaries, we were able to measure the distribution of energy intake throughout the day. Using a daily food waste collection method and having the food content subsequently analyzed may provide a precise estimate of intake, but fails to show when food consumption occurs throughout the day.[37] Food diaries were obtained for one day. Although this method of data collection can lead to under-reporting[38] due to relying on the participants' ability to remember items consumed throughout the day and judgement to estimate portions eaten, participants reported the food diary represented their usual intake of combat rations during the training, and food diaries were verified with a dietitian and rectified when needed.

Since combat rations are standardized meals, precise nutritional information for each item was available directly from the CAF Food Services, reducing the errors associated with estimating the energy from each food, thus increasing precision.

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[36] Margolis et al., "Effects of Winter Military Training", P.J. Jones et al., Adequacy of Food Rations"; Ahmed et al., "Energy Balance"; Mandic et al., "The Effects of Exercise"; Charlot et al., "Daily Energy Balance."

[37] Margolis et al., "Effects of Winter Military Training"; M. Ahmed, I. Mandic, W. Lou, L. Goodman, I. Jacobs, M.R. L'Abbe, "Validation of a Tablet Application for Assessing Dietary Intakes Compared with the Measured Food Intake/Food Waste Method in Military Personnel Consuming Field Rations," *Nutrients* 9, 3 (2017). doi:10.3390/nu9030200.

[38] P.J. Jones et al., "Adequacy of Food Rations."

Conclusions

From this study, we can conclude that the bodyweight of participants decreased after consumption of combat rations while in-field training in the Arctic when energy intake was significantly lower than estimated daily energy requirements. However, participants regained weight by the end of the training when they had access to fresh feeding. Body composition changes were not measured. These findings highlight the challenges in adequately feeding soldiers with combat rations in extreme climates. More research is needed to explore ways to mitigate this problem. Results from this study can be taken into consideration in the development of combat rations better suited for military training in the Arctic to reduce energy deficit and promote optimal energy intake.

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