Nutrition and Physical Activity in British Army Officer Cadet Training Part 2 - Daily Distribution of Energy and Macronutrient Intake

Victoria C. Edwards[1], Stephen D. Myers[1], Sophie L. Wardle[2,3], Andrew G. Siddall[1], Steven D. Powell[1], Sarah Needham-Beck[1], Sarah Jackson[2], Julie P. Greeves[2,3,4], Sam D. Blacker[1]

[1]Occupational Performance Research Group, Institute of Sport, University of Chichester, College Lane, Chichester, West Sussex, PO19 6PE, [2]Army Personnel Research Capability, Army Headquarters, Andover, Hampshire, SP11 8HT, [3]Division of Surgery and Interventional Science, University College London, London, UK, [4]Norwich Medical School, University of East Anglia, Norwich, UK.

Running Title: Distribution of Dietary Intake in Officer Cadet Training

Dr Victoria C. Edwards, Occupational Performance Research Group, Institute of Sport, University of Chichester, PO19 6PE, E-mail: vicky-edwards14@sky.com, Telephone: +44 (0) 1243 793473

Abstract

Dietary intake and physical activity impact performance and adaptation during training. The aims of this study were to compare energy and macronutrient intake during British Army Officer Cadet training with dietary guidelines and describe daily distribution of energy and macronutrient intake and estimated energy expenditure (EE). Thirteen participants (seven women) were monitored during three discrete periods of military training for nine days on-camp (CAMP), five days' field exercise (FEX) and nine days of a mixture of the two (MIX). Dietary intake was measured using researcher-led food weighing and food diaries and EE was estimated from wrist-worn accelerometers. Energy intake was below guidelines for men (4600kcal·d^{-1}) and women (3500kcal·d^{-1}) during CAMP (men: -16%; women -9%), FEX (men: -33%; women: -42%) and MIX (men and women both -34%). Carbohydrate intake of men and women were below guidelines (6g·kg·d^{-1}) during CAMP (men: -10%; women: -9%), FEX (men: -18%; women: -37%), and MIX (men: -3%; women: -39%), respectively. Protein intake was above guidelines (1.2kcal·kg·d^{-1}) for men and women during CAMP (men: 48%; women: 39%) and MIX (men: 9%; women: 3%), but below guidelines during FEX (men: -13%; women: -27%). Energy and macronutrient intake during CAMP centred around mealtimes with a discernible sleep/wake cycle for EE. During FEX, energy and macronutrient intake were individually variable and EE was high throughout the day and night. These findings could be used to inform evidenced-based interventions to change the amount and timing of energy and macronutrient intake around physical activity to optimise performance and adaptations during military training.

Key Words: Nutrient timing, Military, Energy Balance

INTRODUCTION

British Army Officer Cadet (OC) training is characterised by high physical activity levels (Bilzon et al., 2006). Consequently, nutritional intake is essential for individuals to meet, and adapt to, the demands of training (Beals et al., 2015); enhance and/or maintain physical and cognitive performance (McClung & Gaffney-Stomberg, 2016); and reduce risk of fatigue, injury and illness (Rodriguez et al., 2009). In the first article in this dual submission we reported OCs were in negative energy balance (EB; Range, greatest to lowest EB across all conditions, men: -2289 to -868, women: -2104 to -542 kcal·d^{-1}) and were categorised as having low energy availability (men: -5 to 21, women: 5 to 25 kcal·kgFFM·d^{-1}) during training (Edwards et al., [Under Review]). This second article investigates the timing of energy and macronutrient intake in relation to OCs energy expenditure (EE).

Dietary guidelines for the UK Armed Forces (Military Dietary Reference Values; MDRVs) suggest appropriate energy and macronutrient intake personnel in different scenarios. It is recommended that OCs consume 4600 (men) and 3500 (women) kcal·d^{-1} during their compulsory basic training, which includes the Commissioning Course (CC) for OCs (SACN, 2016). The macronutrient recommendations for OCs are based on the provision of adequate nutritional needs to meet the demands of training and are, therefore, set as a percentage of the total recommended energy intake (EI) stated in the MDRVs (50 to 65% of total EI from carbohydrate, 10 to 15% from protein and 25 to 35% from fat) (Gillen et al., 2017; SACN, 2016).

In sports settings it is recommended that macronutrient intakes are prescribed per kilogram of body mass rather than as a percentage of EI (Phillips & Van Loon, 2011). Athletic guidelines for protein intake, suggest that requirements for individuals with high training loads should consume 1.2 to 2.0 g·kg·d^{-1} (Phillips & Van Loon, 2011; Rodriguez et al., 2009), where protein intake at the higher end of the recommendation may optimise the desired adaptive response to long-term training. Athletic guidelines for carbohydrate intake range from 3 to 12 g·kg·d^{-1} for athletes, with the higher intakes (>

6 g·kg·d^{-1}) to maintain/enhance performance when undertaking long duration endurance exercise or high intensity interval training (Potgieter, 2013). Conversely, low carbohydrate intake is associated with reduced soldier performance on military tasks (Montain et al., 1997). Fat intake is recommended to be 20 to 35% of energy intake (equating to approximately 1.5 g·kg·d^{-1} based on MDRVs) (SACN, 2016) to improve metabolic pathways that use fatty acids, to help in the utilisation of nutrients that are absorbed or transported with fat (Horvath et al., 2000), and protect from larger energy deficits due to the higher calorific density.

The provision and timing of dietary intake may be critical during military training to maintain or improve physical and mental performance whilst enhancing recovery and promoting adaptation to training (Beals et al., 2015). The timing of macronutrient intake, particularly protein, and its subsequent effects on training adaptations, has been explored in both controlled laboratory and sports performance settings where macronutrient intake is typically manipulated around a single bout of exercise to determine the influence on performance, muscle protein synthesis (MPS) or muscle damage (Areta et al., 2013; Nosaka et al., 2006). Typically, consuming protein immediately after resistance exercise, with an even distribution of intake throughout the day, is considered the most effective method for stimulating MPS compared with an excessively high protein intake at single and/or infrequent time points each day (Mamerow et al., 2014). Moreover, carbohydrate intake prior to, and during, exercise improves exercise performance at a given workload (Jeukendrup, 2014) and, when taken after exercise in combination with protein, promotes greater glycogen uptake and resynthesis (Ivy et al., 2002).

During military training, the combination of remote locations, consistent physical activity, ‘field stripping’ ration packs, and limited time to eat can influence the intake of OCs leading to energy deficits (Edwards et al., [Under Review]). Therefore, the aim of this study was to 1) determine the energy and macronutrient intake of OCs during training compared with current military and athletic guidelines and 2) determine the daily distribution of dietary intake and energy expenditure during three different military settings; on camp only, during field exercise and a mixture of both camp and field exercise.

METHOD

Participants

Twenty Officer Cadets from RMAS volunteered for each of the conditions (total of 26 individuals). Fifteen participants who successfully completed all data collection periods were included in the study. Two participants (one man and one woman) were excluded from FEX due to injury, therefore 13 participants (six men: 24 ± 1 years, 1.78 ± 0.07 m, 82.1 ± 8.3 kg, and seven women: 22 ± 2 years, 1.69 ± 0.03 m, 70.2 ± 4.2 kg) were included in the final data analysis. Participants were provided with a verbal and written brief on the requirements of the study, in the absence of any uniformed staff, and were offered the opportunity to ask questions before providing informed written consent. Ethical approval was granted by the Ministry of Defence Research Ethics Committee (protocol number 780/MoDREC/16). The study design is described in detail in the accompanying article (Edwards et al., [Under Review]). In brief, dietary intake and EE were measured during three contextually different periods of the CC (Weeks 9, 22 and 34); nine days training in camp (CAMP), five days on a defensive field exercise (FEX) and nine days of combined camp and public-order field-based training (MIX).

Dietary Intake

Dietary intake was measured through researcher-led dietary weighing, and all additional food was recorded in a food diary with food wrappers also collected in a zip-lock bag. Daily distribution of energy and macronutrient intake was categorised into meals [M: breakfast (M1: 0600 - 0800), lunch (M2: 1200 - 1400) and dinner (M3: 1800 - 2000)], and snacks [S: pre-breakfast (S1: 0000 - 0600), mid-morning (S2: 0800 - 1200), mid-afternoon (S3: 1400 - 1800) and evening (S4: 2000 - 0000)] (Figure 1).

Food items that were recorded as being eaten at the crossover point of the two categories, *e.g.,* 0800; M1 and S2, were classed as a snack or meal based on the nature of the item.

INSERT FIGURE 1 HERE

Activity Monitoring

In the first article in this dual submission (Edwards et al., [Under Review]), doubly labelled water (DLW) was used to measure 10-day average EE. Also, however as DLW only provides a measure of EE over a 10-day period, hourly EE over the data collection periods was estimated using a wrist-worn tri-axial accelerometer (GENEActiv, Activinsights, UK). This tri-axial accelerometer has previously been demonstrated to be a valid measure of physical activity and EE (Esliger et al., 2011) and accelerometers have been successfully used to monitor physically demanding occupations without causing undue burden upon participants (Blacker et al., 2009; Richmond et al., 2014). The GENEActiv devices were set at a sampling frequency of 50 Hz and programmed to each participant's sex, age, height and body mass (measured at the beginning of each sampling block) and were worn continuously. Raw acceleration data were analysed using a commercially available macro in a Microsoft Excel spreadsheet (Activinsights, UK) to generate gravity-subtracted sum of vector magnitudes per minute of wear time and corresponding bands of physical activity intensity in metabolic equivalents (METs) per min (MET·mins^{-1}). Any minute with a zero value was replaced with 0.9 METs to reflect a low baseline of estimated resting metabolism; data (per day) were deemed invalid and excluded from analysis if the device was worn < 65% of the day. Hourly EE was calculated using MET·mins^{-1} and participant body mass (kg) using Equation 1a (Bushman, 2012). To adjust for previously observed underestimation of EE measured in the same study participants compared to the gold-standard measure of DLW, a correction factor was applied to the measurements from the GENEActiv, using regression Equation 1b (Blacker et al., 2019).

a) $$EE = MET.mins\ x\ 3.5 \times BM\ /\ 200$$

b) $$Adjusted\ EE = 563.116 + (0.886\ \times EE_{GENEActiv})$$

Equation 1: Calculation of hourly estimated Energy Expenditure (EE) (a) and adjusted EE (b)

Data Analysis

Results are reported as mean ± standard deviation unless otherwise stated. Statistical analysis was conducted using Statistical Package for the Social Sciences (SPSS; IBM SPSS version 23 for Windows, IBM Corporation, Chicago, IL) and statistical significance was set *a priori* at a long-run type I error rate of 5% (i.e. $\alpha = 0.05$). Normality was confirmed using Shapiro-Wilk tests for dependent variables. To compare dietary data with the guidelines (single known point values for men and women), one-sample t-tests with reported effect sizes (Cohen's d) and 95% confidence intervals (CI) were conducted for mean energy intake against the MDRVs and for relative carbohydrate, protein and fat intake against the minimum requirement of athletic guidelines for men and women separately. Because each condition contained a mixture of the same and different individuals between-condition comparisons were not appropriate and the difference in average intake of energy, carbohydrate, protein and fat during meal times compared with snack times using paired sample t-tests within condition, with reported effect size (Cohen's d) and 95% CIs for mean difference. Interpretation of Cohen's d is as follows: ≤ 0.2 trivial effect , 0.21 to 0.50 small effect, 0.51 to 0.80 moderate effect and ≥ 0.8 large effect (Cohen, 1988).

RESULTS

Total Dietary Intake

Energy intake of OCs was 16% and 9% below the MDRVs for men (4600 kcal·d^{-1}) and women (3500 kcal·d^{-1}, Table 1), respectively, during CAMP. These discrepancies were larger in FEX (men: -33%; women: -42%) and MIX (men and women both -34%). Relative carbohydrate intake of men and women was below the minimum guidelines (6 g·kg·d^{-1}) during CAMP by 10% and 9% respectively, during FEX by 18% and 37% respectively, and during MIX by 33% and 39%, respectively (Table 1). In contrast, relative protein intake was above athletic guidelines (1.2 $kcal \cdot kg \cdot d^{-1}$) for men and women by 48% and 39% during CAMP and 9% and 3% during MIX, but was below guidelines by 13% and 27% in men and women, respectively, during FEX (Table 1). Relative fat intake followed a similar pattern to protein, with intake greater than the guidelines (1.5 $g \cdot kg \cdot d^{-1}$) during CAMP (men: 25%; women: 21%) but lower during FEX (men: -30%; women -42%) and MIX (men: -12%; women: -18%) (Table 1).

INSERT TABLE 1 HERE

Distribution of Dietary Intake

The average EI of OCs from meal and snack times appeared to be different during both CAMP and MIX, irrespective of gender but this was not apparent during FEX (Table 2). There was no apparent difference in meal type between gender, irrespective of condition for CAMP ($F_{(1,5)} = 4.747$, $p = 0.081$, $n_p^2 = 0.487$) and FEX ($F_{(1,5)} = 0.340$, $p = 0.585$, $n_p^2 = 0.064$), however men had a greater average EI irrespective of meal type during MIX ($F_{(1,5)} = 10.045$, $p = 0.025$, $n_p^2 = 0.668$, mean difference [95% CIs]: 107 $kcal \cdot meal^{-1}$ [20,194]). These results were mirrored when split by macronutrients where, during CAMP average carbohydrate, protein and fat intake during meals were higher than snacks (Figure 2), irrespective of gender. For FEX, however, the null hypothesis that average intake of each macronutrient were not different between meals and snacks could not be rejected. No gender difference was apparent during FEX, irrespective of condition ($p > 0.05$). During MIX, average intake of carbohydrates, protein and fat appeared to be different between meals and snacks, irrespective of gender (Table 2). Similarly, men had a greater intake of average EI across meals and snacks, irrespective of meal type for protein ($F_{(1,5)} = 13.237$, $p = 0.015$, $n_p^2 = 0.726$, mean difference [95% CIs]: 2.8 $g \cdot meal^{-1}$ [0.8, 4.8]) and fat $F_{(1,5)} = 7.410$, $p = 0.042$, $n_p^2 = 0.597$, 3.9 $g \cdot meal^{-1}$ [0.2, 7.7]), but not carbohydrates ($F_{(1,5)} = 5.795$, $p = 0.061$, $n_p^2 = 0.537$).

INSERT TABLE 2 HERE

Distribution of average and individual protein (Figure 3, panels A to C) and carbohydrate (Figure 3, panels D to F) intake for each meal period is shown in Figure 3 alongside hourly EE. Group-average data demonstrates protein and carbohydrate intake in CAMP and MIX are distributed around standard core mealtimes but appears more evenly distributed during FEX. However, individual data shows that the assumed even distribution in FEX is a product of high inter-individual variation in intake pattern within this setting, resulting in similar average values across core meal and snack periods.

Energy Expenditure

Average hourly EE across the day is shown in Figure 3 (panels G to I), demonstrating that during FEX, the group-average distribution of EE remained consistently high throughout the entire 24-hour day (*i.e.,* no clear sleep / wake periods) compared with CAMP and MIX which had more typical sleep / wake patterns.

INSERT FIGURE 2 HERE

INSERT FIGURE 3 HERE

DISCUSSION

The present study is the first to document the timing of energy and macronutrient intake concurrently with hourly estimated EE in a military setting. During the periods of FEX and MIX, EI was lower than current military dietary guidelines (men: 4600 and women: 3500 kcal·d^{-1}) and carbohydrate and fat were lower than the recommended minimum athletic guidelines (carbohydrate: 6 g·kg·d^{-1}; fat: 1.5 g·kg·d^{-1}). However, the only instance where protein intake was lower than athletic guidelines was for men and women during FEX (1.2 g·kg·d^{-1}) and was above the minimum recommended intake during CAMP. The EI distribution during training settings on military camp centred around expected core meal times (breakfast, lunch, dinner), with lower intake from snacks, and a discernible sleep/wake cycle for EE. This pattern was in contrast to FEX where the pattern of feeding was individually variable, in conjunction with consistently high EE throughout the day and night.

Compared with the current study, previous research in the British Army demonstrated similar EI (men: 2846 ± 573 and women: 2207 ± 585 kcal·d^{-1}), carbohydrate intake (men: 4.8 ± 1.3 and women: 3.8 ± 1.4 g·kg·d^{-1}), and protein intake (men: 1.5 ± 0.3 and women: 1.3 ± 0.3 g·kg·d^{-1}) in recruits undergoing basic training (O'Leary et al., 2018). The under-consumption in the present study is typical of that observed in previous research in military settings (Fallowfield et al., 2010; McAdam et al., 2018). A common theme between training courses demonstrating high EEs, is that OCs are often physically active for a large part of the day (Hoyt et al., 2001), sleep deprived (Shippee et al., 1994) and carry external loads (Tharion et al., 2005). This suggests, therefore, that MDRVs may not be high enough specifically in the training environment. As reported in the first article within this dual submission (Edwards et al., [Under Review]), estimated EE (measured within the same cohort) was high and, in some case, would have required an energy intake substantially higher than the MDRVs.

During FEX, participants were provided with ration packs which have an energy provision of 4000 kcal, consisting of 495 g carbohydrate, 164 g protein, and 152 g fat (Davey et al., 2013), based on previous military dietary reference values for military training courses (Casey, 2008). Personnel are required to carry their own food and often discard any unwanted items based on personal preference to reduce carried mass. Therefore, although adequate food is supplied to the OCs, it is unlikely that the whole ration pack is consumed. Lower nutritional intake during military field exercises are not uncommon and can provide opportunity for military trainees to understand potential physical and psychological stressors of operational deployment and prepare them for aspects of the stress of combat (Tharion et al., 2005). As such, strenuous field training that includes sleep disruption and elicits severe energy deficit is often designed deliberately to prepare personnel for the consequences of deployment, despite being at odds with optimal strategies for long-term improvement in physical performance (Nindl et al., 2007; Richmond et al., 2014). Pasiakos and Margolis (2017) state that in the context of the operational objective, some degree of energy deficit is expected and may be well tolerated as long as protein and carbohydrate intakes are consistent with recommendations. As such, during short-term moderate energy deficits, it is advisable to consume a combination of protein and carbohydrate intake at the higher end of the recommended athletic guidelines (6 - 10 g·kg·d^{-1} carbohydrate and 1.2 - 2.0 g·kg·d^{-1} protein) (Phillips & Van Loon, 2011; Rodriguez et al., 2009). This intake may support the demands of training, whilst also mitigating negative effects produced through nutritional deficits such as loss in lean body mass (Tarnopolsky, 2004). The present study demonstrated that the relative intake of carbohydrate and protein during CAMP were in line with recommendations while during FEX, carbohydrate (men: 5.1, women 3.8 g·kg·d^{-1}), protein (men: 1.1 and women: 0.9 g·kg·d^{-1}) and fat (men: 1.0 and women: 0.9 g·kg·d^{-1}) intake were below the recommended range.

During training on camp, EI distribution centred around the three core meal times (breakfast, lunch, dinner) and individual EI data more closely reflected group means. This demonstrated a more typical pattern of feeding and a typical wake/sleep cycle, with EE lower during the morning and evening, and at a basal level overnight. During FEX however, OCs experienced severe energy deficit (Edwards et al., [Under Review]), and individual feeding patterns revealed no consistent distribution of energy or macronutrient intake, with participants' intake peaking at different times throughout each day, likely reflecting OCs eating only when time permitted. As such, the distribution of EI during FEX contained high inter-individual variation, which was masked by a misleadingly "even" distribution when observing only group-average data.

The effects of optimising the timing of carbohydrate intake around exercise on performance are well-documented (Jeukendrup, 2014), but the distribution of carbohydrate intake around multiple daily exercise bouts in military training has not previously been examined. Prolonged exercise of moderate-to-high intensity will deplete carbohydrate stores, potentially leading to a decrease in work output (Coyle et al., 1985), muscle tissue breakdown and immunosuppression (Gleeson et al., 2004). The intake of carbohydrate pre-, during and post-exercise can offset these changes and are important for exercise performance (Kerksick et al., 2008).

There is strong evidence that suggests different distributions of protein across the day and around physical activity could impact recovery and adaptation to training (Areta et al., 2013; Mamerow et al., 2014). However, these studies were conducted in recreationally-active civilians who typically undertake one exercise bout per day. In contrast, when military personnel are required to undertake multiple exercise bouts of varying intensities and durations, and at irregular times over a period of 24 hours, adapted nutritional strategies are likely needed. In trained cyclists undergoing approximately 7 hours of intense training per day (similar to that of OCs), an increased protein intake attenuated a post-training decrement in time trial performance and more effectively restored performance during a subsequent week of recovery in comparison to a control group (Witard et al., 2011). Therefore, consuming a greater intake (>20 g) of protein per meal, and at multiple periods throughout the day, may have benefits to OCs and be vital for prolonged work and recovery in field settings.

During the more structured training settings in the present study (CAMP and MIX), the distribution of protein was similar to that reported for civilian adults and athletes, where daily peak protein (and energy) intake is skewed towards the evening meal. Specifically, protein intake during the evening meal is typically threefold greater compared with breakfast (evening; 38 g vs. breakfast; 13 g) in civilians (Mathias et al., 2017) and twofold greater (breakfast ~19 g; lunch ~25 g; dinner ~38 g) in athletes (Gillen et al., 2017). Mamerow et al. (2014) demonstrated that consuming a moderate amount (~30 g) of high-quality protein three times a day resulted in 25% greater MPS than the common practice of skewing the majority of protein consumption towards the evening meal. It has been demonstrated that a more optimal provision and timing of protein intake after exercise can significantly improve power output, muscle strength, endurance and mental alertness in subsequent bouts of exercise (Rodriguez et al., 2009). However, during FEX individual protein intake was highly variable and did not follow any specific feeding pattern. In the context of military training, these outcomes are important considerations in temporal adaptation from the cumulative effect of arduous daily physical training and for maximal recovery between these training sessions (Rodriguez et al., 2009).

Protein intake was considerably lower in late evening, post-dinner (S4), for all three conditions, despite EE remaining high during these periods. Protein intake immediately prior to sleep has been shown to be effectively digested and absorbed, increasing amino acid availability and augmenting MPS rates overnight (Gillen et al., 2017; Res et al., 2012). In military populations, pre-sleep/late-evening may represent an opportunity to increase overall protein provision and improve potential for skeletal muscle adaptation to physical training.

There are several strengths and limitations in the present study. Firstly, it is acknowledged that food diaries can underestimate dietary intake (Hill & Davies, 2001) and that it is possible that the burden of weighing food influenced participants' behaviour and eating habits (such as reduced intake in the dining hall), and therefore may not have accurately represented their usual intake. However, during FEX the use of zip-lock bags and collection of all wrappers allowed the researchers to capture all food intake during the field exercises and therefore likely limited the underestimation of intake. Further, the time in which the participant ate the food items was not always recorded clearly and thus were retrospectively recorded when the researcher reminded the participant when collecting the wrappers, therefore it could be likely, due to sleep deprivation and long waking hours, that the time food items were eaten may have occasionally been inaccurate. Secondly, the use of tri-axial accelerometer allowed a unique insight into the physical activity profile of acute periods throughout the course due to the nature of the data collection in both a field- and training-based setting, however breakage and loss of activity monitoring devices meant that EE data were affected. In some respect, this data loss was also due to the wear-time cut-off of <65%, but this cut-off is necessary to avoid including inaccurate, low daily EE and skewing overall estimation. Additionally, the sample size in the present study was limited to the number of participants that could be monitored as part of the project contract and ethics approval and thus may not be representative of a large cohort of OCs. Despite the limitations, for the aims of this specific study, the authors believe that the tri-axial accelerometer and combined dietary weighing/food diaries was the most practical way to accurately estimate hourly EE and distribution of dietary intake in field settings without undue burden to participants.

CONCLUSION

In conclusion, the present study is the first to document the total and daily distribution of energy and macronutrient intake in parallel with EE during three different military training settings. Compared to military and athletic guidelines, total energy and macronutrient intake was below the recommended intake. Additionally, total energy expenditure was greatest during military FEX, where OCs were kept active throughout the entire day, including during the night and early mornings, but this work pattern also resulted in variable patterns of dietary intake both within- and between- participants. In a more structured setting where sleep was not disrupted, a more typical three-meal eating pattern was observed. Based on the overarching principle that evenly distributing EI throughout the day is likely to promote maintenance of muscle mass and exercise recovery, individual data indicates that nutritional intake during arduous field training may be suboptimal for occupational performance, and thus could be adapted to optimise recovery and long-term adaptations to training. Future research should evaluate potential strategies to improve the daily distribution of energy and macronutrient intake in military settings and to explore whether such interventions could enhance recovery and adaptation during training.

Acknowledgments: We would like to acknowledge Dr Jane Thompson, Dr Ella Walker, Dr Sarah Coakley, Dr Ben Lee, Dr Rianne Costello, Tessa Flood, Julianne Doherty and Christopher Vine for their role in data collection.

Authorships: The study was designed by VCE, SDB, SDM, AGS, SLW, SJ and JPG; data were collected and analysed by VCE, AGS, SDP and SNB. All authors contributed to manuscript preparation and approved the final version of the paper.

Conflict of Interest: There are no conflicts of interest.

Funding Sources: This research was funded by the Army Personnel Research Capability (British Army, Ministry of Defence) through the Defence Human Capability Science and Technology Centre (DHCSTC).

References

Areta, J. L., Burke, L. M., Ross, M. L., Camera, D. M., West, D. W., Broad, E. M., Jeacocke, N. A., Moore, D. R., Stellingwerff, T., Phillips, S. M., Hawley, J. A., & Coffey, V. G. (2013). Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. *Journal of Physiology, 591*(9), 2319-2331. https://doi.org/10.1113/jphysiol.2012.244897

Beals, K., Darnell, M. E., Lovalekar, M., Baker, R. A., Nagai, T., San-Adams, T., & Wirt, M. D. (2015). Suboptimal Nutritional Characteristics in Male and Female Soldiers Compared to Sports Nutrition Guidelines. *Military Medicine, 180*(12), 1239-1246. https://doi.org/10.7205/MILMED-D-14-00515

Bilzon, J. L. J., Wilkinson, D. M., Richmond, V. L., Coward, A. W., Izard, R. M., & Rayson, M. P. (2006). Gender Differences in the Physical Demands of British Army Officer Cadet Training: 1726 Board #99. *Medicine & Science in Sports & Exercise, 38*(5).

Blacker, S. D., Siddall, A. G., Needham-Beck, S., Powell, S. D., Edwards, V. C., Kefyalew, S. S., Singh, P. A., Orford, E. R., Venables, M., Jackson, S., Greeves, J. P., & Myers, S. D. (2019). Equation to Estimate Total Energy Expenditure in Military Populations Using a Wrist-Worn Physical Activity Monitor. *Medicine & Science in Sports & Exercise, 51*(6), 275-276.

Blacker, S. D., Wilkinson, D. M., & Rayson, M. P. (2009). Gender Differences in the Physical Demands of British Army Recruit Training. *Military Medicine, 174*(8). https://doi.org/10.7205/MILMED-D-01-3708

Bushman, B. A. (2012). Wouldn’t You Like to Know: How Can I Use METs to Quantify the Amount of Aerobic Exercise? *ACSM's Health & Fitness Journal, 16*(2), 5-7. https://doi.org/10.1249/01.FIT.0000413045.15742.7b

Casey, S. (2008). *Military Dietary Reference Values.* QinetiQ Ltd.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Earlbaum Associates In Lawrence Earlbaum Associates.

Coyle, E. F., Coggan, A. R., Hemmert, M. K., Lowe, R. C., & Walters, T. J. (1985). Substrate usage during prolonged exercise following a preexercise meal. *Journal of Applied Physiology, 59*, 429-433. https://doi.org/10.1152/jappl.1985.59.2.429

Davey, T., Byles, D., & Fallowfield, J. L. (2013). *A Review Of The Ministry Of Defence Feeding Ration Scales: Nutritional Requirements, Daily Messing Rate And Monetary Supplements* (Report No. 2013.012). Institute of Naval Medicine.

Edwards, V. C., Myers, S. D., Wardle, S. L., Siddall, A. G., Powell, S. D., Needham-Beck, S., Kefyalew, S. S., Singh, P. A., Orford, E. R., Venables, M. C., Jackson, S., Greeves, J. P., & Blacker, S. D.

([Under Review]). Nutrition and Physical Activity during British Army Officer Cadet Training: Part 1 - Energy Balance and Energy Availability.

Esliger, D., Rowlands, A., Hurst, T., Catt, M., Murray, P., & Eston, R. (2011). Validation of the GENEActiv accelerometer. *Medicine and Science in Sports and Exercise, 43*(6), 1085-1093. https://doi.org/DOI: 10.1249/MSS.0b013e31820513be

Fallowfield, J. L., Cobley, R., Davey, T., Delves, S. K., & Dziubak, A. (2010). *An Evaluation of the Physical Training Progression During Royal Marine Young Officer Training*. Institute of Naval Medicine.

Gillen, J. B., Trommelen, J., Wardenaar, F. C., Brinkmans, N. Y., Versteegen, J. J., Jonvik, K. L., Kapp, C., de Vries, J., van den Borne, J. J., Gibala, M. J., & van Loon, L. J. (2017). Dietary Protein Intake and Distribution Patterns of Well-Trained Dutch Athletes. *International Journal of Sport Nutrition and Exercise Metabolism, 27*(2), 105-114. https://doi.org/10.1123/ijsnem.2016-0154

Gleeson, M., Nieman, D. C., & Pedersen, B. K. (2004). Exercise, nutrition and immune function. *Journal of Sports Science, 22*(1), 115-125. https://doi.org/10.1080/0264041031000140590

Hill, R. J., & Davies, P. S. W. (2001). The validity of self-reported energy intake as determined using the doubly labelled water technique [Review article]. *British Journal of Nutrition, 85*, 415-430. https://doi.org/10.1079/BJN2000281

Horvath, P. J., Eagen, C. K., Ryer-Calvin, S. D., & Pendergast, D. R. (2000). The Effects of Varying Dietary Fat on the Nutrient Intake in Male and Female Runners. *Journal of the American College of Nutrition, 19*(1), 42-51. https://doi.org/10.1080/07315724.2000.10718913

Hoyt, R. W., Buller, M. J., DeLany, J. P., Stultz, D., Warren, K., Hamlet, M. P., Shantz, D., Matthew, W. T., Tharion, W. J., Smith, P., & Smith, B. (2001). *Warfighter physiological status monitoring (WPSM): energy balance and thermal status during a 10-day cold weather US Marine Corps Infantry Officer Course field exercise* (Technical Report No. ADA396133). Army Research Institute of Environmental Medicine.

Ivy, J. L., Goforth, H. W., Damon, B. M., Mccauley, T. R., Parsons, E. C., & Price, T. B. (2002). Early postexercise muscle glycogen recovery is enhanced with a carbohydrate-protein supplement. *Journal of Applied Physiology, 93*, 1337-1344. https://doi.org/10.1152/japplphysiol.00394.2002

Jeukendrup, A. E. (2014). A step towards personalized sports nutrition: carbohydrate intake during exercise. *Sports Medicine, 44*(Suppl 1), S25-33. https://doi.org/10.1007/s40279-014-0148-z

Kerksick, C., Harvey, T., Stout, J., Campbell, B., Wilborn, C., Kreider, R., Kalman, D., Ziegenfuss, T., Lopez, H., Landis, J., Ivy, J. L., & Antonio, J. (2008). International Society of Sports Nutrition position stand: nutrient timing. *Journal of the International Society of Sports Nutrition, 5*, 17. https://doi.org/10.1186/1550-2783-5-17

Mamerow, M. M., Mettler, J. A., English, K. L., Casperson, S. L., Arentson-Lantz, E., Sheffield-Moore, M., Layman, D. K., & Paddon-Jones, D. (2014). Dietary protein distribution positively influences 24-h muscle protein synthesis in healthy adults. *Journal of Nutrition, 144*(6), 876-880. https://doi.org/10.3945/jn.113.185280

Mathias, K. C., Almoosawi, S., & Karagounis, L. G. (2017). Protein and Energy Intakes Are Skewed toward the Evening among Children and Adolescents in the United States NHANES 2013–2014. *The Journal of Nutrition, 147*(6), 1160-1166. https://doi.org/10.3945/jn.116.245621

McAdam, J., McGinnis, K., Ory, R., Young, K., Fruge, A. D., Roberts, M., & Sefton, J. (2018). Estimation of energy balance and training volume during Army Initial Entry Training. *Journal of the International Society of Sports Nutrition, 15*(1), 55. https://doi.org/10.1186/s12970-018-0262-7

McClung, J. P., & Gaffney-Stomberg, E. (2016). Optimizing Performance, Health and Well-being: Nutritional Factors. *Military Medicine, 181*(1). https://doi.org/doi.org/10.7205/MILMED-D-15-00202

Montain, S., Shippee, R. L., & Tharion, W. J. (1997). *Carbohydrate-Electrolyte Solution during Military Training. Effects on Physical Performance, Mood State and Immune Function* (Technical Report No. T95-13) U.S. Army Research Institute of Environmental Medicine.

Nindl, B. C., Barnes, B. R., Alemany, J. A., Frykman, P. N., Shippee, R. L., & Friedl, K. E. (2007). Physiological consequences of U.S. Army Ranger training. *Medicine & Science in Sports & Exercise, 39*(8), 1380-1387. https://doi.org/10.1249/MSS.0b013e318067e2f7

Nosaka, K., Sacco, P., & Mawatari, K. (2006). Effects of Amino Acid Supplementation on Muscle Soreness and Damage. *International Journal of Sport Nutrition and Exercise Metabolism, 16*, 620-635. https://doi.org/10.1123/ijsnem.16.6.620

O'Leary, T. J., Saunders, S. C., McGuire, S. J., Venables, M. C., & Izard, R. M. (2018). Sex Differences in Training Loads during British Army Basic Training. *Medicine and Science in Sports and Exercise, 50*(12), 2565-2574. https://doi.org/DOI: 10.1249/mss.0000000000001716

Pasiakos, S. M., & Margolis, L. M. (2017). 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. *British Journal of Nutrition, 117*(6), 894-896. https://doi.org/10.1017/S0007114517000605

Phillips, S. M., & Van Loon, L. J. (2011). Dietary protein for athletes: from requirements to optimum adaptation. *Journal of Sports Science, 29*(Suppl 1), S29-38. https://doi.org/10.1080/02640414.2011.619204

Potgieter, S. (2013). Sport nutrition: A review of the latest guidelines for exercise and sport nutrition from the American College of Sport Nutrition, the International Olympic Committee and the

International Society for Sports Nutrition. *South African Journal of Clinical Nutrition, 26*(1), 6-16. https://doi.org/DOI: 10.1080/16070658.2013.11734434

Res, P. T., Groen, B., Pennings, B., Beelen, M., Wallis, G. A., Gijsen, A. P., Senden, J. M., & van Loon, L. J. (2012). Protein ingestion before sleep improves postexercise overnight recovery. *Medicine & Science in Sports & Exercise, 44*(8), 1560-1569. https://doi.org/10.1249/MSS.0b013e31824cc363

Richmond, V. L., Horner, F. E., Wilkinson, D. M., Rayson, M. P., Wright, A., & Izard, R. (2014). Energy balance and physical demands during an 8-week arduous military training course. *Military Medicine, 179*(4), 421-427. https://doi.org/10.7205/MILMED-D-13-00313

Rodriguez, N. R., DiMarco, N. M., & Langley, S. (2009). American College of Sports Medicine position stand. Nutrition and athletic performance. *Medicine & Science in Sports & Exercise, 41*(3), 709-731. https://doi.org/10.1249/MSS.0b013e31890eb86.

SACN. (2016). *SACN Statement on Military Dietary Reference Values for Energy* (Report No. SACN/Military/15/02). QinetiQ.

Shippee, R. L., Friedl, K. E., Kramer, T., Mays, M., Popp, K., W, A. E., Fairbrother, B., Hoyt, R., Vogel, J., Marchitelli, L., Frykman, P., Martinez-Lopez, L., Bernton, E., Kramer, M., Tulley, R., Rood, J., DeLany, J., Jezior, D., & Arsenault, J. (1994). *Nutritional and immunological assessment of Ranger students with increased caloric intake* (Technical Report No. T95-5). Army Research Institute of Environmental Medicine.

Tarnopolsky, M. (2004). Protein requirements for endurance athletes. *Nutrition, 20*(7-8), 662-668. https://doi.org/10.1016/j.nut.2004.04.008

Tharion, W. J., Lieberman, H. R., Montain, S. J., Young, A. J., Baker-Fulco, C. J., Delany, J. P., & Hoyt, R. W. (2005). Energy requirements of military personnel. *Appetite, 44*(1), 47-65. https://doi.org/10.1016/j.appet.2003.11.010

Witard, O. C., Jackman, S. R., Kies, A. K., Jeukendrup, A. E., & Tipton, K. D. (2011). Effect of Increased Dietary Protein on Tolerance to Intensified Training. *Medicine & Science in Sports & Exercise, 43*(4), 598-607. https://doi.org/10.1249/MSS.0b013e3181f684c9

Tables

Table 1: Group mean difference and 95% Confidence Intervals (95% CIs) of energy and macronutrient intake between the military dietary reference values as athletic guidelines during camp training (CAMP), field exercise (FEX) and combined camp and field training (MIX) for men and women

	CAMP	**FEX**	**MIX**
Energy Intake			
Men (guidelines: 4600 kcal·d^{-1})			
Average (kcal·d^{-1})	3847 ± 1069	3125 ± 805	3001 ± 450
Mean Difference (kcal·d^{-1})	-753	-1529	-1563
95% CI (kcal·d^{-1})	-1874, 386	-2297, -760	-1995, -1131,
p	0.145	0.004*	< 0.001*
Women (guidelines: 3500 kcal·d^{-1})			
Average (kcal·d^{-1})	3173 ± 493	2015 ± 446	2311 ± 208
Mean Difference (kcal·d^{-1})	-327	-1485	-1189
95% CI (kcal·d^{-1})	-783, 128	- 1897, -1073	-1381, -996
p	0.129	< 0.001*	< 0.001*
Relative Carbohydrate Intake			
Men (guidelines: 6 g·d^{-1})			
Average (g·d^{-1})	5.4 ± 1.2	5.1 ± 1.1	4.1 ± 0.6
Mean Difference (g·d^{-1})	-0.6	-1.1	-2.0
95% CI (g·d^{-1})	-1.9, 0.6	- 2.2, 0.0	-2.5, -1.4
p	0.252	0.049*	< 0.001*
Women (guidelines: 6 g·d^{-1})			
Average (g·d^{-1})	5.4 ± 1.1	3.8 ± 0.8	3.6 ± 0.5
Mean Difference (g·d^{-1})	-0.6	-2.2	-2.4
95% CI (g·d^{-1})	-1.6, 0.4	-3.0, -1.5	- 2.9, -1.9
p	0.219	< 0.001*	< 0.001*
Relative Protein Intake			
Men (guidelines: 1.2 g·d^{-1})			
Average (g·d^{-1})	1.8 ± 0.4	1.1 ± 0.2	1.3 ± 0.2
Mean Difference (g·d^{-1})	0.6	-0.2	0.1
95% CI (g·d^{-1})	0.2, 1.0	-0.3, 0.0	-0.1, 0.3
p	0.014*	0.054	0.184
Women (guidelines: 1.2 g·d^{-1})			
Average (g·d^{-1})	1.7 ± 0.2	0.9 ± 0.3	1.2 ± 0.1
Mean Difference (g·d^{-1})	0.5	-0.3	0.0
95% CI (g·d^{-1})	0.3, 0.7	-0.6, -0.1	-0.1, 0.1
p	0.001*	0.025*	0.479
Relative Fat Intake			
Men (guidelines: 1.5 g·d^{-1})			
Average (g·d^{-1})	1.9 ± 0.4	1.0 ± 0.2	1.3 ± 0.2
Mean Difference (g·d^{-1})	0.4	-0.5	-0.2
95% CI (g·d^{-1})	-0.2, 0.8	-0.6, -0.3	-0.4, 0.0
p	0.061	0.001*	0.052
Women (guidelines: 1.5 g·d^{-1})			
Average (g·d^{-1})	1.8 ± 0.4	0.9 ± 0.3	1.2 ± 0.1
Mean Difference (g·d^{-1})	0.3	-0.6	-0.3
95% CI (g·d^{-1})	-0.1, 0.7	-0.9, -0.4	-0.4, -0.2
p	0.082	0.001*	0.001*

* significant difference from dietary guidelines

Table 2: Mean difference, 95% Confidence Intervals (95% CIs) and reported effect size of energy and macronutrient intake between meal and snack times during camp training (CAMP), field exercise (FEX) and combined camp and field (MIX)

		Mean difference (meal - snack)	95% CI	t	df	p	Cohen's d
CAMP	Energy (kcal·d^{-1})	430 ± 208*	304, 555	7.46	12	< 0.001	2.07
	Carbohydrate (g·d^{-1})	45.8 ± 22.0*	32.3, 59.2	7.39	12	< 0.001	2.05
	Protein (g·d^{-1})	25.9 ± 5.7*	22.5, 29.3	16.51	12	<0.001	4.58
	Fat (g·d^{-1})	13.7 ± 7.2*	9.4, 18.1	6.90	12	0.001	1.91
FEX	Energy (kcal·d^{-1})	35 ± 313	-154, 224	0.40	12	0.695	0.11
	Carbohydrate (g·d^{-1})	-7.0 ± 29.6	-24.9, 10.9	-0.85	12	0.411	-0.24
	Protein (g·d^{-1})	2.4 ± 8.6	-2.8, 7.6	1.00	12	0.337	0.28
	Fat (g·d^{-1})	7.3 ± 14.8	-1.6, 16.2	1.79	12	0.099	0.50
MIX	Energy (kcal·d^{-1})	334 ± 151*	243, 425	8.00	12	< 0.001	2.22
	Carbohydrate (g·d^{-1})	30.3 ± 13.8*	22.0, 38.6	7.94	12	< 0.001	2.20
	Protein (g·d^{-1})	16.2 ± 3.7*	14.0, 18.4	15.98	12	< 0.001	4.43
	Fat (g·d^{-1})	14.2 ± 5.2*	11.0, 17.3	9.68	12	< 0.001	2.68

* represents difference between intake at meal times and intake at snack times, $p < 0.05$.

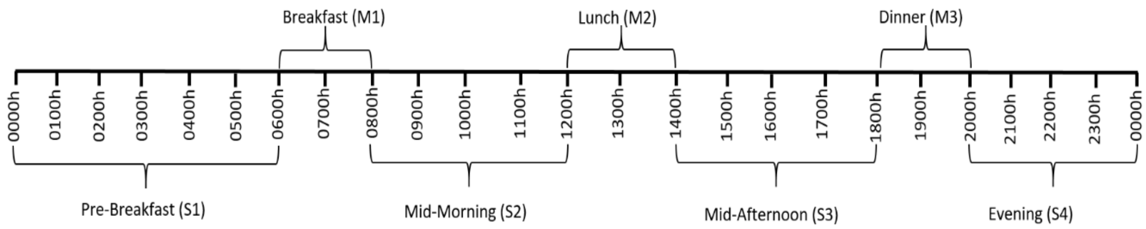

Figure 1: Schematic of timings for Meal (M) and Snack (S) categories.

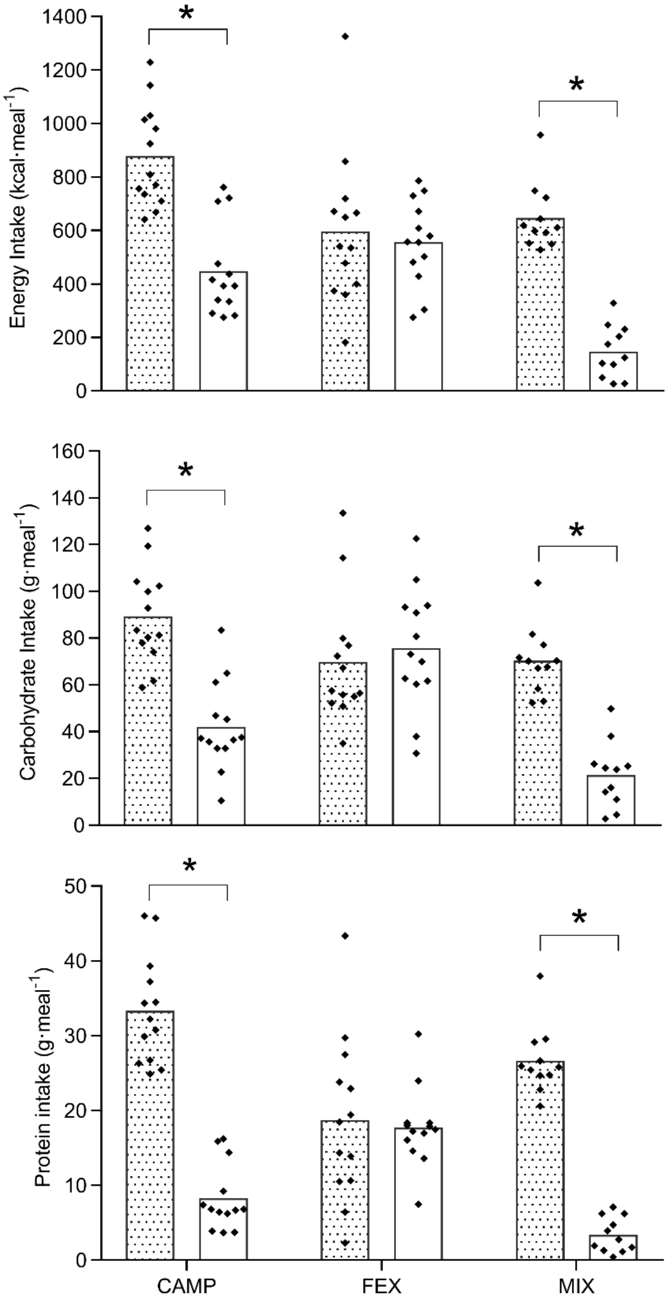

Figure 2: Energy (kcal·meal^{-1}), carbohydrate and protein (g·meal^{-1}) of all Meals (M; dotted bar) and all Snacks (S; white bar) during camp training (CAMP), field exercise (FEX) and combined camp and field training (MIX) showing individual intakes. * represents statistical significance between meal and snacks, $p < 0.05$.

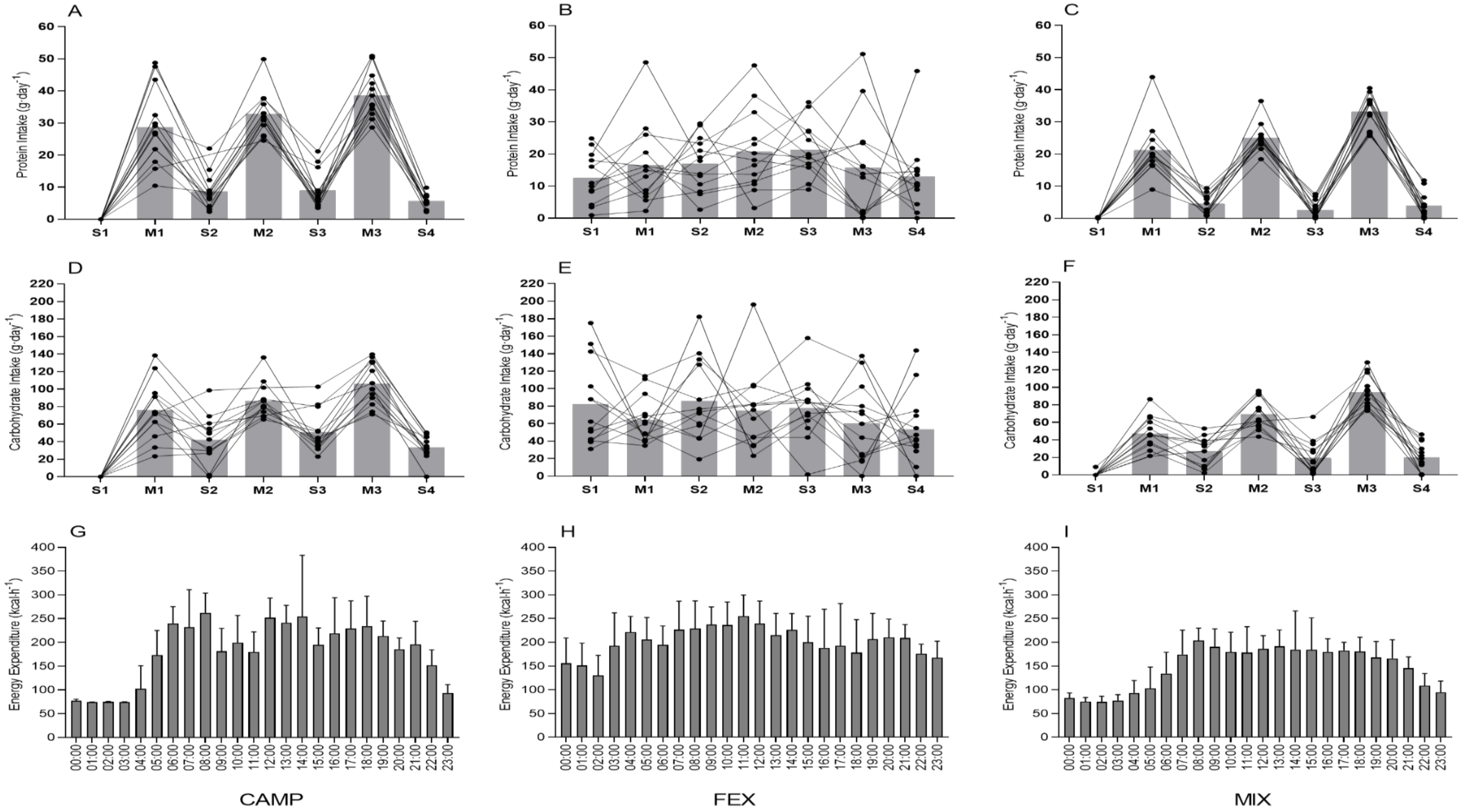

Figure 3: Average (bars) and individual (black circles) daily distribution of protein (A-C) and carbohydrate intake (D-F), and the distribution of estimated hourly Energy Expenditure [with standard deviation] (G-I) for training in camp (CAMP) on field exercise (FEX) and combined camp and field training (MIX). No data are shown during S1 for CAMP as no food was consumed during this period.