Scientific Advisory Committee on Nutrition

SACN STATEMENT ON MILITARY DIETARY REFERENCE VALUES FOR ENERGY

December 2016

Background

1. In 2008, the Ministry of Defence (MOD) commissioned QinetiQ[1] to prepare military Dietary Reference Values (DRVs) for energy and nutrient intakes specifically for training and operational (T&O) military personnel, non-operational/non-training (NONT) military personnel and adolescents in military training (Casey, 2008). The military energy intake recommendations informed the MOD's policy document on catering food provision and nutrition (MOD, 2016) which aims to provide Armed Forces personnel with the energy required to fulfil their military roles. However, the UK military DRVs drew extensively on military research and recommendations from the United States, and were largely based on historical physical activity and body composition data.

2. The principal differentiators between personnel with respect to the guidance presented by the military DRVs are males vs. females and T&O vs. NONT. These differentiators drive the energy requirement (which is modified for physical activity level during T&O), and in turn the nutrient requirements. The data informing energy provision in the current military DRVs are largely Army-centric, and do not take into account the other UK military services (namely, Royal Navy (RN) and Royal Air Force (RAF)), which undertake military training as well as land and/or non-land operational deployments. In terms of macronutrient intakes, the current guidance (for carbohydrates and protein) draws on the American College of Sports Medicine, American Dietetic Association and Dietitians of Canada guidance (ACSM, ADA, DC, 2000) and recommendations published by the International Olympic Committee Medical Commission (IOC, 2003a, 2003b). They are therefore based on evidence from athletic populations undertaking sports training and competition rather than being specific to military populations.

3. At the time of drafting the military DRVs (Casey, 2008), there was a lack of studies that had investigated military populations undertaking occupational roles. Moreover, limited data were available describing the nutritional requirements of UK personnel undertaking military training, as well as land and sea operations. Thus, the evidence informing the military DRVs was somewhat limited in its scope. However, since publishing the

[1] QinetiQ is a British multinational defence technology company, with its headquarters in Farnborough, Hampshire, UK. It originated from the former UK Government Defence Evaluation and Research Agency (DERA), following privatisation in June 2001.

military DRVs, work commissioned by the Army Recruiting and Training Division (ARTD) of the British Army, and a programme of work tasked by the UK MOD's Surgeon General (see paragraph 5), has gathered data from UK military personnel – in training and on operations – to address a number of the military DRV limitations from an energy requirements perspective.

4. The primary objective of the ARTD-commissioned work was to assess the physical demands of Army initial military training for recruits and officer cadets, and comment on its acceptability in terms of achieving the physical training objectives (Shaw & Fallowfield, 2014[2]). A secondary, but nonetheless important, objective of the commissioned studies was to gather evidence related to energy balance across the training programmes.

5. The Surgeon General's Armed Forces Feeding Project has evaluated the adequacy of feeding provision in training (Fallowfield *et al.*, 2010a; Linnane *et al.*, 2010; Dziubak *et al.*, 2011; Fallowfield *et al.*, 2012a; Fallowfield *et al.*, 2012b), and on operations on land (Fallowfield *et al.*, 2014) and at sea (Fallowfield *et al.*, 2012c; Fallowfield *et al.*, 2013). The adequacy of feeding provision for UK military roles, in training and on operations, was assessed in terms of the physical demands and estimated energy requirements (relative to the energy intakes) and associated changes in physical fitness and body composition. This work (which involved all three military services) has provided an expanded evidence base to inform the required energy provision to UK Armed Forces personnel.

6. Over recent years, evidence has emerged to suggest that the wider societal trends towards increased body mass and obesity are also prevalent in the Armed Forces (Wood, 2007; Shaw *et al*., 2013). A study investigating the prevalence of obesity in RN personnel, showed that 23% and 37% of male and female participants respectively were classified as being at risk of obesity-related diseases, as assessed by measurements of their waist circumference (Shaw *et al*., 2013). This risk has been shown to increase with age (Sundin *et al*., 2011). Moreover, whilst initial (Phase-1)[3] military training is associated with a reduction in body fat on entry to the Armed Forces, this is not maintained during (Phase-2) trade training (Shaw & Fallowfield, 2013). It is hypothesised that this is most likely as a consequence of a poor diet (Shaw & Fallowfield, 2013). The health and economic impacts of overweight and obesity on the UK Armed Forces are considerable. For example, in the RN, excess body mass has been associated with 1) an increased risk of injury (Bridger, 2003); 2) a higher risk of being medically downgraded as unfit for duty (Bennett *et al.,* 2011); 3) a reduced self-reported ability to work (Bennett & Bridger, 2010).

7. Nutrition is fundamental to military physical capability, as well as the health and well-being of personnel. The implications of having a poorly nourished force are

---

[2] This review was undertaken at the request of the Ministry of Defence who provided access to a number of internal Institute of Naval Medicine (INM), Optimal Performance Limited and Defence Science and Technology Laboratory (Dstl) reports which are included in the reference list. Documents are available as follows: INM reports from the INM librarian at NAVYINM-CSINFOLIBAO@mod.uk;Optimal Performance Limited and Dstl reports from the Dstl Knowledge Services Information Centre at knowledgeservices@dstl.gov.uk.

[3] Military training in the UK is divided into phases of training. Phase-1 training refers to 'initial military training', where the purpose is to turn civilians into partly trained service personnel. This training is completed through Phase-2 training, where recruits and officer cadets learn their specific trade or specialism that will support their professional role within the Armed Forces.

considerable. These include 1) increased risk of ill health; 2) increased associated medical care costs; 3) a reduced number of military personnel on duty due to absenteeism; 4) reduced operational readiness; 5) decreased retention of personnel (Dall et al., 2008; McLaughlin & Wittert, 2009). A reduction in military personnel and the prevailing tempo of operational commitments make it absolutely necessary for *all* UK military personnel to be ready and fit to deploy. As such, it is therefore imperative that measures are taken to promote optimal health and wellbeing, as well as to reverse any trends towards adverse health indicators. Dietary balance and nutritional quality of the food provision, and the nutritional (energy) intakes of Armed Forces personnel, need to be improved to be consistent with national guidelines for healthy eating. Moreover, the MOD requires a tighter specification to ensure that external agencies (contract caterers) procure and cater to the necessary standards to achieve a healthier provision.

8. Since 2011, Government Departments and Agencies have been required to meet Government Buying Standards for Food and Catering Services (GBSF) as part of the Greening Government Commitments. The MOD was given an exemption for active service/training personnel, where standards had already been set given the higher assessment of need in these situations. GBSF prescribe nutritional and environmental criteria for awarding food service/catering delivery to reduce energy, salt, saturated fat and sugar content while increasing the provision of fruit & vegetables, oily fish and dietary fibre.

9. Against this background, the MOD asked the Scientific Advisory Committee on Nutrition (SACN) to consider whether the recent evidence describing the energy requirements of military personnel was sufficient to allow UK military DRVs for energy to be updated, applying the approach used to determine the revised DRVs for energy for the general population in 2011 (SACN, 2011). The Institute of Naval Medicine requested advice on military-specific DRVs for those roles and/or activities where there were evidenced energy expenditures that were different from the estimated average requirements (EAR) for UK population subgroups.

Terms of Reference for the Military DRV for Energy Working Group

10. The terms of reference for the Military DRV for Energy Working Group were to:

- Provide recommendations for estimated DRVs for energy for those military occupational roles that have evidenced requirements different from the estimated average requirements for UK population subgroups recommended by SACN in 2011.

- Provide recommendations that take into account environment and relevant population descriptors such as age, body size (including consideration of body composition), levels of physical activity, and gender.

- Consider the implications of these energy recommendations for the nutrient requirements of UK military populations – especially in terms of macronutrient requirements for high energy occupational roles.

11. In addressing these terms of reference, this position statement: considers the available evidence related to the energy requirements of military personnel; identifies evidence gaps and how these could be addressed; and makes recommendations for DRVs for energy for military personnel.

12. Due to limitations in the availability of specific data and the importance of delivering recommendations within a reasonable time, this document provides a position statement rather than a full risk assessment report.

Dietary Reference Values for energy for the general UK population: SACN's 2011 report

13. In 2011, SACN reviewed the DRVs for energy for the general UK population, updating the Committee on Medical Aspects of Food Policy (COMA) recommendations published in 1991 (COMA, 1991).

14. For most nutrients, the Dietary Reference Value is identified as the Reference Nutrient Intake (RNI), which is the intake sufficient to meet the requirements of 97.5% of people in a group. However, for dietary energy, the DRV is defined differently i.e. it is equal to the EAR. The RNI for dietary energy is not used as it represents an excess energy intake for the majority of the population.

15. The 2011 report used a "prescriptive" approach, using a Body Mass Index (BMI) of 22.5 kg/m^2, to devise energy requirements. In recognition that the UK population had a high and increasing proportion of overweight and obese individuals it set energy reference values in relation to body weights that were likely to be consistent with general health. Adoption of these prescriptive values by groups with body weights below or above such ranges would tend to mediate weight change towards the healthier, more desirable body weight range.

16. The SACN Framework for the Evaluation of Evidence (SACN, 2012) was used as the basis for identifying and assessing published evidence on Total Energy Expenditure (TEE), which was used to guide derivation of energy reference values. Only studies using the Doubly Labelled Water (DLW) method to measure TEE were considered. The DLW method (International Atomic Energy Agency, 2009) is generally recognised as the most accurate measure of free-living TEE currently available. DLW measures the rate of carbon dioxide production, and hence TEE, in free-living subjects over a period of several days to several weeks, providing more accurate measures of TEE than other non-calorimetric methods (e.g. heart rate monitoring) (Levine, 2005).

17. A factorial approach was adopted to derive energy requirements based on the assumption that TEE (or EAR) is equal to basal metabolic rate (BMR) x physical activity level (PAL). TEE values were measured in a reference population using the DLW method and divided by estimated BMR values to extract PAL values. This means that the reference populations studied by DLW were described primarily by PAL values. For the UK population, BMR values were then estimated from BMR prediction equations (the Henry equation) (Henry, 2005) using relevant anthropometric data from the population. The PAL values derived from the reference population were used to estimate TEE and EAR values for the UK population, based on the latter's BMR values. A population average

value (median) for PAL, as well as the extent to which it is lower (25^{th} percentile) or higher (75^{th} percentile) for less or more active population groups, was also provided.

Dietary Reference Values for energy for the UK Military Population: Approaches and Methods

18. A range of methods has been used to estimate energy expenditure in UK Armed Forces personnel, in training and on operations. These methods have included the DLW method, physical activity diaries, task analysis questionnaires, heart rate monitoring, analysis of global position system data and analysis of accelerometer data (Fallowfield *et al.*, 2010a; Linnane *et al.*, 2010; Dziubak *et al.*, 2011; Fallowfield et al., 2012a; Fallowfield *et al.*, 2012b; Fallowfield *et al.*, 2012c; Fallowfield *et al.*, 2013; Fallowfield *et al.*, 2014; Shaw & Fallowfield, 2014).

19. Consistent with the methods adopted to derive DRVs for energy for the general UK population, the present review of military energy requirements only considered data from studies using the DLW method to measure TEE. A comprehensive analysis and discussion of these DLW studies is provided in the annex to this position statement.

20. The section that follows addresses a series of questions that were posed by the working group. This allowed the working group's terms of reference to be addressed systematically and the data available to be tested against the approach taken in SACN's 2011 report.

Do the studies examined represent all types of training in the military services?

21. DLW data were collated from Army and RAF Phase-1 initial military training (see paragraph 6). Army Phase-1 training is longer than RAF training (15 weeks & 10 weeks respectively) and deemed to be more physically demanding. DLW data are not available for RN Phase-1 training. However, from a comparison of recruit demographics, entry physical fitness requirements, training programme duration, physical training progression, physical training intensities, and pass-out physical fitness requirements, it could be considered to be equivalent to RAF Phase-1 training (Linnane *et al.*, 2010; Dziubak *et al.*, 2011).

22. DLW data were also collated from longer duration and more physically arduous Army initial military training programmes, which prepared personnel for Dismounted Close Combat (DCC) roles (Shaw & Fallowfield, 2014). The most arduous initial military programme was that supporting the Parachute Regiment (Shaw & Fallowfield, 2014), where the energy requirements for Parachute Regiment recruits (from a consideration of physical fitness requirements, training programme duration, physical training progression and physical training intensities) would be similar to those of Royal Marine (RM) recruits (Davey *et al.*, 2010; Davey *et al.*, 2011). Similarly, male Army officer cadet energy requirements would be similar to those of male RM young officers undertaking military training (Fallowfield *et al.*, 2010b; Fallowfield *et al.*, 2011). Whilst a similar argument could also be made that the daily energy requirements of RAF and RN officer cadets would be similar to those of RAF and RN recruits, officer cadet programmes are significantly longer in duration (Fallowfield *et al.*, 2010a; Linnane *et al.*, 2010; Dziubak *et al.*, 2011; Fallowfield et al., 2012a; Shaw & Fallowfield, 2014).

23. No DLW data were available on specialist groups in the UK military at the time of these analyses, however such work is now in the planning stage. Whilst it is known that specialist groups (e.g. military divers, Special Forces) are likely to have higher energy requirements than the UK population, by virtue of the physical demands of their roles or the unique requirements of the role, there are presently no specific data available to approximate these requirements. However, it could be argued that the data collated from the Phase-3 Section Commander's Battle Course (Shaw & Fallowfield, 2014) would provide an indication of the energy requirements of some, although definitely not all, components of the Special Forces' role.

24. Similarly, DLW data are currently only available for land-based, DCC operational deployments (Fallowfield *et al*., 2014); energy requirements during maritime operations have to date only been estimated from non-DLW methods (see paragraph 18). Whilst maritime roles are generally less physically demanding than DCC roles, it should be noted that higher energy requirements than the UK civilian population arise during this active service from long working hours, rather than from increased physical activity *per se* (Fallowfield *et al*., 2012c; Fallowfield *et al*., 2013).

25. Until specific DLW data become available for specialist military groups, those on maritime operations and those not included in this report, it was agreed that this position statement should present estimated energy requirements that would meet the needs of a range of military service personnel in training and on operations. As there is a growing evidence base to suggest that a relatively large proportion of the UK military population would have the same energy requirements as the general UK population, these energy requirements have also been included in the report (see Table 1).

26. The DLW data used to inform the revised military DRVs for energy recommendations in this position statement were collected between June 2001 and September 2010; Phase-1 Army Recruit Training (i.e. the Common Military Syllabus (Recruits)) data were collected in 2001, with the remainder being collected between 2003 and 2010.

Are the DLW data sufficient to derive DRVs for energy?

27. The available DLW dataset on military personnel is relatively small, but it is specific to the populations of concern. A total of 276 DLW and weight/height measurements were made (196 males and 80 females); however, as some of these were repeat measurements, and measurements at the beginning and end of the courses were not always made in the same volunteers, it was agreed that only the weight and height measurements that were taken in volunteers at the beginning of the courses (n=169) would be used to calculate the BMI of the "reference male" and "reference female". This ensured that the individual weight measurements used for these calculations were not influenced by weight changes during the training period.

28. The PAL values were calculated from measures of TEE derived from DLW data (Schoeller *et al*., 1986; Bluck, 2008) and from the BMR calculated using the Henry equations; this approach was consistent with the methods adopted in the SACN report on UK population DRVs for energy. However, in contrast to the "prescriptive" approach used to estimate energy reference values for the general population (see paragraph 15), the calculations for military DRVs for energy were based on mean body weight and

height of the actual reference population, resulting in a “reference male” and a “reference female”. For the UK military reference population, the mean BMI was 23.9 kg/m^2 for men and 22.0 kg/m^2 for women.

29. No systematic difference in BMI was observed between the start and end of the measurement period. However, it should be noted that the sample size was relatively small and the pre and post measurements were not always undertaken with the same research participants (see paragraph 27).

30. The DLW dataset was skewed towards a young age group (mean age: 22.1 years); therefore it was not representative of the whole UK military service population (age range: 16 to 60 years).[4] However, in terms of BMI and physical fitness, the dataset was considered to be representative of military service personnel 1) in training and 2) undertaking occupational roles with greater energy requirements than the UK civilian population. Therefore, from a risk assessment perspective, the dataset reflects the energy requirements of personnel involved in these activities. The demographic data of research participants included in these analyses are provided in Table A3.

Dietary Reference Values for energy for the UK military population –derivation

How should population EAR values be identified for military personnel?

31. From the analyses undertaken on the DLW measurements no gender differences were observed in PAL values, enabling men and women to be grouped together. Three relatively distinct groupings, with different energy requirements, were identified: Active Service, Military Training Courses A and Military Training Courses B. These groupings differed by their PAL value only; there were no differences between the anthropometric measures of the men in the different groupings and the women in the different groupings. The small differences in fat-free mass (FFM) % between the groupings (see Table A4) were considered to be insufficient to alter the interpretation of results. For the purpose of setting military DRVs it was assumed that the heights and body weights of personnel on future Active Service or in either of the two Military Training Courses groupings would be similar to the current volunteers. Therefore single values for height and body weight of all male personnel and of all female personnel across groups were calculated separately (i.e. a reference male and a reference female).

32. BMR is age (and gender) dependent and different age bands are used to calculate predicted BMR by the Henry equation. For the current dataset, the appropriate age bands were 18-30 years and 30-60 years. BMR calculations were initially performed using the appropriate age-related equation. However, as there was little difference in BMR values regardless of which age-specific equation was used, it was agreed to use the BMR prediction equation for the 18-30 years age group for all volunteers to provide one reference male and one reference female value across all activity groups. This allowed the TEE (and hence the EAR) for the reference male and the reference female, following either Active Service or either of the Military Training Courses groupings, to be determined from the appropriate PAL values for each of these three groupings. Thus,

[4] Personnel can start their service career from 16 years of age. As a trained rank, they might serve until they are circa 40 – 45 years; officers will presently serve until they are circa 55 – 60 years.

although EARs for energy were set by age group for the general population, in the case of military personnel it was considered appropriate to provide a combined EAR for energy for all age groups within each activity group.

33. Variation in the PAL values within the three groupings was accommodated by defining a range of PAL and EAR values: the 25^{th} percentile, the median and the 75^{th} percentile, with energy in MJ/day and kcal/day rounded to two significant figures (see Table 1). These values refer to the reference male (body weight 75.7 kg; height 1.78 m; BMR 7.34 MJ/day) and reference female (body weight 60.0 kg; height 1.65 m; BMR 5.61MJ/day) service persons.

34. The median value provides a guide to the overall energy requirement during training or active service. However, there are likely to be times when personnel will be more or less active, and hence require more or less energy; the 25^{th} and 75^{th} percentiles provide guidance with respect to these reduced or increased energy requirements, respectively. In the SACN energy report, the terms 'less active' and 'more active' were used to describe the upper and lower ends of activity levels in the UK population. However, such descriptors would not be appropriate for military personnel governed by this specific guidance; all personnel would be undertaking the same work (or military training), such that differences in PAL will likely reflect very subtle factors in terms of their impact on energy requirements.

35. Inter-individual differences in energy expenditure were greater in active service than during training. This likely reflects the programmed nature of military training, in contrast with the dynamic and/or reactive nature of military operations. From a risk management perspective, these inter-individual differences in energy requirements should be taken into consideration when allocating rations for these activities, especially in the operational environment where the implications of poor risk management could be far more profound. Military risk managers will also need to be cognisant of the provisioning requirements of individuals in the 25^{th} and 75^{th} centiles. Furthermore, military service personnel with a BMI higher or lower than the mean may lose or gain body weight respectively, if rationing is based on these mean values.

36. It was not possible to determine the effect of environmental conditions on energy requirements *per se* from the available evidence base. Evidence from the general scientific literature suggests that environmental conditions, such as extremes in temperature and altitude, are likely to have modest overall effects on the energy requirements of service personnel (Garby *et al.,* 1990; Valencia *et al.,* 1992; Burstein et al., 1996; Debevec *et al.,* 2014). Observed changes in energy expenditure are likely to arise from both changes in external work depending on clothing, equipment and/or terrain (Pandolf *et al.*, 1977) and changes in internal work as a consequence of altered thermogenesis and the impacts of relative hypoxia (Westerterp-Plantenga *et al.,* 2002; Debevec *et al.,* 2014). Adaptation to the effects of environmental change is likely to occur with more prolonged exposure, so the impacts will be greatest in the short term (Corbett *et al.,* 2014).

Table 1: Estimated Average Requirements (EAR) for the general population and the three groupings of service personnel based on Physical Activity Level (PAL)

Level	Group	PAL values			Gender	EAR (MJ/day)[a]			EAR (kcal/day)[a]		
		25th percentile	Median	75th percentile		25th percentile	Median	75th percentile	25th percentile	Median	75th percentile
1	General Population	1.49	1.63	1.78	**M**[b]	10.9	12.0	13.1	2600	2900	3100
					F[c]	8.4	9.2	10.1	2000	2200	2400
2	Active Service	1.90	2.08	2.16	**M**	14.0	15.2	15.9	3300	3600	3800
					F	10.8	11.7	12.2	2600	2800	2900
3	Military Training Courses A[d]	2.15	2.32	2.44	**M**	15.8	17.0	17.9	3800	4100	4300
					F	12.1	13.1	13.8	2900	3100	3300
4	Military Training Courses B[e]	2.51	2.62	2.78	**M**	18.4	19.2	20.4	4400	4600	4900
					F	14.2	14.8	15.7	3400	3500	3800

[a] EAR values are rounded to 2 significant figures. The values derive from calculations for the reference male and female as defined in paragraph 33.
[b] M = male
[c] F = female
[d] Included the following training groups: the common military syllabus for recruits (CMS(R)); Royal Air Force (RAF) phase-1 recruits.
[e] Included the following training groups: Common Infantry Course (CIC) – paras and Guards; Commissioning Course for Officer Cadets (CCOC); Section Commander's Battle Course (SCBC) (army infantry soldiers phase-3 training)

37. There is no direct evidence from military populations about the impact of different macronutrient sources on performance, so in making recommendations about macronutrient intake at different energy requirements SACN has extrapolated from the relevant literature in other high exercise intensity settings. Studies performed in other high exercise intensity populations (such as elite athletes) provide evidence that as energy requirements increase, the proportions of macronutrients required to maintain optimum health and physical performance may change. From the evidence available it appears that a higher proportion of energy derived from carbohydrates may be associated with superior performance, particularly when sustained high energy expenditure is required (Brooks & Mercier, 1994; Romijn *et al.*, 1993; Vandenbogaerde *et al.,* 2011; Hawley & Leckey, 2015; Pöchmüller *et al*., 2016). However, this remains a topic of active investigation.

38. Table 2 (to be read in conjunction with Table 1) presents recommended proportions of macronutrients for energy intake levels equivalent to the UK population and for the three groupings of service personnel (see paragraph 31). Level 1 recommendations are the same as for the general UK population. There is insufficient evidence to make precise recommendations for macronutrient intakes at higher levels of energy expenditure. Therefore, a range is provided for carbohydrates and total fat, with absolute protein intakes remaining constant (and hence dropping as a % of total energy as energy intake rises). For this purpose, total energy intake is assumed to be the same as food energy intake; it excludes energy from alcohol since alcohol is not included in provisioning. The lower limit of intake from carbohydrates is set at 50%, to reflect the current recommendation for the general UK population. The upper limit is set to reflect all additional energy being provided as carbohydrate. In practice, it is acknowledged that the proportions for operational ration packs will be determined by risk managers, due to the interaction of energy density and the weight of rations with respect to the implications for load carriage. However, SACN recommends that the proportions of energy from carbohydrate and total fat should be within the ranges provided.

39. Whilst micronutrient status data for UK military populations are somewhat limited, there was no evidence presented that indicated a poor micronutrient status in UK training and operational military populations. As such, SACN concluded that as long as energy requirements were met, and personnel consumed a predominantly healthy balanced diet, the daily micronutrient intakes recommended for the general UK population would be adequate for UK military personnel. Recommendations for the general UK population to take supplemental folic acid (women of child bearing age) and supplemental vitamin D also apply to UK military personnel (NHS Choices).

General recommendations for risk managers[5]

40. Although the focus of this position statement is to ensure that military service personnel are provided with adequate rations to support their energy requirements, it was noted that the importance of a healthy balanced diet should also be emphasised to ensure a balanced nutrient intake and good oral health. To maintain good oral health, it is particularly important that additional energy requirements are not met through an increased

[5] SACN's remit is risk assessment not risk management. These recommendations do not form part of this risk assessment.

consumption of sugar, sugar-containing foods and sugar-sweetened beverages. Free sugars should account for no more than 5% of total dietary energy (SACN, 2015).

Table 2: Recommended proportions of macronutrients, as a percentage of total energy intake, for the general population and the three groupings of service personnel based on Physical Activity Level (PAL)[a] . Total energy intake is assumed to be the same as food energy intake; it excludes energy from alcohol since alcohol is not included in provisioning.

Group	Level	Carbohydrate (%)	Total Fat (%)	Protein (%)
UK Population	1	50	35	15
Active Service	2	50 - 55	31.5 - 35	13.5 - 15
Military Training Courses A[b]	3	50 - 60	28 - 35	12 - 15
Military Training Courses B[c]	4	50 - 65	25 - 35	10 - 15

[a] The proportions for operational ration packs will be determined by risk managers due to the interaction of energy density and the weight of rations with respect to the implications for load carriage.
[b] Included the following training groups: the common military syllabus for recruits (CMS(R)); Royal Air Force (RAF) phase-1 recruits.
[c] Included the following training groups: Common Infantry Course (CIC) – paras and Guards; Commissioning Course for Officer Cadets (CCOC); Section Commander's Battle Course (SCBC)(army infantry soldiers phase-3 training)

41. Public Health England's Eatwell Guide (PHE, 2016) should be followed by military personnel who have the same energy requirements as the general population. Recommendations for the general UK population to take supplemental folic acid (women of child bearing age) and supplemental vitamin D also apply to UK military personnel (NHS Choices). It is recommended that educational programmes are delivered to military personnel to highlight the importance of healthy eating for overall health, to mitigate chronic disease and tooth decay, to highlight the potential contribution of alcohol consumption to total energy intake and adverse effects of excess consumption on health, and to specifically identify the nutrition required to maintain military capability.

42. The Public Health England document *Healthier and More Sustainable Catering: Nutrition principles* (PHE, 2014) should be consulted to assist with developing nutritionally balanced menus in support of meeting the requirement of Government Buying Standards for Food and Catering Services (DEFRA, 2015).

43. Importantly, the additional energy requirements of military personnel on active service or training should not be met, as a matter of course, through foods high in saturated fat, sugar and salt.

Summary and recommendations

Background and approach

44. This position statement considered whether the new evidence describing the energy expenditure of military personnel was sufficient to allow UK military DRVs for energy to be updated using the approach adopted to revise the energy reference values for the general population in 2011. Military-specific DRVs were required for those roles and/or activities where there was evidence for different energy requirements from those of the general population.

45. The present review only considered evidence from studies that used the DLW method to measure TEE.

46. BMR was calculated using the Henry prediction equation for the 18-30 years age group and anthropometric measurements of reference male and female volunteers. PAL values were derived from DLW measurements of reference volunteers.

47. In contrast to SACN's DRVs for energy report, which used a BMI of 22.5 kg/m^2 to devise energy requirements (a "prescriptive" approach), the current report used the actual mean BMI of military personnel volunteers involved in the DLW studies.

Recommendations

48. Following careful consideration of the DLW data available and other known military-relevant research, SACN recommends that:

- Four different DRVs for energy are provided for military service personnel, corresponding to different levels of physical activity intensity. The first level corresponds to the requirements of the general population; DRVs for levels two, three and four reflect higher levels of physical activity (see Table 1).

- A different range for each macronutrient (i.e. carbohydrate, protein and total fat), expressed as a percentage of total energy intake (excluding energy from alcohol)[6], is provided for each physical activity level (see Table 2 and paragraphs 37 and 38).

- For both recommended EARs for food energy (Table 1) and proportions of macronutrients (Table 2), levels two, three and four are only relevant to military personnel with energy requirements different from the UK EARs recommended by SACN in 2011.

49. There is insufficient evidence to suggest that different DRVs for energy are required for military personnel based on environmental temperature, age or body size. Similarly, there is insufficient evidence that military populations require a different micronutrient intake from the general population.

[6] Total energy intake is assumed to be the same as food energy intake; it excludes energy from alcohol since alcohol is not included in provisioning.

Research recommendations

50. This position statement represents a considerable advance in understanding the energy requirements of military personnel. The setting of DRVs for energy for this population is, to some extent, more straightforward than for the general population as the range of activities is known and less varied for many specific groups of military personnel. Nevertheless, gaps in knowledge still remain: specific groups within the Armed Forces remain unrepresented in this evidence base and only small numbers of individual volunteers were involved in the military groups which have been studied.

51. Determining future recommendations for energy requirements, which will improve the reliability of present values, will require research in the following areas:

- Collection of reliable height and weight measurements of military personnel entering the services; this would enable the BMR values for the reference male and reference female, from which DRVs for energy are calculated, to be updated if values change.

- Analysis of alternative measures of energy expenditure which have already been collected in military personnel, especially those which allow integrated measurements of TEE; this would enable a comparison to be made with TEE estimates from DLW measures where these have been collected in the same volunteers.

- Development of new, and improvement of existing, measures of energy expenditure which can be used as reliable alternatives to the DLW technique.

- Collection of DLW data on military personnel involved in maritime operations and on other Armed Forces groups not included in this report, for whom energy expenditure is likely to differ from the general population.

General recommendations for risk managers[7]

52. Military service personnel should consume a healthy balanced diet to ensure good nutrition and good oral health. To maintain good oral health, it is particularly important that additional energy requirements are not met through an increased consumption of sugar, sugar-containing foods and sugar-sweetened beverages. Free sugars should account for no more than 5% of total dietary energy (SACN, 2015).

53. Public Health England's Eatwell Guide (PHE, 2016) should be followed by military personnel who have the same energy requirements as the general population. Recommendations for the general UK population to take supplemental folic acid (women of child bearing age) and supplemental vitamin D also apply to UK military personnel (NHS Choices).

[7] SACN's remit is risk assessment not risk management. These recommendations do not form part of this risk assessment.

54. Educational programmes should be delivered to military personnel to highlight the importance of healthy eating for overall health, to mitigate chronic disease and tooth decay, to highlight the potential contribution of alcohol consumption to total energy intake and adverse effects of excess consumption on health, and to specifically identify the nutrition required to maintain military capability.

55. Public Health England's *Healthier and More Sustainable Catering: Nutrition principles* (PHE, 2014) should be consulted to assist with developing nutritionally balanced menus in support of meeting the requirement of Government Buying Standards for Food and Catering Services (DEFRA, 2015).

56. The additional energy requirements of military personnel on active service or training should not be met, as a matter of course, through foods high in saturated fat, sugar and salt.

Annex - Analysis of doubly labelled water data obtained on military personnel

Preamble

57. This annex presents the complete analysis of all doubly labelled water (DLW) data on military personnel provided by the Institute of Naval Medicine (INM) for the purpose of this review. It includes all the DLW studies which have been performed by the INM.

58. A previous analysis of a subset of this DLW data estimated basal metabolic rate (BMR), and hence physical activity level (PAL), from an equation based on the body composition, (fat mass (FM)) and fat free mass (FFM)), of volunteers calculated from DLW total body water (TBW) values. However the complete dataset does not contain the TBW data for all volunteers and it is unlikely that these data will be retrievable. For these studies, (male and female army recruits on the commissioning course for officer cadets at Royal Military Academy Sandhurst (RMAS) and on the Common Military Syllabus for Recruits (CMS(R)) at Winchester), BMR and hence PAL can only be calculated from heights, weight and gender according to the Henry Oxford equations.

59. It is essential that the analysis of all available DLW total energy expenditure (TEE) data involves the same approach to calculating BMR and PAL; therefore all data have been recalculated using the Henry Oxford predication equations. The relationship between BMR predicted from DLW data (BMR_{DLW}) and BMR predicted using the Henry Oxford equation (BMR_H), and the resultant PAL values, is examined further in this report.

Data available and data analysed

60. Table A1 provides a summary of energy expenditure studies that are available for different Armed Forces volunteers in training and on operational service and the methods that were used to assess energy expenditure.

Summary of types of activity studied and environmental conditions at time of study

61. A summary of the different groups studied for the purpose of this review is as follows:

- **Jackson – operations on land**

  18 males; DLW data collected once; TBW data available
  These data are from 18 Royal Marines at a forward operating base where military personnel were stationed for their 6-month tour in Afghanistan. All volunteers undertook patrolling duties on most days or undertook quick reaction force duties as well as general forward operating base duties. Volunteers would have been inactive for much of the time, after their patrolling duties were completed.

- **Common Infantryman's Course (CIC) - army recruits during training**

  a) Paras (20 males, DLW data collected during weeks 1-2 and 19-20; TBW data available)
  These data are from 20 recruits in weeks 1-2 and 11 recruits in weeks 19-20 of a 24-week Common Infantryman's Course (CIC) training course in 2003 for 50 male

Parachute regiment recruits at the Infantry Training Centre Catterick, ITC (C)

b) Guards (16 males; DLW data collected once; TBW available)
These data involve 16 male recruits at the beginning of a 26-week CIC 2005 training course for 41 male Foot Guards recruits at ITC(C).

Table A1: Summary of information available on energy expenditure of Armed Forces[a] personnel

Armed Force	Situation	Gender[b]	Methods used to assess energy expenditure[c]	Analysis (DLW)
RAF	*Recruit training*	M & F	DLW	Completed
Army	*Recruit training* Common Military Syllabus	M & F	DLW, Acc, HR	Completed
	Common Infantryman's Course	M	DLW, Acc, HR	Completed
	Commissioning course for officer cadets	M & F	DLW, Acc, HR	Completed
	Section Commander's Battle Course	M	DLW, Acc, HR	Completed
	Operations on land	M	Acc, HR, TAQ	Not analysed
Royal Marines	*Operations on land*	M	DLW, Acc, HR,TAQ	Completed
Royal Navy	*Operations at sea*	M & F	Acc, HR,TAQ	Not analysed

[a] Summary of information on military personnel provided by the Institute of Naval Medicine for the purpose of this review
[b] M = male; F = female
[c] DLW – Doubly Labelled Water, Acc – Accelerometer, HR – Heart Rate, TAQ – Task Analysis Questionnaire

- **Common Military Syllabus for Recruits (CMS(R)) - army recruits during training**

  a) Army Training Centre (ATC) Pirbright (16 males, 16 females; DLW data collected twice; TBW available)
  These data are from 16 men and 16 women during weeks 1-2 and 13-14 of a 2007 training course involving the 14-week Common Military Syllabus for Recruits (CMS(R)), at the ATC Pirbright (P).

  b) Army Training Regiment (ATR) Winchester (6 males; 8 females; DLW data collected twice; TBW data not available)
  These data involve army recruits, (Adjutant General Corps and Royal Logistics Corps), undergoing training within the CMS(R) at the ATR Winchester in June 2001. DLW measurements were taken during weeks 1-2 and 8-9.

- **RAF Phase-1 - recruits on Phase-1 training**

  11 males and 13 females; DLW data collected twice; TBW available
  These data involve RAF recruits studied twice (A & B) during RAF Phase-1 training at RAF Halton undertaken by Optimal Performance Ltd.

- **Commissioning course for officer cadets (CCOC) at Royal Military Academy Sandhurst, (RMAS) - army officer cadets**

  8 males and 8 females; DLW data collected once; TBW data not available

- **Section Commander's Battle Course (SCBC) Brecon - male infantry soldiers during training**

  30 males; DLW data collected twice; TBW available
  These data involve male army infantry soldiers during Phase-3 training studied during weeks 2-3 (n=28) and weeks 6-7 (n=30).

62. The DLW data derive from a subset of a larger group who were studied with other methods as described in Table A1. For those groups of personnel described above who were studied twice, the first and second cohorts were not identical because of dropouts and/or because some volunteers were only studied during the second cohort.

63. Environmental data (mean daytime temperatures and humidity) for the periods when the measurements were made are shown in Table A2. The weather was typical for the time of year.

Demographics and Anthropometry of volunteers

Presentation of data

64. The complete DLW dataset comprises 20 sets of measurements with 276 separate measurements (196 males and 80 females). With the exception of the male troops on active service, male guards on the Common Infantryman's Course and male and female

officer cadets on the commissioning course at Sandhurst, the majority of volunteers were studied twice i.e. initially and later during training. Therefore, the 276 separate measurements derive from a total of 169 volunteers (124 males and 45 females). Furthermore, as indicated above, where repeat measurements were made the first and second cohorts were not always identical because of dropouts and/or because some volunteers were only studied during the second cohort. Accordingly, the demographic data presented in Table A3 include age, weight, height and BMI for all volunteers at the start of each course (n=169), grouped according to training course while Table A4 shows the same data for all volunteers at the time of each set of DLW measurements (n=276). It also provides FM% and FFM index (kg/h^2) of those volunteers with TBW data available, from which the body composition data can be calculated. Mean ages for the various groups studied ranged from 17.8 to 26.4 years. In Figures A1, A2, A4 and A5 below, several of the data points derive from the same volunteers measured at the beginning and the end of the training period.

Table A2: Environmental conditions at time of study: air temperature and humidity (Source: Met Office)

Service	Situation	Location	Dates	Mean Air Temperature (°C)	Humidity (%)	Mean Wet Bulb Temp. °C
RAF	Phase-1 Recruit Training	RAF Halton, Aylesbury, Bucks, UK	Mar-10 Apr-10	5.9 8.9	70 78	4.4 6.5
Army	CMS(R)	ATC Pirbright, Surrey, UK	Jun-07 Jul-07 Aug-07 Sep-07	15.8 15.8 16.0 14.1	80 80 78 81	13.8 13.8 13.7 12.3
	CMS(R)	ATR Winchester, Hampshire, UK	Jun-01 Jul-01 Aug-01 Sep-01 Oct-01	14.7 17.3 16.8 13.2 13.3	72 74 79 81 88	11.9 14.5 14.6 11.5 12.2
	CIC Paras	ITC Catterick, North Yorkshire, UK	Jan-03 Feb-03 Mar-03 Apr-03 May-03 Jun-03 Jul-03	4.3 2.8 6.5 9.0 11.9 15.6 16.9	84 84 77 71 75 72 77	3.3 1.9 4.8 6.6 9.6 12.8 14.5
	CIC Guards	ITC Catterick, North Yorkshire, UK	Sep-05 Oct-05 Nov-05 Dec-05 Jan-06 Feb-06 Mar-06	14.1 12.2 5.6 4.4 3.9 3.9 4.0	79 85 83 86 88 82 79	12.1 10.9 4.5 3.5 3.2 2.8 2.7
	CCOC	RMAS, Sandhurst, Camberley, Surrey, UK	May-04 Jun-04 Jul-04 Aug-04	12.4 15.7 16.0 17.4	73 75 78 78	9.9 13.1 13.6 15.0

			Sep-04 Oct-04 Nov-04 Dec-04 Jan-05 Feb-05 Mar-05	15.0 10.7 7.7 5.0 6.1 3.8 6.8	77 85 88 89 83 82 79	12.7 9.4 6.8 4.3 5.0 2.8 5.4
	SCBC	Infantry Battle School, Brecon, Powys, Wales	Sep-08 Oct-08 Nov-08 Dec-08	11.0 8.9 5.9 2.3	91 91 93 95	10.2 8.3 5.4 2.0
Royal Marines	Operations	Forward Operating Base Jackson, Helmand Province, Afghanistan	May-10 Jun-10 Jul-10 Aug-10 Sep-10	30.9 34.0 35.2 31.8 25.7	12 8 8 11 11	14.4 15.1 15.6 14.7 11.3

65. All groups exhibited mean BMI values in the healthy range, with the exception of those at SCBC Brecon. The median BMI of this group at the start of training was 25.9 kg/m^2, indicating that 50% of the group was overweight (BMI ≥ 25 kg/m$^{2)}$. Two volunteers in this group were obese (BMI ≥ 30 kg/m$^{2)}$ at the time of the first DLW measurement; however, no individuals were obese by weeks 6-7, due to a small weight loss during training.

66. Figure A1 shows the relationship between body fat (%) and BMI in those volunteers for which body composition data were available (all except ATR Winchester and CCOC). Although for any BMI value there was some variability in the fat content, overall the relationship between body fat and BMI was similar to that observed in other population groups, i.e. a higher fat percentage in women than in men and increasing amounts of body fat as BMI increased. Some of the variability in FFM between groups is discussed further below in relation to Table A4.

67. During the training programmes food was supplied according to the rationing procedures in place at the time. Generally this was sufficient for volunteers to maintain energy balance on the basis of records of body weight changes. As indicated in Table A5, for most volunteers on the training courses, weight was maintained or there were small gains or losses. The exception was men following the SCBC course who lost on average 5 kg and the subset for whom DLW measurements were made who lost 2.43 kg. Body composition measurements indicated that for some cohorts there were losses of fat and gains of FFM.

Energy expenditure

68. The SACN Dietary Reference Values for energy report for the UK population utilised a factorial model for evaluating energy expenditure and requirements. This involves expressing TEE in terms of the PAL where PAL is TEE adjusted for the BMR: i.e. PAL = TEE/BMR. This means that PAL is theoretically independent of those factors influencing BMR (weight, height, age and gender), at least as a first approximation.

Consequently, for any PAL value, TEE and hence the Estimated Average Requirement (EAR) can be predicted for any group from estimates of the BMR.

Table A3: Age, weight, height and BMI of volunteers grouped according to training course (values for volunteers at the start of each course)

Situation	N	Age (years)		Weight (kg)		Height (m)		BMI (kg/m^{2})	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Jackson (Active service)(all male)	18	26.4	5.33	76.1	5.7	1.78	0.05	24.1	1.64
CMS(R)	46	19.6	2.90	65.7	10.1	1.72	0.09	22.0	2.13
Male	22	20.1	3.34	72.9	7.0	1.79	0.07	22.7	2.05
Female	24	19.0	2.39	59.0	7.7	1.66	0.06	21.4	2.03
RAF Phase-1	24	22.4	4.68	67.3	12.4	1.71	0.11	22.8	2.59
Male	11	20.8	3.91	77.9	9.3	1.81	0.05	23.8	3.18
Female	13	23.7	5.04	58.4	5.6	1.63	0.07	21.9	1.61
CIC (M)	36	19.5	2.71	72.8	11.6	1.77	0.06	23.1	2.68
CCOC	16	23.1	1.53	72.3	12.0	1.73	0.11	24.0	2.38
Male	8	23.0	1.93	78.9	10.0	1.81	0.08	23.9	1.85
Female	8	23.1	1.13	65.6	10.2	1.65	0.05	24.0	2.96
SCBC(M)	29	25.8	3.60	79.4	10.3	1.75	0.07	25.9	2.45
All males	124	22.4	4.58	75.7	9.8	1.78	0.07	23.9	2.62
All females	45	21.1	3.88	60.0	7.9	1.65	0.06	22.0	2.28
All Groups	169	22.1	4.43	71.5	11.6	1.74	0.09	23.4	2.67

Table A4: Age, weight, height, BMI for all volunteers and FM% and FFM index (kg/h^2) of volunteers with TBW available (values at the time of each set of DLW measurements)

Situation	Groups	N	Age (years)		Weight (kg)		Height (m)		BMI (kg/m^2)		FM%		FFM index (kg/h^2)	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Operations	Jackson (M)	18	26.4	5.33	76.1	5.69	1.78	0.05	24.1	1.64	16.4	2.84	20.2	1.38
CMS(R)	ATR Winchester (1-2; F)[a]	8	19.1	3.09	61.3	7.37	1.67	0.04	21.9	2.18	NA[c]	NA	NA	NA
CMS(R)	ATR Winchester (1-2; M)	6	23.5	3.73	73.1	8.05	1.76	0.01	23.5	2.49	NA	NA	NA	NA
CMS(R)	ATR Winchester (8-9; F)	6	17.8	2.23	59.3	6.18	1.68	0.04	21.0	1.44	NA	NA	NA	NA
CMS(R)	ATR Winchester (8-9; M)	5	23.2	4.09	72.8	8.96	1.77	0.01	23.3	2.70	NA	NA	NA	NA
CMS(R)	ATC Pirbright (1-2; F)	16	19.0	2.07	57.9	7.78	1.65	0.07	21.1	1.98	28.4	4.59	15.1	1.14
CMS(R)	ATC Pirbright (1-2; M)	16	18.9	2.19	72.9	6.82	1.80	0.08	22.4	1.86	18.3	4.60	18.3	1.31
CMS(R)	ATC Pirbright (13-14; F)	16	18.7	1.92	57.7	7.58	1.64	0.07	21.4	2.10	27.8	4.34	15.4	1.20
CMS(R)	ATC Pirbright (13-14; M)	16	18.6	1.59	72.6	9.47	1.78	0.07	22.7	2.28	18.5	3.55	18.5	1.42

RAF Phase-1	RAF Halton A[b] (F)	13	23.7	5.04	58.4	5.60	1.63	0.07	21.9	1.61	29.8	2.59	15.4	1.17
RAF Phase-1	RAF Halton A (M)	11	20.8	3.91	77.9	9.35	1.81	0.05	23.8	3.18	20.1	4.71	18.9	1.86
RAF Phase-1	RAF Halton B (F)	13	23.8	5.04	58.5	5.65	1.63	0.07	22.0	1.78	30.2	2.59	15.3	1.20
RAF Phase-1	RAF Halton B (M)	11	21.0	3.91	78.2	9.52	1.81	0.05	23.9	2.98	20.8	4.01	18.8	1.85
CIC	Paras (1-2; M)	20	20.1	2.77	72.7	10.90	1.76	0.07	23.4	2.51	14.9	3.58	19.8	1.83
CIC	Paras (19-20; M)	11	20.9	3.48	76.8	10.33	1.80	0.07	23.7	2.36	11.3	2.74	21.0	2.20
CIC	Guards wks.(1-2; M)	16	18.8	2.54	72.8	12.72	1.78	0.06	22.8	2.92	20.6	4.25	18.0	1.58
CCOC	RMAS (F)	8	23.1	1.13	65.6	10.20	1.65	0.05	24.0	2.96	NA	NA	NA	NA
CCOC	RMAS (M)	8	23.0	1.93	78.9	10.05	1.81	0.08	23.9	1.85	NA	NA	NA	NA
SCBC	SCBC Brecon (2-3; M)	28	25.8	3.67	79.7	10.37	1.75	0.07	25.9	2.49	22.4	4.26	20.0	1.62
SCBC	SCBC Brecon (6-7; M)	30	26.0	3.76	78.4	8.27	1.76	0.06	25.3	1.89	18.7	4.10	20.6	1.38
	All males	196	22.5	4.53	76.0	9.60	1.78	0.06	24.0	2.56	18.5	4.82	19.6	1.84
	All females	80	20.8	4.04	59.2	7.40	1.65	0.06	21.8	2.12	28.9	3.79	15.3	1.15
	All Groups	276	22.0	4.46	71.1	11.77	1.74	0.09	23.4	2.64	21.1	6.43	18.5	2.50

[a] Time when DLW measurements were taken during active service/training (specified week(s)) and gender (F=female; M=male)
[b] RAF Halton A refers to the first doubly labelled water measurement; RAF Halton B refers to the second doubly labelled water measurement
[c] NA – FM% and FFM Index could not be calculated for these groups as total body water data were unavailable.

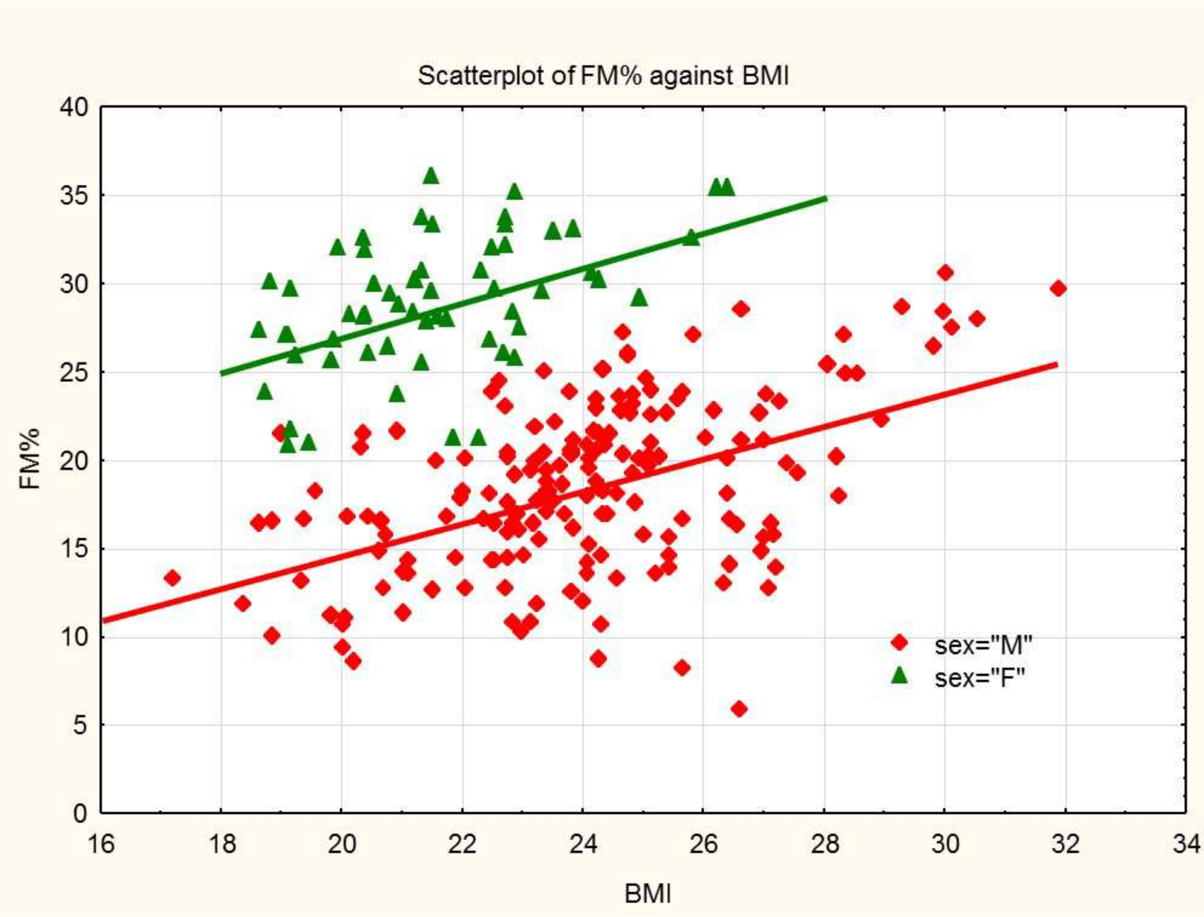

Figure A1: FM% in men and women as a function of BMI

Table A5: Weight changes during training programmes (where data are available)

Situation	Group	Monitoring periods (weeks)	Gender	Weight change (all volunteers)	Weight change (DLW subset)
CMS (R)	ATR Winchester	1-2 and 8-9	Females Males	No change but fat loss (1.5kg) and FFM gain (1.4kg)	No change, but fat loss (2.5kg) and FFM gain (2.5kg)
	ATC Pirbright 2008	1-2 and 13-14	Females	No change	Gain: 0.65 ± 1.76 kg
			Males	Decrease: 1.5 ± 4.2 kg	Gain: 2.3 ± 2.03 kg
RAF Phase-1	RAF Halton	Unspecified	Females Males	DLW was the only method used to assess energy expenditure in this group	Gain: 0.07 ± 0.96 kg Gain:0.27 ± 3.27 kg
CIC	Paras 2003	1-2 and 19-20	Males	Gain: 2.6 ± 3.5 kg; gain of FFM	Gain: 0.95 ± 3.8 kg
	Guards 2005-6	1-2 and 23-24	Males	No change in weight; increase in FFM	N/A
CCOC	RMAS 2004-5	1-2, 6-7, 20-21 and 39-40	Females	No change	N/A
			Males	Gain: 0.8-1kg	N/A
SCBC	SCBC Brecon 2008	1, 2-3, 6-7 and 8	Males	Loss: 5.1 ± 2.6 kg	Loss: 2.43 ± 2.63 kg

69. Although PAL values can be estimated from time-allocated activity diaries in which the duration and energy cost of individual activities (as physical activity ratio (PAR) values) is summed to provide estimates of PAL, in practice this has not been shown to be effective in predicting PAL. PAL values are best estimated from direct measures of 24-hour TEE, e.g. with the DLW method, and BMR. Such measurements in various population groups have indicated that PAL can range from less than 1.3 in immobile volunteers, to values up to 3.6-5.3 in Tour de France cyclists, to 3.96 in an ultra-endurance runner, to an average of 2.8 in marines in cold weather mountain training which included a value of 4.0 during the first 4 days, and up to 6-7 for two men walking to the South pole who were in marked negative energy balance (see Driskell & Wolinsky, 2010). Within the general population, however, the overall range of PAL values for individuals in energy balance, leading sustainable lifestyles, is usually assumed to be between about 1.38 for the most sedentary to 2.5 for the most active.

Limitations of the factorial model

70. Whilst the factorial model works well in terms of the use of PAL values for expressing TEE and for calculating the EAR, it needs to be recognised that PAL values are not entirely satisfactory in terms of categorising activity levels for population groups. This has been discussed extensively elsewhere (see Millward, 2013 for full discussion). Some of the difficulties relate to the following mathematical issues:

- PAL is a ratio (TEE:BMR) while physical activity energy expenditure (PAEE), has an absolute value (PAEE=TEE-thermogenesis-BMR);

- Thermogenesis contributes to PAL but not to PAEE;

- PAL as a measure of absolute PAEE is not independent of weight: i.e. a PAL value as a representation of PAEE will increase with weight or conversely the effect of a fixed amount of PAEE on PAL gets smaller as size increases. The reason is that the increase in BMR with size contributes to both the numerator and denominator in the PAL calculation but PAEE contributes only to the numerator. In other words, to maintain a constant PAL with increasing size, PAEE would need to increase in proportion to the BMR. Thus for a group of soldiers all carrying the same weight the individual PAL values will tend to be lower as their size increases.

71. However, none of the above issues involve large effects, and there is a more important complexity in the PAL–PAEE relationship which is physiological. This relates to the effect of size on both absolute strength and the consequent ease of strength-requiring tasks as well as the absolute energy cost of weight-bearing activities. The issues here are quite complex (as discussed elsewhere: Millward, 2013). They mainly involve the difficulties in relating behavioural changes in terms of activity as measured by accelerometers, to both PAEE and PAL values derived from DLW values of TEE in the obese, compared with volunteers within the healthy body weight range. Thus studies have shown that while similar PAL and PAEE values derived from DLW may be observed in the obese compared with volunteers with healthy weights, accelerometer-derived activity levels on the same volunteers are lower in the obese.

72. Whilst it would be interesting to examine these issues within the volunteers studied here in whom different methods of examining PAEE have been deployed (as described in Table A1), these issues will not influence the main objective of this report, i.e. deriving

food energy requirement values. Nevertheless as will be apparent within the dataset some of the issues do become important in terms of understanding gender differences in PAEE which are not apparent with PAL values (this is discussed below).

Analysis of the DLW data

BMR values for the calculation of PAL from TEE

73. There are a wide range of BMR predictive equations and different organisations choose to use different equations. The SACN Dietary Reference Values for energy report used the Henry Oxford equations on the basis that these had been shown in independent validations to be more appropriate for predicting the BMR within the general population for all age groups and size than the previously used Schofield equations. It has been decided to use the Henry Oxford equations to estimate BMR values in military personnel as well; these BMR predictive equations together with appropriate PAL values will be used to predict EAR values.

74. Since TBW data were available from most volunteers who participated in the DLW studies used to inform this report, this enabled fat free mass (FFM) and fat mass (FM) to be calculated and a prediction equation for BMR based on body composition to be used for this subset of volunteers. As this approach may have advantages over the Henry equation in that variation in body weight in this population may reflect a greater range of FFM/Height than in the general population where variation in fatness is mainly responsible, a comparison of the two approaches is provided below.

75. BMR varies with both FFM and FM (Johnstone *et al.*, 2005) and within the datasets examined in this report (where TBW data were available) BMR has been calculated by an equation based on FFM and FM (BMR = (0.102*FFM)+(0.024*(Wt-FFM))+0.85 MJ/day) (see Westerterp *et al.*, 1995). Using this equation and with FFM and FM calculated from the TBW values deriving from the DLW studies (FFM = 1.37 x TBW) (see Pace & Rathbun, 1945), BMR values were calculated for the dataset. This FM-FFM based BMR equation predicts BMR values which are very highly correlated with those predicted by a similar equation based on FFM and FM reported by Nelson *et al.*, (1992) (r^2= 0.9988) but these latter values are 8% lower (ratio =1.08 (range 1.06-1.11)) and are also lower than values calculated from heights, weights, age and gender by the Henry equations. This gives some confidence in the Westerterp *et al*. (1995) equations which predict mean BMR values very similar to those derived from the Henry equations.

76. A detailed analysis of BMR predicted by the TBW data (BMR_{DLW}) and by the Henry equations (BMR_H) is shown in Table A6. The table shows the ratios of BMR calculated by the DLW-TBW derived equation and the Henry equation within the various groups, for all men and women, and overall. Groups are ranked according to the extent of differences in the two BMR values (in terms of deviation in the ratio from unity).

Table A6: Comparison of BMR_H and BMR_{DLW} and calculated PAL_H and PAL_{DLW} values

Groups	BMR_H/BMR_{DLW} (Median)	p-values (paired tests of BMR_H v BMR_{DLW})	%FFM (Median)	PAL_H/PAL_{DLW} (Median)
Males				
CIC Paras (19-20[a])	0.94	<0.0005	88.9	1.06
CIC Paras (1-2)	0.97	<0.001	85.9	1.03
Jackson	0.97	<0.0001	83.4	1.03
SCBC Brecon (6-7)	0.97	<0.00001	82.0	1.03
CIC Guards (1-2)	1.00	<0.05	79.9	1.00
CMS(R) ATC Pirbright (1-2)	1.00	non-significant	80.1	1.00
CMS(R) ATC Pirbright (13-14)	1.00	non-significant	81.6	1.00
RAF Phase-1 A[b]	1.00	non-significant	80.2	1.00
RAF Phase-1 B	1.01	non-significant	79.8	0.99
SCBC Brecon (2-3)	1.00	non-significant	77.5	1.00
All Males	**0.99**	**<0.05**	**81.8**	**1.01**
Females				
CMS(R) ATC Pirbright (1-2)	1.02	<0.03	71.0	0.98
CMS(R) ATC Pirbright (13-14)	1.01	non-significant	72.7	0.99
RAF Phase-1 A[a]	1.03	non-significant	70.5	0.97
RAF Phase-1 B	1.02	non-significant	70.2	0.98
All Females	**1.02**	**non-significant**	**71.0**	**0.98**
All Groups	**0.99**	**<0.0003**	**79.6**	**1.01**

[a] Time when DLW measurements were taken during active service/training (specified week(s))
[b] RAF Halton A = first DLW measurement; RAF Halton B = second DLW measurement

77. The results show that for men, BMR_H values are slightly but significantly lower than BMR_{DLW} for the CIC Paras, Jackson, SCBC Brecon (weeks 6-7) and CIC Guards, but not significantly different for any other male group. For women, BMR_H values are slightly higher for females in the CMS(R) ATC Pirbright (weeks 1-2) group but not significantly different for any other female group or for women overall. As a result the ratios are slightly lower in males and slightly higher in females overall but the differences are very small and not significant for females.

78. A likely explanation of the differences is the relative ability of the two BMR values to reflect differences in body composition. The BMR_{DLW} is derived from a prediction equation based on FM and FFM and therefore specifically reflects differences in body composition in terms of relative amounts of FFM and FM. In contrast BMR_H is derived from a prediction equation based on weight, height, age and gender derived from a very large number of volunteers and therefore reflects average trends in body composition changes with changes in weight, age and gender. Such trends may involve more marked changes in fatness rather than FFM. If this is the case it might be expected that the BMR_H equations would underestimate BMR for volunteers with high levels of FFM and this seems to be the case as indicated in Table A6. Thus groups with a larger than average %FFM have a greater BMR_{DLW} compared with the Henry-predicted value.

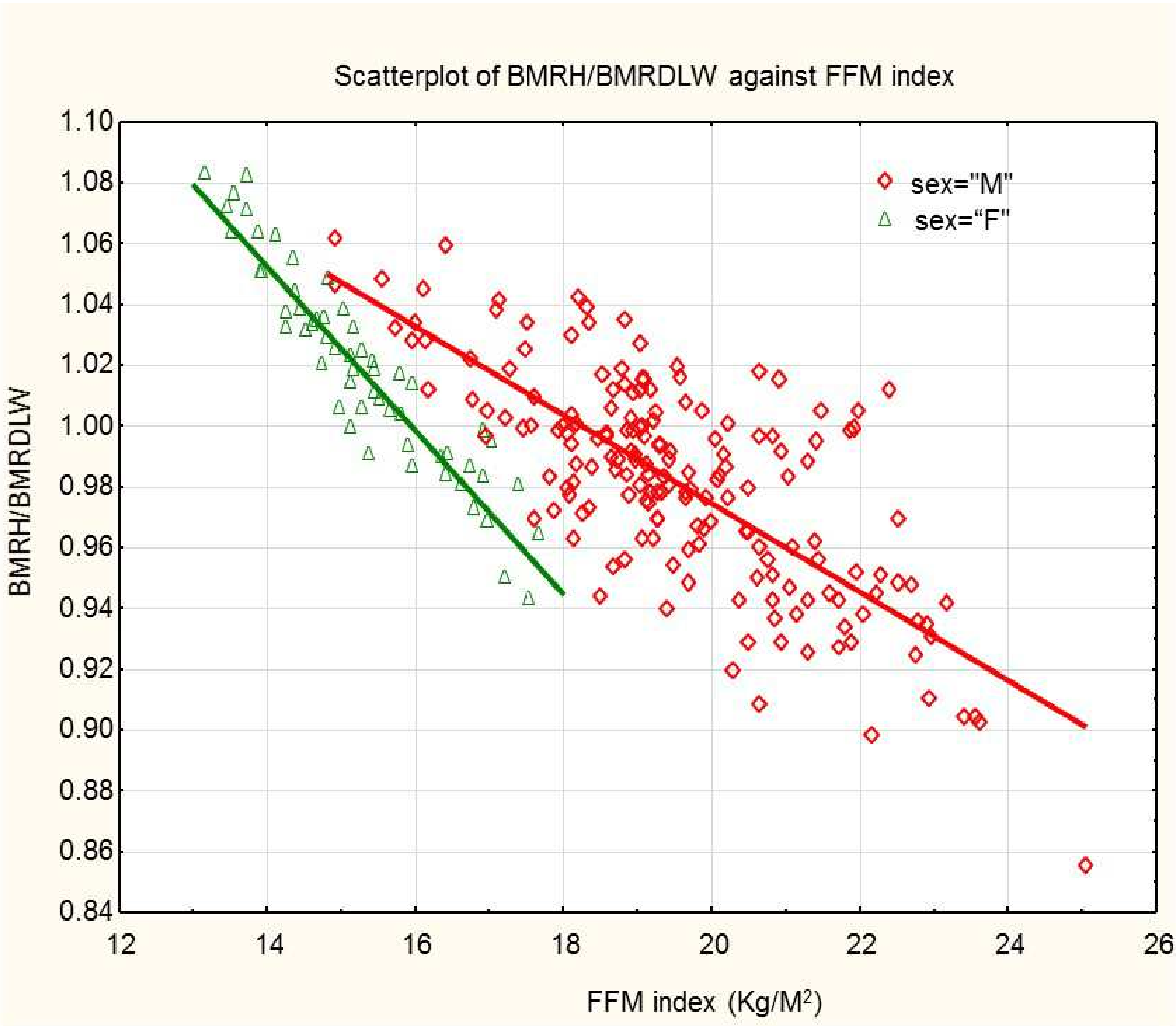

Figure A2: Ratios of BMR_H to BMR_{DLW} as a function of height-adjusted FFM in all men and women.

79. In Figure A2 the ratios of BMR_H to BMR_{DLW} are plotted against FFM adjusted for height, (FFM index, kg/m^2) in all men and women for whom TBW was available. An inverse relationship is clear with ratios falling as FFM increases. The relationship is steeper in women than men, predicting 88% and 55% of the variance respectively. This would tend to confirm the implication that as body composition changes in terms of an increasing proportion of FFM in both men and women, the Henry equations tend to underestimate the BMR.

80. This analysis shows that BMR predicted by TBW data (BMR_{DLW}) is preferable to BMR predicted by the Henry equations (BMR_H). However as there are no TBW data available for CCOC RMAS or CMS(R) ATR Winchester, we can only use the BMR value derived from the Henry Oxford equations for these groups. Because it is essential that the complete analysis of DLW TEE uses the same approach to calculate BMR and PAL, BMR_H is the only BMR which can be calculated for the entire dataset.

81. The important question is whether these differences are likely to influence overall assessment of energy expenditure in terms of PAL values for the purposes of this report. In fact the differences in calculated PAL values are relatively small in terms of mean values. Thus for the CIC Paras at the end of their training, (the group with the largest %FFM), the overestimate of PAL amounted to 6%. For all other groups the differences were 3% or less. Given these small differences, it was decided that all data would be analysed on the basis of the PAL values derived from BMR predicted by the Henry equations as this would provide an acceptable level of accuracy. In subsequent tables of this report the BMR_H values have been used to calculate PAL.

Examination and adjustment of the DLW data

82. The Jackson data involve DLW data collected amongst troops on active service in Afghanistan. Because of concerns around the accuracy of some of the data, possibly due to a change in the slope of the isotopic enrichments after day 7, PAL values were recalculated omitting data from day 8 and day 9 after the DLW dose was administered. A comparison was then done with the PAL calculations that used the full isotope dataset (mainly 9 days) (see Table A7 and Figure A3).

Table A7: Comparison of PAL values calculated from 7-day versus 9-day DLW data

Variable	N	Mean	SD	Median	Min	Max	25th percentile	75th percentile
Jackson (7 days)	18	1.99	0.24	2.02	1.41	2.52	1.87	2.14
Jackson (9 days)	18	2.09	0.29	2.08	1.62	2.97	1.90	2.16

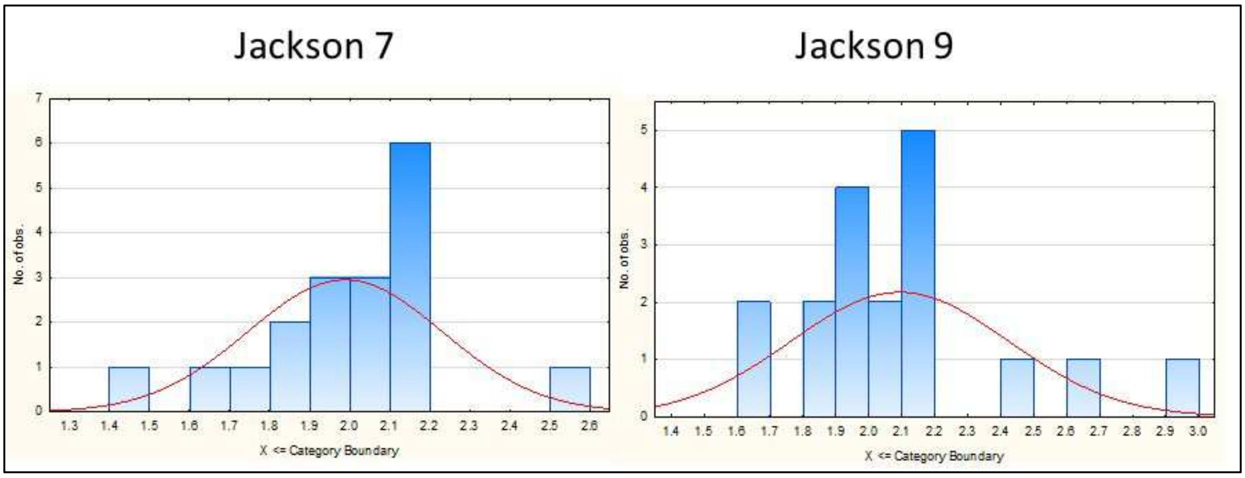

Figure A3: Distribution of PAL values calculated from 7-day and 9-day DLW values for the Jackson group

83. The reanalysis shows that some of the 7-day values are lower than the 9-day values with one individual 7-day value appearing very low (a minimum PAL value of 1.41 compared with 1.62 for the 9 day value).

84. Because the median values for the group are not very different for the 7- and 9-day values (PAL = 2.02 and 2.08 respectively), it could be argued that the choice between the two sets of data is not important to the final outcome of the analysis. However, given that the 9-day values appear more credible, these values have been used in the overall analysis.

BMR values, rates of energy expenditure, PAL values and rates of PAEE

85. Table A8 shows BMR values, rates of energy expenditure, PAL values and rates of PAEE (=TEE-thermogenesis-BMR=0.9xTEE-BMR) for the different groups and for all men and women. It includes measurements separated by both gender and by the timing of the measurements i.e. either initial or later phase of the training period.

86. Overall mean TEE, PAEE and PAL values indicate that all volunteers are very active compared with the general population (PAL = 1.63) as would be expected from their training regimes. A detailed analysis of the differences is provided below.

The relationship between PAL and PAEE

87. The relationship between PAL and PAEE is shown in Figure A4 below, which plots both PAEE in MJ/day (Fig A4(A)) and PAEE/kg FFM (Fig A4(B)) against PAL_{DLW} for all volunteers where FFM has been calculated. The data for males and for females are shown separately. Although for PAEE versus PAL_{DLW} there is an approximate linear relationship (r^2 =0.74 for men and 0.73 for women), PAL is not a very precise predictor of PAEE. Thus for any PAL_{DLW} value, PAEE may vary by ±20% and more at high PAL values in men and women; also PAEE is greater for men than women by about 40%. However, this variability in PAEE at a particular PAL is due to variability in body

weight and especially FFM because after adjusting PAEE for FFM the relationship is much more linear with much less variability, (r^2 = 0.99 for men and 0.98 for women). In fact this is to be expected given the nature of PAL and PAEE. Algebraically, as PAL is the ratio of TEE to BMR and as both BMR and TEE are a function of the FFM, (in the latter case through the BMR component of the TEE), then the close relationship between PAL and PAEE/kg FFM is to be expected. Also because the BMR prediction equation is based on both FFM and FM, with mean values differing with gender, then a gender difference in the relationship between PAL and FFM-adjusted PAEE would be expected and this is observed. Thus for any PAL_{DLW} value, PAEE/kg FFM values are slightly higher for women than for men.

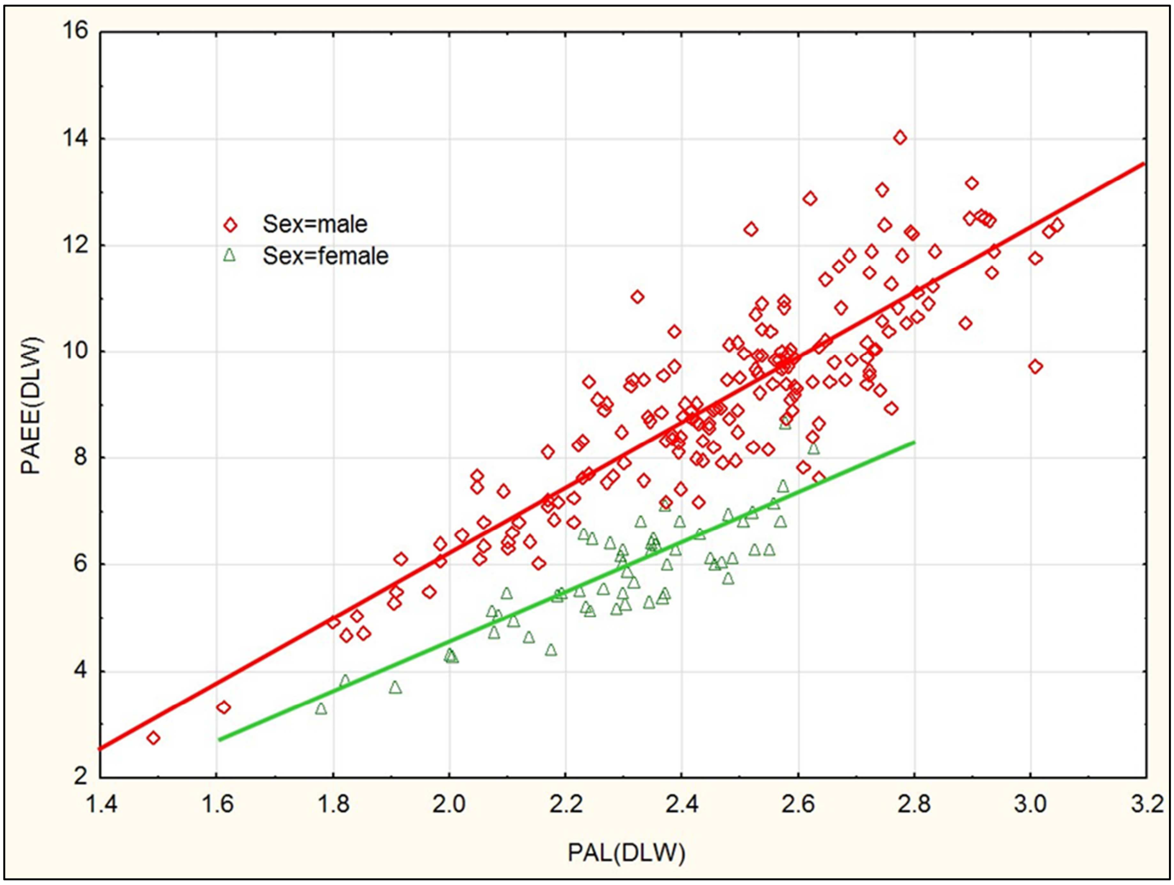

Figure A4 (A): Relationship between PAEE and PAL_{DLW} (Values are those for men and women for whom PAEE and PAL could be calculated from TEE and BMR_{DLW}) calculated from the FFM and FM deriving from total body water; r^2 =0.74 for men and 0.73 for women)

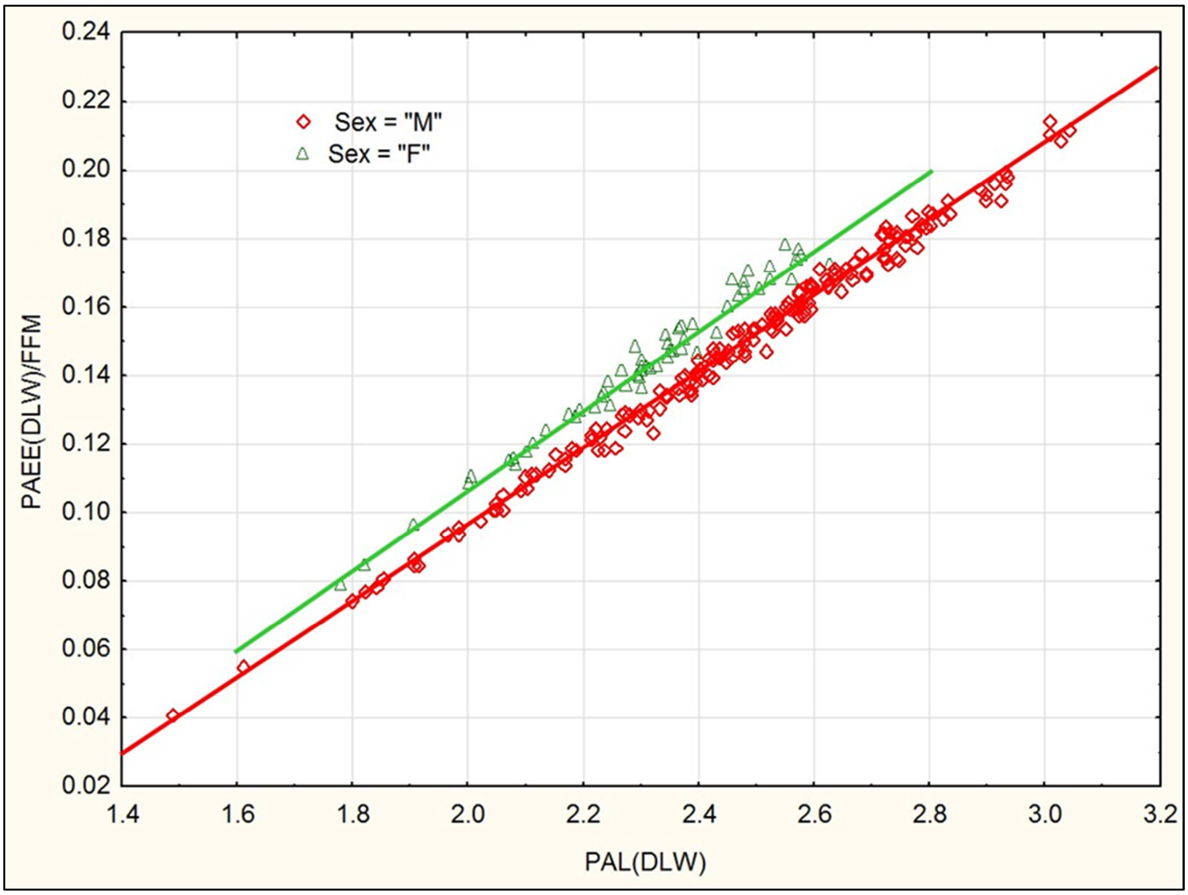

Figure A4 (B): Relationship between PAEE/kg FFM and PAL_{DLW} (Values are those for men and women for whom PAEE/kgFFM and PAL could be calculated from TEE and BMR(DLW) calculated from the FFM and FM deriving from total body water; r^2 = 0.99 for men, 0.98 for women)

Table A8: BMR, energy expenditure, PAEE and PAL values

Situation	Group	N	BMR_H		TEE (MJ/day)		PAEE (MJ/day)		PAEE/kg body wt (MJ/day/kg)		PAL	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Operations	Jackson (M[a])	18	7.31	0.40	15.3	2.57	6.5	2.22	0.085	0.03	2.09	0.33
CMS(R)	ATR Winchester (1-2; F)	8	5.77	0.39	12.4	1.14	5.4	0.78	0.089	0.01	2.15	0.13
CMS(R)	ATR Winchester (1-2; M)	6	7.17	0.49	15.2	1.50	6.5	1.31	0.090	0.02	2.13	0.22
CMS(R)	ATR Winchester (8-9; F)	6	5.70	0.36	12.5	0.62	5.5	0.41	0.094	0.01	2.19	0.10
CMS(R)	ATR Winchester (8-9; M)	5	7.15	0.54	14.8	1.40	6.1	1.18	0.086	0.02	2.07	0.19
CMS(R)	ATC Pirbright (1-2; F)	16	5.57	0.47	12.2	1.44	5.4	0.97	0.094	0.01	2.19	0.16
CMS(R)	ATC Pirbright (1-2; M)	16	7.21	0.48	17.2	2.09	8.3	1.82	0.115	0.03	2.40	0.30
CMS(R)	ATC Pirbright (13-14; F)	16	5.54	0.47	13.3	1.59	6.5	1.08	0.112	0.01	2.41	0.17
CMS(R)	ATC Pirbright (13-14; M)	16	7.16	0.63	17.7	1.86	8.7	1.26	0.121	0.02	2.47	0.17
RAF Phase-1	RAF Halton A[b] (F)	13	5.52	0.39	12.5	0.70	5.7	0.55	0.099	0.01	2.27	0.14
RAF Phase-1	RAF Halton A (M)	11	7.52	0.56	18.1	1.45	8.8	1.20	0.114	0.02	2.41	0.20
RAF Phase-1	RAF Halton B (F)	13	5.53	0.37	12.1	1.58	5.4	1.36	0.093	0.02	2.20	0.28
RAF Phase-1	RAF Halton B (M)	11	7.53	0.58	17.9	1.13	8.5	0.85	0.111	0.02	2.38	0.16

CIC	Paras (1-2; M)	20	7.14	0.72	18.3	2.12	9.4	1.41	0.130	0.02	2.57	0.18
CIC	Paras (19-20; M)	11	7.44	0.68	18.4	2.56	9.1	1.82	0.119	0.02	2.47	0.21
CIC	Guards (1-2; M)	16	7.18	0.83	18.0	2.01	9.0	1.34	0.126	0.02	2.51	0.22
CCOC	RMAS (F)	8	5.90	0.54	15.8	1.90	8.4	1.30	0.128	0.02	2.68	0.20
CCOC	RMAS (M)	8	7.58	0.69	19.8	2.27	10.2	1.53	0.130	0.02	2.61	0.17
SCBC	SCBC Brecon (2-3; M)	28	7.51	0.63	19.6	1.77	10.1	1.06	0.128	0.01	2.62	0.14
SCBC	SCBC Brecon (6-7; M)	30	7.43	0.53	21.0	2.07	11.3	1.47	0.144	0.02	2.83	0.22
	All males	**196**	**7.34**	**0.61**	**18.3**	**2.62**	**9.1**	**2.03**	**0.121**	**0.03**	**2.50**	**0.30**
	All females	**80**	**5.61**	**0.44**	**12.9**	**1.72**	**6.0**	**1.32**	**0.101**	**0.02**	**2.29**	**0.23**
	All Groups	**276**	**6.84**	**0.97**	**16.7**	**3.44**	**8.2**	**2.33**	**0.115**	**0.03**	**2.44**	**0.30**

[a] Time when DLW measurements were taken during active service/training (specified week(s)) and gender (F=female; M=male)
[b] RAF Halton A = first DLW measurement; RAF Halton B = second DLW measurement

88. The regressions shown above in Figure A4 (B) comparing PAEE/kg FFM with PAL_{DLW} do not include all volunteers, only those for whom TBW values were available. This allowed PAEE/kg FFM and PAL_{DLW} to be calculated from the body composition data. For the entire dataset, which includes subjects with no body composition information, a comparison of PAL_H with PAEE can only be done in terms of the correlation of PAEE/kg body weight with PAL_H. This is shown in Figure A5 below, where a similar linear relationship is clear, (r^2 =0.94 for men and for 0.91 women), as would be expected. This is because the algebraic relationship discussed above for the PAL_{DLW} and FFM-adjusted PAEE also applies for PAL_H and weight adjusted PAEE, given that BMR_H is mainly a function of body weight. However, in this case the gender separation is much less obvious with very small differences in the slopes and intercepts of the regressions for men and women.

89. Taking Figure A4 and Figure A5 together it is clear that PAL is a good predictor of PAEE per kg of body weight and especially PAEE per kg FFM within this population group.

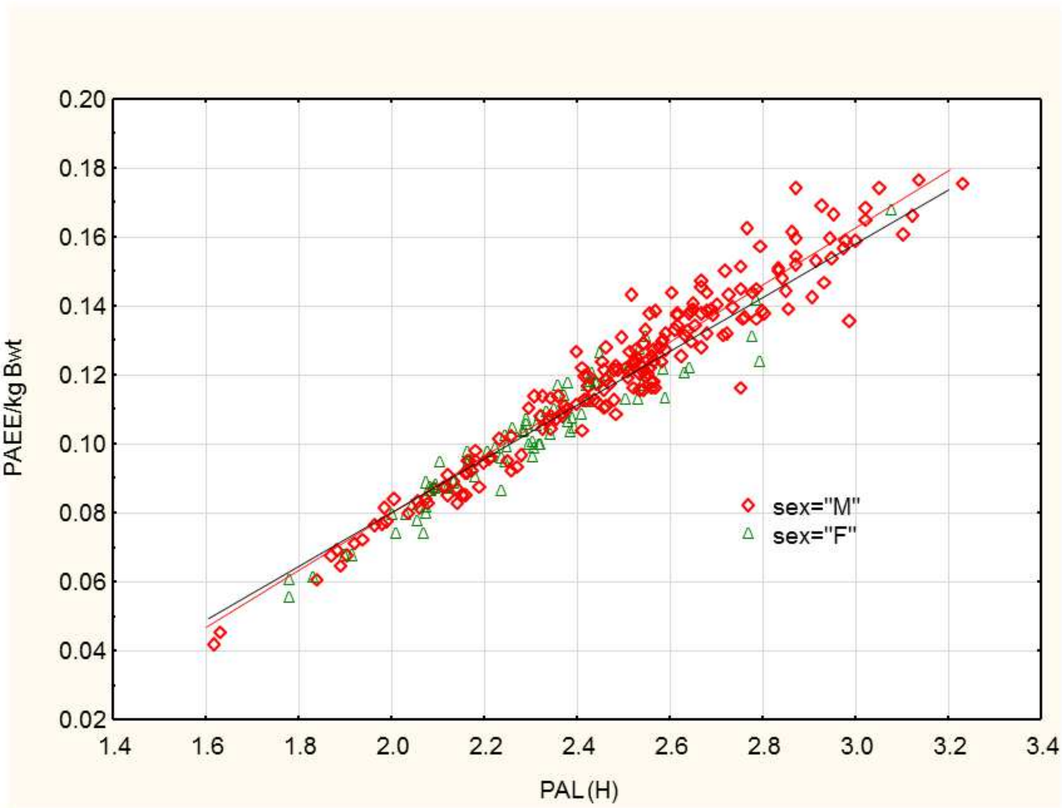

Figure A5: Relationship between PAL_H and PAEE/kg body weight (r^2 =0.94 for men and 0.91 for women)

Conclusions on the relationship between PAL and PAEE among military personnel and trainees

90. The data discussed above show that, after adjustment for size and especially for FFM (where possible), the DLW-derived PAL value captures the variability in physical

activity between men and women within this population group to an acceptable level of accuracy. Therefore within this dataset, where most PAL values are in the active to very active range, and with most volunteers of a healthy body weight and body composition, PAL does represent a good measure of individual physical activity levels, when adjusted for body weight and FFM. It is also an appropriate measure of TEE on which to devise an EAR for energy.

Analysis of variability of PAL_H values between groups

91. The overall range and distribution of PAL_H values between groups and genders is tabulated in Table A9 and shown as box and whisker plots in terms of means and overall range in Figure A6.

Gender effects

92. Within a particular training regime designed for male and female recruits, total energy expenditure will be higher in men because on average they are bigger than women, with a higher BMR/kg; however, is there also a gender difference in the PAL value?

93. Figure A6 shows means and overall ranges of PAL_H, and Figure A7 shows means ± 95% confidence intervals and any significant gender effects between groups. Gender effects are small if they exist at all. Of the seven groups with both male and female volunteers, there are significant gender differences within only two groups: in the initial measurements of volunteers on both RAF Phase-1 and CMS(R) ATC Pirbright training courses. In these two cases, PAL values were slightly lower for women than for men.

94. However, it is apparent in Figure A7 that even within these groups there is some overlap between 95% confidence intervals. For CCOC (RMAS), mean values for women are higher than men and the highest mean overall value for any group, (mean PAL_H = 2.68), with the exception of SCBC Brecon (weeks 6-7). This means that, for the two groups with significant gender effects, this may be due to a Type 1 error suggesting that there are no gender effects within any group. Such a conclusion means that any further inspection of energy expenditure can be made without gender separation of PAL values, thus simplifying the analysis.

Differences in PAL values between groups

95. With no obvious gender differences, the second issue is the extent of any true differences between groups of military personnel irrespective of gender. The overall range of PAL_H values for all groups analysed irrespective of gender is shown graphically in Figure A8.

96. For the front-line troops on active service (Jackson), energy expenditure was most diverse, generating the lowest and some very high energy expenditure levels. The remaining groups generally have less diverse energy expenditure levels, as would be expected since each group was undertaking a specific training programme.

97. There is considerable overlap between groups and a number of different approaches to grouping them together could be used. However the most logical is grouping the troops by the different training courses. Overall, the groups examined fall into three significantly different groupings in terms of mean PAL values: Active Service, Military

Training Courses A (CMS(R) and RAF Phase-1), and Military Training Courses B (CIC, CCOC and SCBC).

98. The range and distribution of PAL values for each training and active service group within each of these three groupings are shown in Table A10. The significant difference in the mean PAL values between the active service grouping and the two training course groupings (Military Training Courses A and B) and also between the active service grouping and five of the individual training course groups is indicated by the number superscripts (1, 2 and 3) in Table A10. Table A10 also shows the 95% confidence intervals for each grouping, which is also shown graphically as box plots in Figure A9B.

Table A9: PAL values by group and gender: means and distribution

Situation	Group	PAL					
		Mean	**Min**	**25th percentile**	**Median**	**75th percentile**	**Max**
Operations	JACKSON (M[a])	2.09	1.62	1.90	2.08	2.16	2.97
CMS(R)	ATR Winchester (1-2; F)	2.15	2.00	2.08	2.12	2.20	2.41
CMS(R)	ATR Winchester (1-2; M)	2.13	1.89	1.98	2.06	2.37	2.42
CMS(R)	ATR Winchester (8-9; F)	2.19	2.07	2.09	2.18	2.29	2.33
CMS(R)	ATR Winchester (8-9; M)	2.07	1.84	1.99	2.00	2.18	2.34
CMS(R)	ATC Pirbright (1-2; F)	2.19	1.90	2.07	2.17	2.33	2.43
CMS(R)	ATC Pirbright (1-2; M)	2.40	2.07	2.16	2.33	2.63	2.92
CMS(R)	ATC Pirbright (13-14; F)	2.41	2.16	2.27	2.39	2.54	2.79
CMS(R)	ATC Pirbright (13-14; M)	2.47	2.11	2.40	2.47	2.56	2.78
RAF Phase-1	RAF Halton A[b](F)	2.27	2.01	2.18	2.29	2.35	2.46
RAF Phase-1	RAF Halton A (M)	2.41	2.03	2.27	2.42	2.59	2.69
RAF Phase-1	RAF Halton B (F)	2.20	1.78	1.91	2.31	2.42	2.53
RAF Phase-1	RAF Halton B (M)	2.38	2.16	2.19	2.42	2.52	2.56

CIC	Paras (1-2; M)	2.57	2.21	2.46	2.57	2.74	2.86
CIC	Paras (19-20; M)	2.47	2.06	2.36	2.53	2.57	2.73
CIC	Guards (1-2; M)	2.51	2.23	2.30	2.51	2.61	2.95
CCOC	RMAS (F)	2.68	2.45	2.55	2.64	2.79	3.08
CCOC	RMAS (M)	2.61	2.33	2.52	2.59	2.71	2.87
SCBC	SCBC Brecon (2-3; M)	2.62	2.32	2.54	2.63	2.68	2.93
SCBC	SCBC Brecon (6-7; M)	2.83	2.44	2.65	2.85	3.00	3.23
	All males	**2.50**	**1.62**	**2.32**	**2.53**	**2.68**	**3.23**
	All females	**2.29**	**1.78**	**2.12**	**2.30**	**2.43**	**3.08**
	All personnel under training	**2.46**	**1.78**	**2.26**	**2.46**	**2.64**	**3.23**
	All Groups	**2.44**	**1.62**	**2.22**	**2.45**	**2.63**	**3.23**

[a] Time when DLW measurements were taken during active service/training (specified week(s)) and gender (F=female; M=male)
[b] RAF Halton A = first DLW measurement; RAF Halton B = second DLW measurement

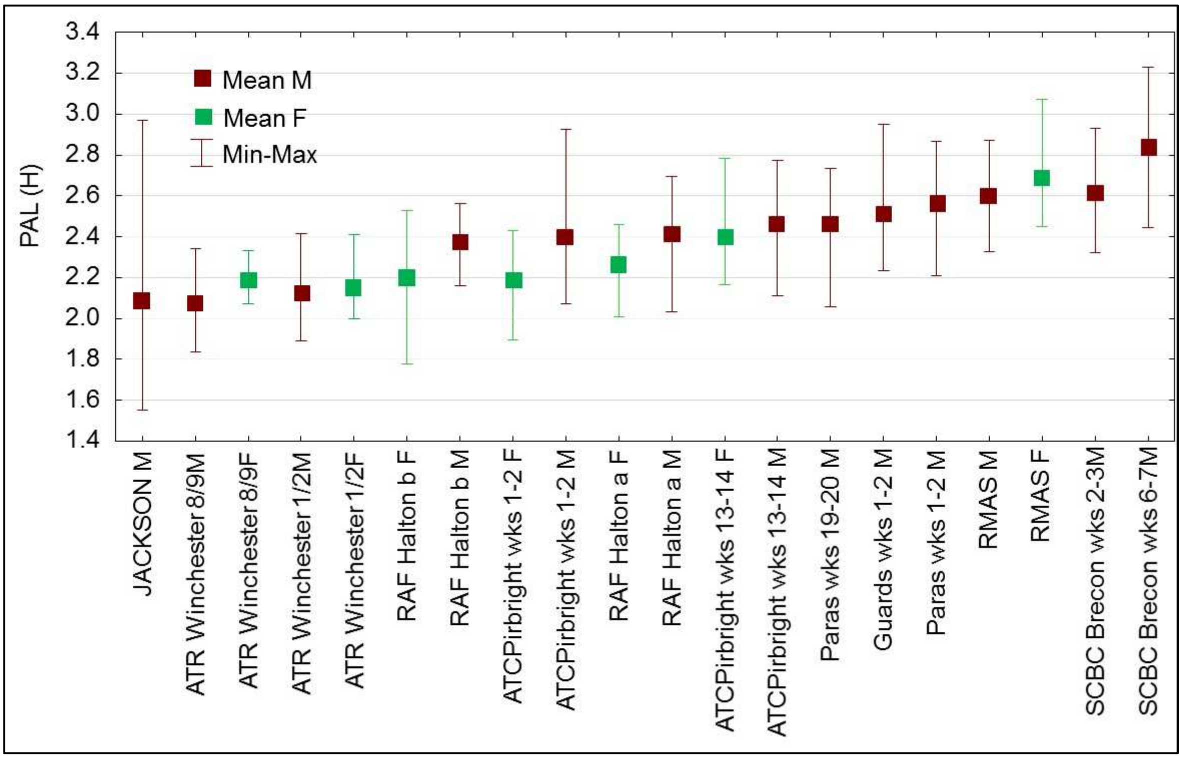

Figure A6: PAL_H values, means and range

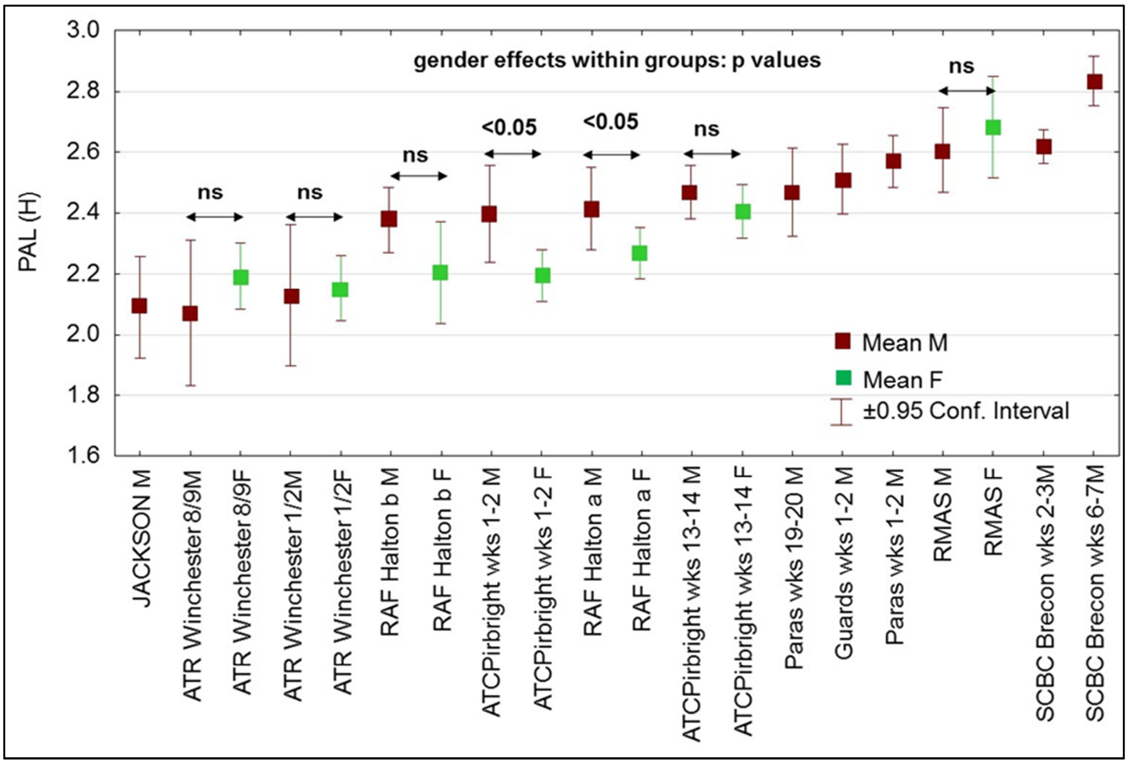

Figure A7: PAL_H values, means and within-group gender differences

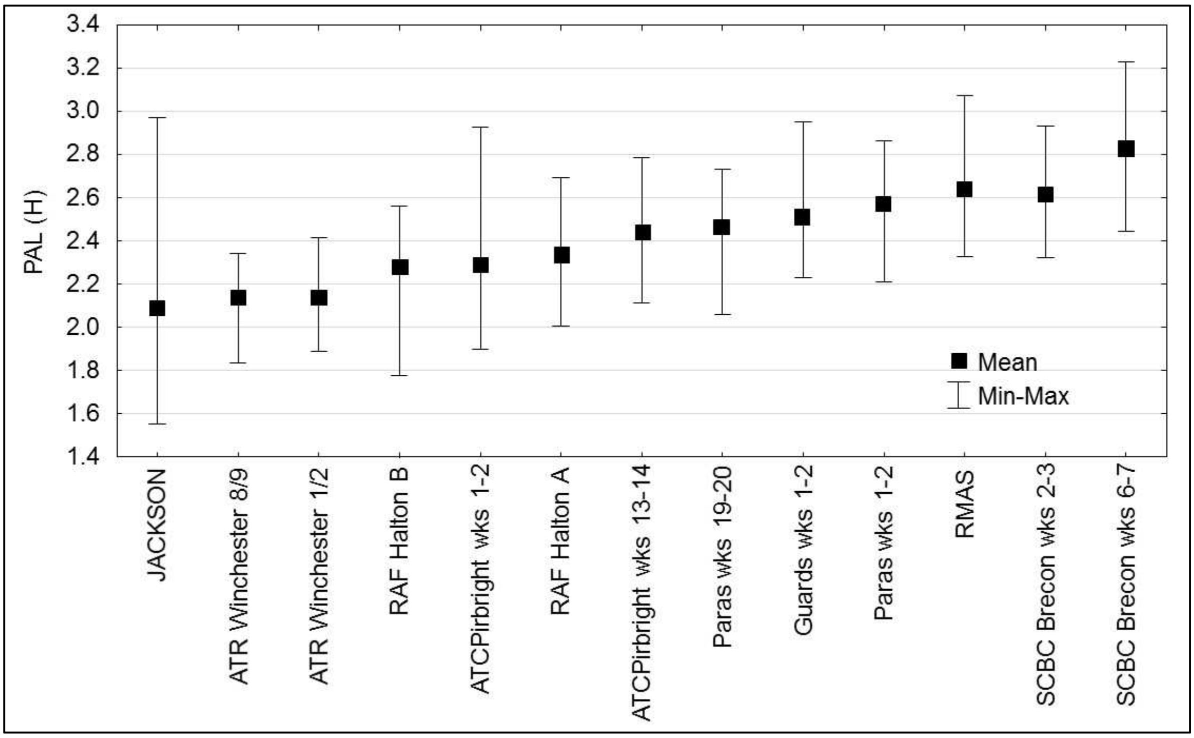

Figure A8: Overall range of PAL values between groups not separated by gender

Table A10: Overall range of PAL values between courses and groups (not separated by gender)

Situation/Group	N	Mean	95%CI		SD	Min	25th percentile	Median	75th percentile	Max
Active Service (Jackson)	**18**	**2.09 [1]**	**1.93**	**2.26**	**0.33**	**1.62**	**1.90**	**2.08**	**2.16**	**2.97**
Military Training Courses A	**137**	**2.30[2]**	**2.27**	**2.34**	**0.23**	**1.78**	**2.15**	**2.32**	**2.44**	**2.92**
CMS(R)	*89*	*2.30 [2]*			*0.23*	*1.84*	*2.12*	*2.31*	*2.43*	*2.92*
ATR Winchester (1-2[a])	13	2.15			0.17	1.89	2.07	2.13	2.24	2.42
ATR Winchester (8-9)	12	2.12			0.16	1.84	2.00	2.12	2.25	2.34
ATC Pirbright(1-2)	32	2.30			0.26	1.90	2.10	2.23	2.40	2.92
ATC Pirbright (13-14)	32	2.44			0.17	2.11	2.33	2.44	2.54	2.79
RAF Phase-1	*48*	*2.31 [2]*			*0.21*	*1.78*	*2.17*	*2.34*	*2.45*	*2.69*
RAF Halton A	24	2.33			0.18	2.01	2.22	2.34	2.43	2.69
RAF Halton B	24	2.28			0.24	1.78	2.16	2.34	2.49	2.56
Military Training Courses B	**121**	**2.64 [3]**	**2.60**	**2.68**	**0.22**	**2.06**	**2.51**	**2.62**	**2.78**	**3.23**
CIC	*47*	*2.53 [3]*			*0.20*	*2.06*	*2.40*	*2.54*	*2.65*	*2.95*
Paras (1-2)	20	2.57			0.18	2.21	2.46	2.57	2.74	2.86
Paras (19-20)	11	2.47			0.21	2.06	2.36	2.53	2.57	2.73
Guards (1-2)	16	2.51			0.22	2.23	2.30	2.51	2.61	2.95
CCOC (RMAS)	*16*	*2.64 [3]*			*0.18*	*2.33*	*2.52*	*2.63*	*2.77*	*3.08*
SCBC Brecon	*58*	*2.73[3]*			*0.18*	*2.32*	*2.56*	*2.68*	*2.90*	*3.23*
(2-3)	28	2.62			0.14	2.32	2.54	2.63	2.68	2.93
(6-7)	30	2.83			0.22	2.44	2.65	2.85	3.00	3.23
All Groups	**276**	**2.44**			**0.30**	**1.62**	**2.22**	**2.45**	**2.63**	**3.23**

[a] Time when DLW measurements were taken during active service/training (specified week(s))

Note: The significant differences between the mean PAL values of active service and the 5 training courses and between active service and the two groups of training courses (Military Training Courses A & B) are indicated by the letter superscripts (groups with different superscripts are significantly different).

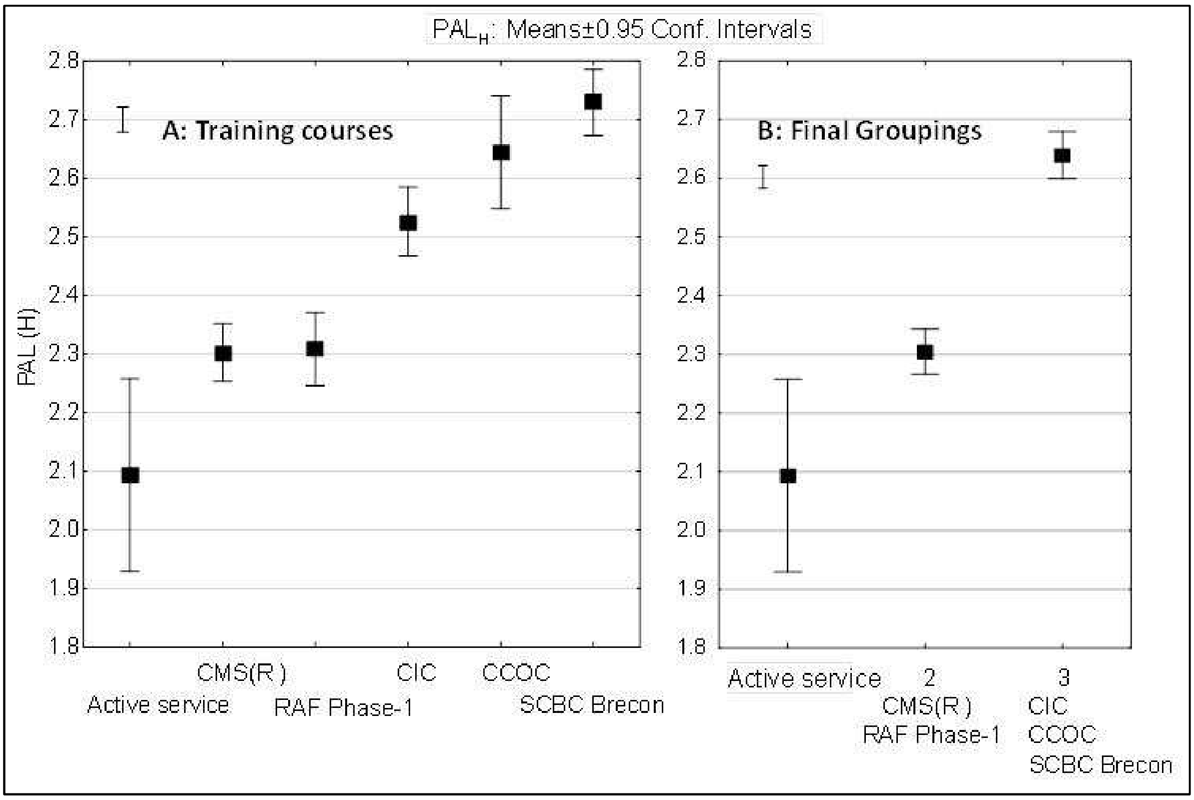

Figure A9: Means and 95% confidence intervals of PAL$_H$ values between frontline troops and A: those on the five training courses and B: the two final groupings

Table A11: Age, weight, height, BMI for volunteers in final groupings

Groupings	**N**	**Sex**	**Age (years) Mean**	**SD**	**Weight (kg) Mean**	**SD**	**Height (m) Mean**	**SD**	**BMI (kg/m^2) Mean**	**SD**
Active Service	18	M	26.4	5.33	76.1	5.7	1.78	0.05	24.1	1.64
Training Courses A	65 72	M F	20.3 20.5	3.40 4.17	74.6 58.5	8.7 6.7	1.79 1.65	0.06 0.06	23.1 21.6	2.51 1.87
Training Courses B	113 8	M F	23.2 23.1	4.36 1.13	76.8 65.6	10.5 10.2	1.77 1.65	0.07 0.05	24.5 24.0	2.60 2.96
All men	196		22.5	4.53	76.0	9.6	1.78	0.06	24.0	2.56
All women	80		20.8	4.04	59.2	7.4	1.65	0.06	21.8	2.12
All Groups	276		22.0	4.46	71.1	11.8	1.74	0.09	23.4	2.64

99. Table A11 shows the age, weight, height and BMI for volunteers in the final three groupings. The overall distribution of PAL values for the volunteers identified in Table A10 is shown in Figure A10 compared with that of the general population (as described by SACN, 2011).

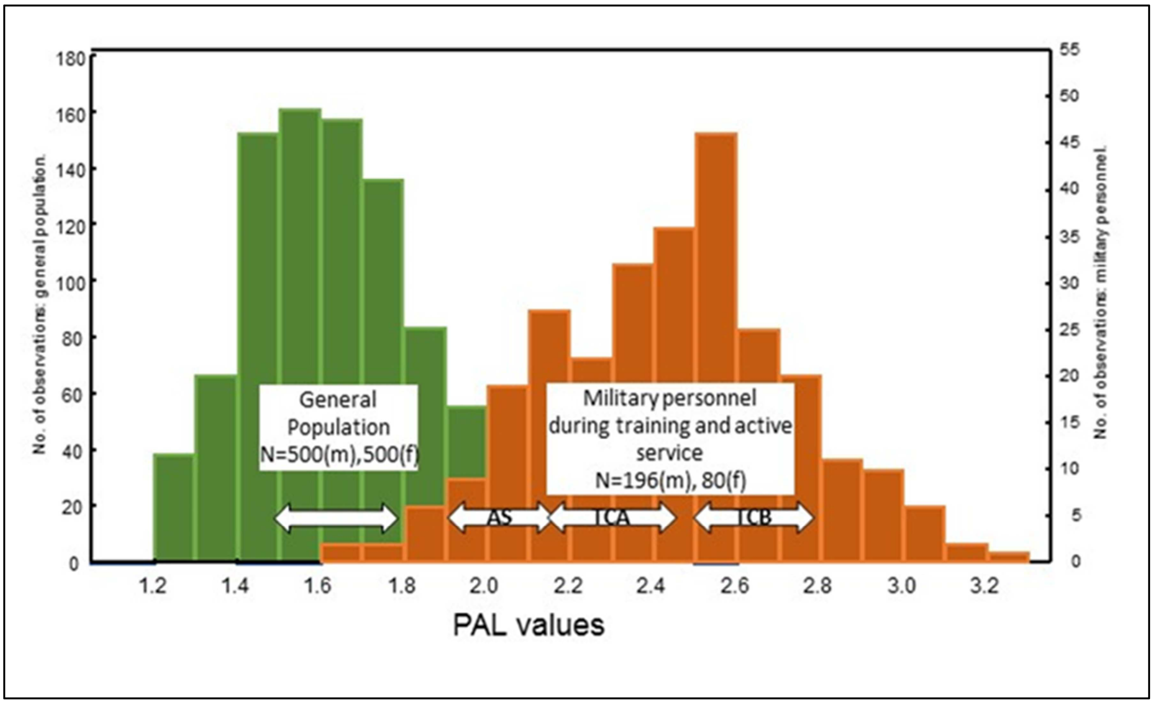

Figure A10 Overall distribution of PAL values for the current dataset of military volunteers compared with the general population as described by SACN (2011)[a]

[a] The ranges indicated by the double ended arrows are the 25th to 75th-percentiles. AS, TCA and TCB refer to the final groupings identified in Table A10.

Discussion

100. This report is a complete analysis of all DLW data on military personnel provided by the INM for the purpose of this review.

101. It needs to be emphasised that all troops examined were very active, with activity levels in the top 5% of the distribution examined for the general population (see Figure A10). For volunteers following the B group of training courses, energy expenditure was at levels which may only be sustainable for short periods of time.

102. Energy expenditure on the CMS(R) and the RAF Phase-1 training courses was lower than on the CIC, the CCOC and SCBC training courses.

103. An explanation for this (provided by the INM), was that the physical training load (in terms of training intensity, frequency and duration), and hence physical demands, are lower for the initial military training programmes of the Armed Forces which include CMS(R) and RAF Phase-1. In contrast, the loads carried, the required intensity of training and the duration of the courses are higher for the CIC, the CCOC at Sandhurst and the SCBC at Brecon. These differences reflect the training requirements each programme is designed to address, and indeed the required occupational physical capability of trainees at the completion of their respective programmes.

104. Although the nature of the training within the various courses studied here has not been examined in detail for this report, it would appear that activity levels for many

individuals, men and women alike, must have been at the limits of their capability. However, data on body weight changes during training listed in Table A5, indicate that in almost all cases weight was maintained or there were small gains or losses; the exceptions were men following the SCBC course who lost on average 5.1 kg and the subset for whom DLW measurements were made who lost 2.43 kg. For this group, which was heaviest at the start of training, with two volunteers who were obese (BMI$\geq$30 kg/m^2), the small weight loss meant that none were obese at the end of training. This would suggest that overall energy intakes were adequate.

References

American College of Sports Medicine (ACSM) American Dietetic Association (ADA) and Dietitians of Canada (DC) (2000). Joint position statement: Nutrition and athletic performance. *Me Sci Sports Exerc* **32,** 2130-2145.

Bennett A & Bridger R. (2010) *Ergonomic Risk Assessment Aboard RFA Argus. Report 2010.025.* Alverstoke, UK: Institute of Naval Medicine

Bennett A, Brasher K & Bridger RS (2011) *Body Mass Index and Changes in Body Mass in Royal Navy Personnel 2007-2011. Report 2011.044.* Alverstoke, UK: Institute of Naval Medicine

Bluck LJC (2008) Doubly Labelled Water for the Measurement of Total Energy Expenditure in Man – Progress and Applications in the Last Decade. *Nutr Bull* **33,** 80 – 90.

Brooks GA & Mercier J (1994) Balance of carbohydrate and lipid utilization during exercise: the “crossover concept”. *J Appl Physiol* **76,** 2253-61

Bridger RS. (2003) *Systematic Review of Occupational Exposures and Knee Disorders. Report 2003.031.* Alverstoke, UK: Institute of Naval Medicine

Burstein, R, Coward AW, Askew WE, Carmel K, Irving C, Shpilberg O, Moran D, Pikarsky A, Ginot G *et al.* (1996) Energy expenditure variations in soldiers performing military activities under cold and hot climate conditions. *Mil Med* **161,** 750-4

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

Committee on Medical Aspects of Food Policy (COMA) (1991) *Report on Health and Social Subjects 41 Dietary Reference Values (DRVs) for Food Energy and Nutrients for the UK, Report of the Panel on DRVs of the Committee on Medical Aspects of Food Policy*. London: The Stationery Office

Corbett J, Neal RA, Lunt HC & Tipton MJ (2014) Adaptation to heat and exercise performance under cooler conditions; a new hot topic. *Sports Med* **44,** 1323-31

Dall TM, Zhang Y, Chen YJ, Askarinam Wagner RC, Hogan PF, Fagan NK, Olaiya ST & Tornberg DN (2008) Costs Associated with Being Overweight and with Obesity, High Alcohol Consumption and Tobacco Use within the Military Health System's Tricare Prime-Enrolled Population. *Am J Health Promot* **22,** 120-139.

Davey T, Delves SK, Layden J, Lanham-New SA & Fallowfield JL (2010) Macro and micro-nutrient intakes of Royal Marine recruits during 32 weeks of military training. *Proc Nutr Soc* **69,** E63.

Davey T, Allsopp AJ, Delves SK, Lanham-New SA & Fallowfield JL (2011) *The Relationship of Food Provision and Nutrient Intake to Training Outcome in Royal Marine Recruits: Final Report. Report* 2011.003. Alverstoke, UK: Institute of Naval Medicine

Debevec T, Bali TC, Simpson EJ, Macdonald IA, Eiken O & Mekjavic IB (2014) Separate and combined effects of 21-day bedrest and hypoxic confinement on body composition. *Eur J Appl Physiol* **114,** 2411-25

Department for Environment, Food & Rural Affairs (DEFRA) (2015) *The Government buying standards for food and catering services.* Available at: https://www.gov.uk/government/publications/sustainable-procurement-the-gbs-for-food-and-catering-services (Accessed: 6 June 2016)

Driskell, JA & Wolinsky, I (eds) (2010) *Nutritional Assessment of Athletes*. Second Edition Boca Raton: CRC Press

Dziubak A, Fallowfield JL, House C, Taylor R, Cobley R, Minnock E, Zioupos P, Davey T & Allsopp AJ (2011) *Surgeon General's Armed Forces Feeding Project: An Evaluation of Physical Training Progression, Dietary Intake and Bone Health in Royal Navy Phase-1 Recruits at HMS Raleigh. Report 2011.042.* Alverstoke, UK: Institute of Naval Medicine

Fallowfield JL, Delves SK, Cobley R, Nevola VR, Verral NG, Lanham New SA, Lambert H & Allsopp AJ (2010a) Surgeon *General's Armed Forces Feeding Project: An Evaluation of the Physical Training Progression and Dietary Intake during Royal Navy Initial Officer Training. Report 2010.038.* Alverstoke, UK: Institute of Naval Medicine

Fallowfield JL, Cobley R, Davey T, Delves SK & Dziubak A (2010b) An Evaluation of the Physical Training Progression During Royal Marine Young Officer Training: 08 Batch Report (Sept 08 – Dec 09). *Report* 2010.021. Alverstoke, UK: Institute of Naval Medicine

Fallowfield JL, Cobley R, Davey T, Delves SK, Brown P & Dziubak A (2011) An Evaluation of the Physical Training Progression During Royal Marine Young Officer Training: 09 Batch Report (Sept 09 – Dec 10). *Report* 2011.017. Alverstoke, UK: Institute of Naval Medicine

Fallowfield JL, Dziubak A, Leiper R, Cobley R, Delves SK, Bentley C, Minnock E, Zioupos P, Lambert H *et al.* (2012a) *Surgeon General's Armed Forces Feeding Project: An Evaluation of Physical Training Progression, Dietary Intake and Bone Health in Royal Air Force Phase-1 Recruits at RAF Halton; Final Report. Report 2012.005.* Alverstoke, UK: Institute of Naval Medicine

Fallowfield JL, Shaw A, Pearson E, Cox V & Wood P (2012b) *Surgeon General's Armed Forces Feeding Project: An Evaluation of the Physical Training Progression and Dietary Intake during Royal Air Force Officer Training. Report 2012.017.* Alverstoke, UK: Institute of Naval Medicine

Fallowfield JL, Delves SK, Brown P, Dziubak & Bentley C (2012c) *Surgeon General's Armed Forces Feeding Project: Operational Feeding Onboard Ship (HMS Dauntless). Report 2012.009.* Alverstoke, UK: Institute of Naval Medicine

Fallowfield JL, Delves SK, Shaw AM, Bentley C, Lanham-New SA, Busbridge M, Darch S, Britland S & Allsopp AJ (2013) *Surgeon General's Armed Forces Feeding Project: Operational Feeding Onboard Ship (HMS Daring). Report 2013.028.* Alverstoke, UK: Institute of Naval Medicine

Fallowfield JL Delves SK, Hill NE, Cobley R, Brown P, Lanham-New SA, Frost G, Brett SJ, Murphy KG *et al.* (2014) Energy Expenditure, Nutritional Status, Body Composition and Physical Fitness of Royal Marines during a 6-Month Operational Deployment in Afghanistan. *Br J Nutr* **112,** 821–829.

Garby L, Lammert O & Nielsen E (1990) Changes in energy expenditure of light physical activity during a 10 day period at 34 degrees C environmental temperature. *Eur J Clin Nutr* **44,** 241-4

Hawley JA & Leckey JJ (2015) Carbohydrate Dependence During Prolonged, Intense Endurance Exercise *Sports Med* **45,** S5-S12

Henry CJK (2005) Basal metabolic rate studies in humans: measurement and development of new equations. *Public Health Nutr* **8,** 1133–1152.

International Atomic Energy Agency (IAEA) (2009) *Assessment of body composition and total energy expenditure in humans using stable isotope techniques*. Vienna: International Atomic Energy Agency.

International Olympic Committee (IOC) (2003a) *Nutrition for Athletes. Proceedings of a Consensus Conference of the International Olympic Committee (IOC) Medical Commission Nutrition and Sport Working Group.* Lausanne, Switzerland: IOM

International Olympic Committee (IOC) (2003b) *Nutrition for Athletes: A practical guide to eating for health and performance.* Nutrition Working Group, International Olympic Committee Medical Commission.

Johnstone AM, Murison SD, Duncan JS, Rance KA, & Speakman JR (2005). Factors influencing variation in basal metabolic rate include fat-free mass, fat mass, age, and circulating thyroxine but not sex, circulating leptin, or triiodothyronine *Am J Clin Nutr* **82,** 941–8.

Levine JA (2005) Measurement of energy expenditure. *Public Health Nutr* **8,** 1123-1132.

Linnane DM, Brown PI, Wilkinson DM, Blacker SD, Richmond VL, Horner FE & Rayson MP (2010) *A Physical Work Demands Analysis of Phase One Training at RAF Halton. Report OPL/10/10* Bristol, UK: Optimal Performance Ltd.

McLaughlin R & Wittert G (2009) The Obesity Epidemic: Implications for Recruitment and Retention of Defence Force Personnel. *Obes Rev* ***10,*** 693-699.

Millward D. Joe (2013) Energy balance and obesity: a UK perspective on the gluttony-sloth debate. *Nutr Res Rev* **26,** 89–109.

MOD (2016) *Defence catering manual (volumes 1-4) (JSP 456)* Available at: https://www.gov.uk/government/collections/defence-catering-manual-jsp-456 (Accessed: 6 June 2016)

Nelson KM, Weinsier RL, Long CL, Schutz Y (1992) Prediction of resting energy expenditure from fat-free mass and fat mass. *Am J Clin Nutr* **56,** 848–56.

NHS Choices http://www.nhs.uk/conditions/vitamins-minerals/pages/vitamin-d.aspx and http://www.nhs.uk/chq/Pages/913.aspx (Accessed: 7 October 2016)

Pace N & Rathbun EN (1945) Studies on body composition. III. The body water and chemically combined nitrogen content in relation to fat content. *J Biol Chem* **158,** 685–91

Pandolf KB, Givoni B, Goldman RF (1977) Predicting energy expenditure with loads while standing or walking very slowly *J Appl Physiol Respir Environ Exerc Physiol* **43,** 577-81

Pöchmüller M, Schwingshackl L, Colombani PC, Hoffmann G (2016) A systematic review and meta-analysis of carbohydrate benefits associated with randomized controlled competition-based performance trials *J Int Soc Sports Nutr* **13,** 27

Public Health England (2014) *Healthier and More Sustainable Catering: Nutrition principles. The scientific principles for developing nutrient-based standards for planning nutritionally balanced menus.* London, UK: Public Health England Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/347883/Nutrition_principles.pdf (Accessed 27 February 2016).

Public Health England (2016) *The Eatwell Guide: helping you eat a healthy balanced diet* Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/510366/UPDATED_Eatwell-23MAR2016_England.pdf (Accessed: 7 April 2016)

Romijn JA, Coyle EF, Sidossis LS, Gastaldelli A, Horowitz JF, Endert E, Wolfe RR (1993) Regulation of endogenous fat and carbohydrate metabolism in relation to exercise intensity and duration *Am J Physiol* **265,** E380-91

Scientific Advisory Committee on Nutrition (SACN) (2011) *Dietary Reference Values for Energy*. London: TSO.

Scientific Advisory Committee on Nutrition (SACN) (2012) *SACN Framework for Evaluation of Evidence.* Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/480493/SACN_Framework_for_the_Evaluation_of_Evidence.pdf (Accessed 26 Jan 2016).

Scientific Advisory Committee on Nutrition (SACN) (2015) *Carbohydrates and Health.* London: TSO.

Schoeller DAE, Ravussin Y, Schutz KJ, Acheson KJ, Baertschi P & Jecquire E. (1986) Energy Expenditure by Doubly Labeled Water: Validation in Humans and Proposed Calculation. *Am J Physiol* **250,** R823 – R830

Shaw AM, Simpson D, Davey T & Fallowfield JL (2013) *Surgeon General's Armed Forces Feeding Project: The Royal Navy: Obesity, Eating Behaviours and Factors Influencing Food Choices. Report* 2013.022. Alverstoke, UK: Institute of Naval Medicine

Shaw AM & Fallowfield JL (2013) *Surgeon General's Armed Forces Feeding Project: Body Composition Changes of Royal Navy and Royal Air Force Recruits during Phase-1 and Phase-2 Training. Report 2013.023.* Alverstoke, UK: Institute of Naval Medicine

Shaw AM & Fallowfield JL (2014) Surgeon General's Armed Forces Feeding Project: A Review of the Physical Demands and Nutritional Requirements of British Army Recruit and Officer Cadet Training. Report 2014.021. Alverstoke, UK: Institute of Naval Medicine

Sundin J, Fear NT, Wessely S & Rona RJ (2011) Obesity in the UK Armed Forces: Risk Factors. *Mil Med* **176,** 507-12.

Valencia ME, McNeill G, Brockway JM & Smith JS (1992) The effect of environmental temperature and humidity on 24 h energy expenditure in men. *Br J Nutr* **68,** 319-27.

Vandenbogaerde TJ, Hopkins WG (2011) Effects of acute carbohydrate supplementation on endurance performance: a meta-analysis. *Sports Med* **41,** 773-92.

Westerterp KR, Donkers JH, Fredrix EW & Boekhoudt P (1995) Energy intake, physical activity and body weight: a simulation model *Brit J Nutr* **73,** 331-341

Westerterp-Plantenga MS, van Marken Lichtenbelt WD, Cilissen C & Top S (2002) Energy metabolism in women during short exposure to the thermoneutral zone. *Physiol Behav* **75,** 227-35

Wood P. (2007). *The Prevalence of UK Service Personnel at Risk of Obesity Related Ill Health. Dstl Technical Report: DstlTR27252*.