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Diet macronutrient composition, physical activity and body composition in soldiers during six months deployment

Diet composition, physical activity and body composition in soldiers during deployment

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STRUCTURED SUMMARY

Introduction

Optimal diet together with good physical fitness maintains readiness and military performance during longer deployments. The purpose of this study was to describe changes in dietary macronutrient and energy intake, total physical activity and body composition during a 6-month deployment in South Lebanon. Furthermore, associations of diet macronutrient intake and physical activity on body composition were also studied.

Materials and Methods

Forty male soldiers kept a 3-day food diary and their body composition was measured via bioimpedance and ultrasonography. Total physical activity was evaluated by accelerometers in a subgroup of participants. Measurements were conducted in the PRE-, MID- and POST-deployment.

Results

Mean carbohydrate intakes were 39.5-42.6 E%, protein intakes 18.7-22.3 E% and fat intakes 34.9-35.7 E%. Daily energy intake remained stable (10.1-10.3 MJ/D). Total physical activity was decreased during deployment (e.g. step count from 9835 ± 2743 to 8388 ± 2875 steps/day, $p=0.007$). Skeletal muscle mass and subcutaneous fat increased by 1.3% ($p=0.019$) and 1.9% ($p=0.006$), respectively. Energy and fat intake associated positively with body mass and skeletal muscle mass ($r=0.31$-0.48, $p<0.05$-0.001).

Conclusions

Carbohydrate intakes and physical activity were low, compared to the general recommendations. Protein intakes were relatively high. Skeletal muscle mass and subcutaneous fat increased. Suboptimal diet together with low level of physical activity may have a negative impact on body composition, physical performance, and cardiometabolic health. Consequently, soldiers should be encouraged to consume more fibre-rich carbohydrates and less saturated fatty acids as well as maintain a high level of physical fitness to sustain military readiness during long-term deployments.

INTRODUCTION

Military deployments are often physically and mentally demanding. Soldiers have to maintain continuously high levels of readiness and must respond to external stimuli whenever needed. Optimal nutritional status improves physical and mental performance, helps to prevent infections and enhances recovery after diseases and injury (1). However, previous studies have found fluctuations in the diet and nutritional status during prolonged deployments (2,3). For example, a worsened dietary quality, including decreased intake of calcium and vitamin D, was observed in special operators during deployment (3). Furthermore, reduced energy and food intake has been demonstrated to occur due to high temperature, stress and menu fatigue (2).

The total energy expenditure of soldiers is dependent on their military tasks in different environments. In garrisons, energy expenditure varies from 13.0 to 29.9 MJ/d (3100 -7100 kcal/d) in male soldiers (4), in field exercises 20.9-41.9 MJ/d (5000-10000 kcal/d) (5-8) and in longer deployments 10.5-15.1 MJ/d (2500-3600 kcal/d) (2,9-10). If the energy expenditure is very high, body mass often decreases, which occurs frequently in demanding military operations (2,6,8-10). For example, in a 6-month military operation in Chad, a decrease of 3.5% in body mass was found (9). Furthermore, during the first half of a 6-month deployment in Afghanistan, the body mass of soldiers decreased by 4.6%, which was partly regained (+2.2%) during the last three months (2). In another study, fat free mass decreased by 3.5 % and body fat increased by 1.9 % during 9- months' deployment in Afghanistan (9). These changes were also accompanied by decreases in aerobic capacity (-4.5%) and upper body muscle power (-4.9%).

Several studies (2, 8-10) have assessed the changes in physical fitness, strength and endurance capacity induced by military deployments, but only a few studies (11) have reported total physical activity or work load responses of deployment. Energy expenditure can partially reflect the amount of total physical activity but a more direct form of measurement is needed to describe how active or passive soldiers are in their duties and in their leisure time.

The main purpose of the present study was to describe changes in dietary macronutrient and energy intake, total physical activity and body composition during a 6-month deployment in South Lebanon. In addition, associations of dietary macronutrient intake and physical activity on body composition were investigated during deployment.

METHODS

Subjects and study design

Forty healthy Finnish male soldiers (mean ± SD age 29.5 ± 8.4 yrs., height 178.7 ± 6.5 cm, body mass 77.8 ± 8.7 kg, BMI 24.4 ± 2.7 kg/m^2) who were deployed for six months in a military operation in Lebanon, voluntarily took part in the study. They were informed of the study design and gave their written consent to participate. The study protocol and procedure were reviewed by the Ethical Committee of the Central Finland Health Care District.

All measurements were carried out three times in a military base in South-Lebanon. Initial measurements (PRE) were undertaken after a two week acclimatization period, and the respective measurements were repeated after 9 (MID) and 19 weeks (POST) after the initial measurements.

Dietary intake

The dietary intake data were estimated from 3-day food diaries on consecutive days of a week in all three measurement points. Participants were asked to maintain their regular food consumption and to register all the food, fluid and nutritional supplements immediately after each meal by writing them down to food diary. They were asked to estimate food weights using household measures and standard units. The research group weighed certain portions (meat, fish, bread, fruits, vegetables) to improve accuracy of the measurements. Food diaries were reviewed and then analyzed with Nutri Flow (Flow-team, Oulu, Finland) software program. Digital questionnaire was used in MID deployment to record the use of protein supplements.

In the camp breakfast, lunch and dinner were supplied from Mondays to Saturdays and on Sundays, only brunch and dinner were served. In addition, there was a possibility to buy beverages, snacks and meals from local restaurants outside the camp or when patrolling. Use of alcohol was restricted to two portions per day.

Physical activity

Total daily physical activity (PA) data were collected from a subgroup of participants (n=29), while the rest of the participants were obligated to their military duties. Total PA was measured via a three-dimensional accelerometer at a frequency of 100 Hz (Hookie AM20, Traxmeet, Oulu, Finland). The participants were instructed to wear the device on the left side of their waist at all times while they were awake for ten days, except during showering, sauna or swimming. The data were analyzed and calculated for sedentary behavior (SB), e.g. standing and sitting/lying (metabolic equivalent, MET < 1.5), and for physical activity, e.g. step count, number of breaks during SB, MET mean, MET max (/min), light PA (MET 1.5-3.0) and moderate to vigorous PA (MVPA, MET > 3.0) (12,13).

The participants were able to do strength and aerobic training (cycling, rowing, treadmill running) in two gyms in the camp. In addition, there was opportunity for walking, Nordic walking and running inside the military area as well as some ball games (soccer, beach volley, basketball).

Body composition

All body composition measurements were recorded in a fasting state in the morning (0530-0730, with participants wearing underwear. Body mass, skeletal muscle mass, fat mass and fat % were determined by using a segmental multi-frequency bioimpedance analysis assessment (InBody 720, Biospace, South Korea). Waist circumference was measured with a measurement tape (Seca 210, Seca, Hamburg, Germany) midway between the lowest rib and the iliac crest after light expiration. The average of three measurements was used.

Subcutaneous fat and muscle thickness of the vastus lateralis (VL) and triceps brachii (TB) muscles were measured via ultrasonography technique (Sonoace R3, Samsung Medison, Co & Ltd, Seoul, Korea). Measurement points of VL and TB were marked earlier based on anatomical landmarks. The probe was moved manually on the electrode gel over the marked points of the skin avoiding compression of muscle tissue. The leg support was used to diminish compression to the tissue. Three scans were taken for later analysis with an electrical caliper and the image processing system integrated in the ultrasound device and the average of these scans was used.

Statistical analyses

Statistical analyses were carried out by commercial software (IBM SPSS 22.0.0, Chicago, Illinois, USA). Data were analyzed by repeated-measured ANOVA and paired t-tests. If assumptions were not met logarithm transformations were applied (protein intake (E%, g/d), CHO intake (g/d), fibre intake (g/d), subcutaneous fat of VL and TB (cm)) or nonparametric Friedman's tests utilized (water intake, PUFA). Spearman's product moment correlation coefficients were used for testing linearity of body composition, dietary intake and physical activity data. The statistical significance was met when p-values were under 0.05.

RESULTS

Nutrient intakes

Participants ate 4.9 ± 1.0 (PRE), 4.7 ± 0.9 (MID) and 4.4 ± 0.8 (POST) meals per day (means ± SD). Reported energy intake was 10.1 - 10.5 MJ/d during deployment. Carbohydrate (CHO) intake E%, g/d) increased from PRE to MID. Protein intake (E%, g/d) decreased from PRE to MID but then recovered. Water intake decreased from PRE to POST (**Table 1**). A total of 57.5 % of participants reported using of protein supplements in the MID deployment. Alcohol intake (g/d) was 2.9 ± 6.0 (PRE), 2.3 ± 5.7 (MID) and 1.7 ± 4.6 (POST).

Total physical activity

Step count, light PA, MVPA, standing, sitting and lying and number of breaks during SB decreased from PRE to MID (**Table 2**). Step count, MET mean, MVPA and number of breaks during SB decreased from PRE to POST.

Body composition

Skeletal muscle mass (SMM) increased from PRE to POST. Waist circumference decreased from PRE to MID and further to POST. Body mass, BMI, fat mass, fat % or visceral fat area did not change statistically significantly during the deployment. Body composition data are shown in **Table 3**.

Muscle thickness of TB increased from PRE to MID and further to POST (3.84±0.63, 3.92±0.55, 4.04±0.62, respectively, p=0.016 MID_POST, p=0.013 PRE_POST). Muscle thickness of VL decreased from MID (3.81±0.71) to POST (3.58±0.72, p=0.019). Subcutaneous fat thickness of VL first decreased from PRE (1.03±0.47) to MID (0.97±0.45, p=0.047) but, thereafter, returned to baseline by POST (1.05±0.45, p=0.006 MID_POST). Subcutaneous fat thickness of TB increased from the PRE (0.67±0.26) to POST deployment (0.72±0.24, p=0.003).

Energy and fat intake correlated positively with SMM in all measurement points. Fat intake correlated positively with body mass in PRE, MID and POST, and energy intake with body mass in MID and POST. Other statistically significant correlations are presented in **Table 4**. Protein intake did not correlate significantly with body mass, SMM or fat %.

Statistically significant correlations were found between standing time (MET < 1.5) and body mass, BMI, fat mass, fat%, visceral fat area and waist circumference in the PRE and POST measurements (**Table 5**).

DISCUSSION

The present results demonstrated that the macronutrient intake did not meet the general nutritional requirements (14) or the Military Dietary Reference Intakes (MDRI) (15). Energy intake remained low and stable during the deployment. The daily physical activity of soldiers was very low, but their body mass did not change, indicating that the soldiers actually remained in energy balance. According to body composition measurements, skeletal muscle mass increased slightly. In addition, ultrasound measurements revealed that subcutaneous fat thickness increased in the upper and lower extremities, while muscle thickness increased only in the upper body. Energy and fat intake associated with skeletal muscle mass and the total time accumulated from standing with body mass, BMI, fat mass, fat%, visceral fat area, and waist circumference during the PRE and POST measurements.

Macronutrient intake

Intake of carbohydrate remained below 45 E% in all measurement points while the recommended level is 45-60 E% according to the Nordic Nutrition Recommendations (14). Carbohydrate intake increased during the first half of the deployment, but returned to the baseline levels by POST. Increased carbohydrate intake was related mainly to increased saccharose intake during the first half of the deployment. According to MDRI soldiers should consume carbohydrates < 494 g/d in operational environment (15) when mean carbohydrate intake remained only 242-269 g/d in this study. For soldiers carbohydrates are the main energy substrate for physical and military training and together with adequate energy intake they are essential for recovery (16). The average fat intake followed the Nordic Nutrition Recommendations and partly the MDRIs, where fat intake is recommended ≤ 35 E% (14,15). In addition the soldiers consumed more saturated fatty acids (12.3-13.2 E%) than is typically recommended (14). However, saturated fat intake was not as high as the Finnish general population according to National FINDIET 2012 Survey (17). Protein intake decreased during the first half of the deployment but during PRE and during POST the mean intake was more than 20 E% which is higher than the Nordic recommendation (10-20 E%) (14). Soldiers consumed protein ≥ 117 g/d in all measurement points which exceeds MDRIs in garrison (63-119 g/d) and in operation (≥ 91 g/d). Increased protein intake may be beneficial for soldiers in military operations in maintaining their lean body mass and improving recovery (18). Overall, macronutrient intake during the deployment supports the findings of National FINDIET 2012 Survey (17). Similar results were observed in soldiers of the 101st Airborne Division and in Afghanistan, who consumed less carbohydrates and more saturated fat than is recommended (18,2). In all circumstances, soldiers need to ensure that the macronutrient contents of their diet support the maintenance or development of physical performance and health. For example, carbohydrate ingestion has been found to reduce cortisol response in stressful environments and this may have potential implications in a successful performance of military operations (19).

Factors explaining changes in macronutrient intake in the present study are unclear. Breakfast, lunch and dinner were systematically supplied on six days per week, but on Sundays, only brunch and dinner were served. Other meals and snacks could be bought at local restaurants outside the military base. A total of 57.5 % soldiers reported the use of protein supplements in MID deployment, which may explain changes in protein intake. Together with progressive strength training, this could also explain increased muscle mass in the upper limbs. However, subcutaneous fat mass increased in the upper and lower limbs at the same time, which may indicate that soldiers probably got too much energy from the diet. The operational situation changed in the MID deployment in the South Lebanon, which may have negatively influenced food consumption and exercise routines. Some soldiers also reported a decreased mood-state and too monotonous life on the camp during the latter half of the operation, which might possibly have had a negative effect on their health behavior.

Physical activity

Total daily physical activity decreased during the deployment according to step count, mean MET and MVPA, while the time for sedentary behavior (MET < 1.5) increased. Step count did not meet the minimum daily health recommendation (10 000 steps) (20). One reason for the observed level of physical activity is low work load and calm security situation in the operational area (11). Secondly, the camp area was not wide that the soldiers took only few steps for their daily routines. Despite the training facilities inside the camp, the soldiers could not sustain their levels of physical activity during this deployment. Heart rate responses and stable hormonal levels support the assumption that the soldiers did not experience overload symptoms (11). Due to the nature of accelerometer movement detection, some stationary physical activity such as weight lifting was not necessarily recorded by the accelerometers (21).

Low work load combined with increased sedentary behavior needs to be monitored, especially, if the soldiers have to maintain their readiness during the deployment. While the operational duties may change rapidly, soldiers should maintain their readiness at all the times and thus, enhance their physical training during passive phases of operation.

Body composition

Total skeletal muscle mass slightly increased during the deployment but muscle thickness of TB, measured by ultrasonography, increased from PRE to MID and MID to POST while muscle thickness of VL decreased from MID to POST. However, increased skeletal muscle mass in upper limbs is a positive finding of the present study but at the same time, subcutaneous fat increased in TB (PRE-POST) and in VL (MID-POST). Total fat% or fat mass did not change during the deployment.

These results could at least partly be explained by the results of physical activity: the soldiers became more passive and subcutaneous fat increased simultaneously in their body. Despite the increase in skeletal muscle mass, excessive subcutaneous fat in the upper and lower limbs is not beneficial for soldiers. Total time, accumulating from standing, correlated positively with body mass, VFA, fat mass, fat%, waist circumference and subcutaneous fat thickness of VL in the PRE- and POST-deployment. This may indicate that soldiers' standing time increased, which diminished their physically active minutes. A previous study did not find association between sedentary behavior and fat mass but a positive association between higher physical activity and fat free mass was observed (22). Energy and fat intake (g/d) were positively correlated with body mass and skeletal muscle mass in all measurement points in the present study, when observing the amount of energy and fat eaten. Systematic literature review by Fogelholm et al suggested, nevertheless, that proportional macronutrient composition of the diet (E%) did not predict changes in body weight or waist circumference in longitudinal cohort studies (23).

Strengths and limitations of the study

A unique set of data regarding food intake straight from the deployment area was obtained under a controlled situation due to a research group in the vicinity which enabled the accurate observation of food servings during the measurements. To date, there are only a few studies (2,3,9), where nutritional information has been recorded straight from the operational area. However, food diaries often underestimate nutrient intake due to underreporting (24), which can lead to lower reported energy intake levels. Inaccuracy and forgetfulness may also distort data of food diaries (24).

The use of accelerometers is an objective method to objectively estimate daily physical activity and sedentary behavior (21). Nevertheless, the method describes better only endurance-type activities. Some strength training exercises and their intensities may not be accurately recorded by an accelerometer worn at the hip level and, for example, strength training performed standing (e.g. biceps curl) may be interpreted as sedentary behavior or light PA by the accelerometer.

Bioimpedance results only partly supported the ultrasonography data. While fat thicknesses increased in TB and VL, whole body fat mass or fat% did not change during the deployment. Bioimpedance analysis is based on fluid content of the body and despite the controlled measurements, results can be inaccurate, particularly, on the individual level. Fat free mass estimated via bioimpedance has been reported to have poor accuracy compared to DXA (25). Body composition measurement with ultrasound can also be a valid method to estimate thicknesses of muscle and subcutaneous fat (26). Landmarks by micro pigmentation were drawn to skin to make sure the same spots of measurements and the same investigator conducted the measurements throughout the study.

CONCLUSION

Inadequate carbohydrate intake, low physical activity and an increase of subcutaneous fat during long-term deployment indicate that soldiers need to modify their dietary habits and exercise routines to respond the changing circumstances. Based on the present findings, the soldiers should be encouraged to eat more healthy carbohydrates (e.g. whole grains, fruits and vegetables) and less foods with saturated fatty acids (fatty meat and dairy) whilst maintaining adequate protein consumption in their daily diet during the operation. In calm security situation the enhanced physical training program should be recommended to sustain optimal body composition, physical fitness and military readiness during deployment period.

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Table 1. Mean (±SD) energy, dietary macronutrient and water intake during the deployment (n=40).

	PRE	MID	POST
Daily energy intake (MJ/d (kcal/d))	10.3 ± 2.6 (2454 ± 616)	10.5 ± 2.8 (2521 ± 660)	10.1 ± 2.8 (2425 ± 676)
Carbohydrates (E %)	39.5 ± 6.9	42.6 ± 7.7 p=0.007 PRE_MID	40.1 ± 9.1
Protein (E %)	21.7 ± 3.8	18.7 ± 4.6 p<0.001 PRE_MID	22.3 ± 5.0 p<0.001 MID_POST
Fat (E %)	35.0 ± 7.0	35.7 ± 5.0	34.9 ± 7.0
Carbohydrates (g/d)	242.8 ± 77.5	268.5 ± 85.0 p=0.038 PRE_MID	242.4 ± 84.7 p=0.024 MID_POST
Protein (g/d)	132.5 ± 40.3	117.3 ± 41.0 p=0.006 PRE_MID	134.7 ± 46.2 p=0.002 MID_POST
Fat (g/d)	95.6 ± 31.6	100.4 ± 31.4	95.0 ± 35.0
Fibre (g/d)	17.5 ± 8.4	21.3 ± 10.4 p=0.019 PRE_MID	16.0 ± 7.6 p<0.001 MID_POST
Saccharose (E %)	10.2 ± 5.2	11.9 ± 5.0 p=0.039 PRE_MID	10.6 ± 6.0
Saturated fatty acids (E %)	13.2 ± 2.7	12.5 ± 2.5	12.3 ± 3.3
Monounsaturated fatty acids (E %)	12.6 ± 2.2	12.5 ± 2.2	11.9 ± 2.8
Polyunsaturated fatty acids (E %)	15.7 ± 54.8	16.2 ± 37.6	8.6 ± 18.6
Water (L/d)	4.5 ± 1.6	4.2 ± 1.7	3.7 ± 1.6 p<0.001 PRE_POST

Table 2. Mean (±SD) total daily physical activity and sedentary behavior data.

	PRE (n=29)	MID (n=29)	POST (n=29)
Step count	9835 ± 2743	8538 ± 2699 p=0.010 PRE_MID	8388 ± 2875 p=0.007 PRE_POST
MET mean	1.59 ± 0.16	1.55 ± 0.16	1.52 ± 0.15 p=0.046 PRE_POST
MET max (/min)	7.80 ± 1.41	7.86 ± 1.46	8.29 ± 1.87
Light PA (MET 1.5-3.0) (h:min)	1:50 ± 0:26	1:36 ± 0:22 p=0.036 PRE_MID	1:41 ± 0:28
MV PA (MET > 3.0) (h:min)	1:12 ± 0:23	1:03 ± 0:24 p=0.007 PRE_MID	1:00 ± 0:24 p=0.001 PRE_POST
Standing (h:min)	2:05 ± 0:32	1:38 ± 0:28 p<0.001 PRE_MID	1:48 ± 0:49 p=0.001 PRE_POST
Sitting and lying (h:min)	11:00 ± 1:49	10:32 ± 1:35 p=0.005 PRE_MID	11:15 ± 1:46
Number of breaks during SB	37 ± 9	33 ± 10 p=0.001 PRE_MID	31 ± 9 p=0.002 PRE_POST

MET = metabolic equivalent, PA = physical activity, MV = moderate and vigorous, SD= sedentary behaviour

Table 3. Mean (±SD) body composition characteristics during the deployment (n=40).

	PRE	MID	POST
Body mass (kg)	77.8 ± 8.7	78.0 ± 9.0	78.3 ± 9.5
Skeletal muscle mass (kg)	38.5 ± 4.3	38.7 ± 4.3	39.0 ± 4.7 p=0.009 PRE_POST
Body fat %	13.6 ± 4.3	13.2 ± 4.4	13.3 ± 4.1
Visceral fat area (cm^2)	49.5 ± 18.3	51.8 ± 22.3	51.9 ± 20.1
Waist circumference (cm)	86.2 ± 7.0	83.6 ± 6.6 p<0.001 PRE_MID	83.3 ± 6.6 p<0.001 PRE_POST

Table 4. Correlation coefficients and their p-values (n=40) between energy, CHO and fat intake and body composition.

	Body mass	SMM	Fat %
Energy intake (kcal/d)	MID: 0.31, p=0.05 POST: 0.38, p=0.02	PRE: 0.41, p=0.01 MID: 0.35, p= 0.03 POST: 0.48, p= 0.02	
CHO intake (g/d)	PRE: 0.41, p=0.01 POST: 0.48, p=0.01		PRE= -0.32, p=0.05
Fat intake (g/d)	PRE: 0.31, p=0.05 MID: 0.38, p=0.02 POST: 0.38, p=0.02	PRE: 0.42, p=0.01 MID: 0.43, p=0.01 POST: 0.41, p=0.01	

SMM=skeletal muscle mass

Table 5. Correlations and their p-values (n=36-37) between standing time and some body composition variables

Physical activity	Body mass	Fat %	VFA	WC
Standing time	PRE: 0.38, p=0.02 (n=37) POST: 0.37, p=0.03 (n=36)	0.44, p=0.01 (n=37) 0.54, p=0.01 (n=36)	0.37, p=0.02 (n=37) 0.60, p=0.01 (n=36)	0.46, p=0.01 (n=37) 0.48, p=0.01 (n=36)

VFA= visceral fat area, WC=waist circumference