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Invited Commentary

Negative energy balance and loss of body mass and fat-free mass in military personnel subsisting on combat rations during training and combat operations: a comment on Tassone and Baker

The inability for military service members to achieve energy balance while subsisting primarily combat rations during strenuous military operations is well documented[1–4], and military leaders have recognised this problem for centuries[5]. For decades, the militaries of many nations have sponsored considerable research to understand the consequences of severe negative energy balance and to develop nutritional interventions to enhance field-feeding and increase total energy intake[6,7].

In this issue of the journal, Tassone & Baker[8] present a systematic review of the literature assessing the effects of combat ration use on body mass and body composition during military training and combat operations. They searched ten databases and aggregated information from thirty studies, published between 1976 and 2016 that focused on energy balance and alterations in body mass and composition in military personnel subsisting solely on combat rations for periods lasting 3–40 d[8]. Tassone and Baker subsequently analysed each investigation for risk of bias, study quality and strength of evidence using validated scoring systems. Overwhelmingly, the studies were judged to be of neutral quality, at moderate risk of bias (i.e. methodological limitations), with strength of evidence ranging low to high (only six of thirty were judged high)[8]. The most commonly cited limitations in the studies reviewed were that they lacked dietary controls, balanced study designs (i.e. control group), and often failed to control the timing of study measurements, and the conditions during which the measures were performed. Although the majority of studies were appropriately critiqued for methodological limitations, the authors rightfully acknowledged that conducting research studies during field training exercises designed to achieve a military, not scientific, objective is challenging, often forcing researchers to choose lower quality analytical methods and collect potentially flawed data because they cannot impact the overarching military mission.

Tassone & Baker[8] categorise and present their findings according to the duration of the training exercise and use of combat rations. They reported that during 3–7 d training exercises, where military personnel subsisted primarily on combat rations, energy expenditures were high and result in severe energy deficits[9,10]. However, when training exercises are this short, body mass losses were small (<3 % of initial body mass), and generally not considered to be detrimental to performance[11]. However, during longer training exercises, that is, 8–12 d of near-continuous physical activities and limited time to eat, the energy deficits were large (−9 to −10 MJ/d), resulting in total body mass losses exceeding 5 % of initial body mass[12,13]. In contrast, during even longer training exercises, that is 20–30 d, energy deficits observed were lower and body mass losses were less than observed during shorter training exercises, largely because energy expenditures were not as high as those commonly reported during short-term training exercises[8].

Two critical issues become apparent when reading the review by Tassone & Baker[8]. First, the overwhelming number of studies demonstrating that military personnel subsisting primarily on combat rations will underfeed, lose body mass and fat-free mass (FFM), were conducted during training exercises designed to expose military personnel to a variety of stressors, including intentional underfeeding[4,9,10,14–16]. Therefore, results from those studies must be interpreted in the context of that type of training, understanding that the stressors imposed, including environment, physical activity level, sleep and food availability, are designed to elicit a military-specific adaptation. The duration of the training, metabolic stress, and food availability during those programmes vary greatly, resulting in considerably different physiological and psychological responses. In fact, while the study of US Army Ranger students reported dramatic losses of body mass and FFM, the students were intentionally grossly underfed, those observations were reported over 20 years ago, and combat ration provisions during US Army Ranger School have since been increased to at least 9·2 MJ/d (two Meal Ready to Eat™ per day)[17]. Failing to appreciate how specific nuances to each training exercise could affect physiological and psychological outcomes, and how they may differ from actual combat/deployment operations, may lead to erroneous recommendations by nutrition researchers and military nutrition policy makers. More importantly, Tassone & Baker[8] focus their review solely on changes in body mass and body composition when military personnel subsist on combat rations. There is no discussion on whether the observed losses of body mass or FFM, actually affected performance. They do highlight a report by the Institute of Medicine that attempts to define tolerable upper limits of body mass loss before appreciable decrements in performance are observed[11]. However, many of the papers they reviewed did report changes in performance. What remains unclear is whether the performance declines observed were a direct result of negative energy balance, body mass and FFM loss. In addition, whether the performance metrics reported in most papers (i.e. vertical jump, lower-body peak power, mood, vigilance, etc.) are at all relevant for performance of military duties and functions are not clear. It very well may be that occasional exposure to severe negative energy balance is associated with only minimal performance impairment. The real risk of impaired performance for military personnel subsisting solely on combat rations probably only manifests after many back-to-back episodes of negative energy balance, without recovery periods with adequate recovery nutrition.

Tassone & Baker[8] suggest some actionable recommendations. One recommendation was to provide nutrition education relevant to the training exercise military personnel perform, as a better understanding of the importance of energy and nutrients to fuel performance may improve dietary intake (i.e. macronutrient type and energy). However, while education may help military personnel develop coping strategies, education alone will not prevent negative energy balance and its associated effects on body mass and body composition, when the energy expended exceeds the amount of energy provided in a full daily allotment of most combat rations (in the USA, i.e. equal to three Meal Ready to Eat™ or approximately 15 MJ/d)[15]. During some short-term training operations energy expenditures exceeded approximately 19 MJ/d. Unless supplemental nutrition, or additional combat rations are provided to personnel participating in those types of training or operations, energy balance will not be achieved, and energy deficits of approximately 4 MJ/d will be sustained. What exacerbates this problem is that military personnel will generally 'field-strip' their rations, choosing to carry only particular ration components, while discarding the remainder of the food products provided, to limit the total amount of weight carried during the mission (e.g. weapons, body armor, ammunition, water, food, etc.)[18]. Developing a tailorable education programme that recognises these realities and provides more effective 'field-stripping' strategies could help. Such an education programme would have to (1) acknowledge how the challenges they might encounter during operations would limit dietary intake and how poor nutrition might influence those challenges, (2) provide relevant examples of the consequences of underfeeding during operations that would be meaningful to them, to include muscle loss and military-specific performance declines (i.e. decision making capabilities, marksmanship, ability to perform long sustained patrols while carrying heavy loads), particularly if the operations are repeated with limited time to recover between missions and (3) offer simple, non-technical, mitigation strategies to enhance field-feeding.

Tassone & Baker[8] also suggested a need to ensure military personnel are consuming the recommended level of dietary protein (1·5–2·0 g/kg per d) to minimise FFM loss[19]. However, for dietary protein to be effectively used for protein-requiring body processes instead of serving as a substrate for energy metabolism, a critical amount of dietary energy intake must be consumed. One study showed that Soldiers who simply ate more during a 4-d winter training exercise were not only able to attenuate the severity of the energy deficit to approximately 40 % of total daily energy needs (an energy deficit level typically used to induce about a 1 kg weight loss per week in overweight and obese individuals), but were also able to minimise the effects of underfeeding on whole-body protein balance[9]. They did so while meeting protein recommendations for military operations[19] and carbohydrate recommendations by the American College of Sports Medicine, the Academy of Nutrition and Dietetics, and the Dietitians of Canada[20]. While that study was only 4 d, the data suggest that there is an acceptable level of energy deficit (approximately 40 %) during strenuous military operations as long as both protein and carbohydrate are consumed within recommended levels.

How sex differences influence energy, macronutrient and micronutrient requirements during military operations remains poorly understood. Combat roles are no longer exclusive to males, and of the thirty studies identified by Tassone and Baker, only one included female service members. Total energy expenditures will likely be lower for females than males because of their lower body mass[21,22] and these lower energy requirements may make achievement of energy balance more attainable for females than males when both are subsisting on the same rations. Beyond total energy needs, females also oxidise fat at a higher rate and carbohydrate at a lower rate than males[23,24]. Differences in substrate oxidation may contribute to differences in body composition responses to military training between male and female military personnel. Hoyt *et al.*[22] reported that training in a semi-starved state (energy intake = 0·2–2·2 MJ/d) for 7 d caused greater FFM loss in male (4·0 kg) *v*. female (2·5 kg) Soldiers. Females were able to more efficiently use body fat (7·3 mg fat/min per kg FFM, 89 % of total daily energy expenditure was attributed to fat) compared to their male counterparts (5·2 mg fat/min per kg FFM and 74 %). This study, which is limited by a small sample size (males: *n* 10; females: *n* 6), highlights the potential for sex-based differences in how male and females respond to military training, which could affect how they should be fed.

The systematic review by Tassone & Baker[8] provides a contemporary review of the literature, describing the severity and impact of negative energy balance on body weight and composition during military operations spanning from 3 to 40 d. This review highlights that though inadequate energy intake has been an issue plaguing military operations for centuries, it remains a contemporary concern. In the context of actual mission objectives, some degree of negative energy balance, body mass and FFM loss are entirely expected and may also be well-tolerated, as long as protein and carbohydrate intakes are consistent with recommendations for periods of increased metabolic stress[9]. One limitation of the review by Tassone & Baker[8] is that there is no critical evaluation of the effects of negative energy balance, body mass and FFM loss on military performance. Thus, a literature review examining the impact of negative energy balance and combat rations on physical and psychological performance responses to military operations would be an excellent follow-on paper to compliment the Tassone & Baker report[9]. Finally, there is a clear need to capture more data on sex-specific dietary requirements, as the number of females taking on combat roles continues to grow in modern militaries.

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