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Australian Defence Force Nutritional Requirements in the 21st Century (Version 1)

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ABSTRACT

This report addresses the determinants of military nutritional requirements—that is, the relevant variables that determine the types and quantities of foods necessary to support ADF training and operations—and the current state of knowledge about nutritional requirements. It also includes recommendations on nutritional standards for ADF rationing systems, and suggests areas of research that will help fill the gaps in our knowledge. Nutritional standards are recommended for fresh (i.e. in-barracks or garrison) feeding and for combat ration packs. These standards are based largely on the Nutrient Reference Values recommended by the National Health and Medical Research Council for Australia and New Zealand, but include specific Military Nutrient Reference Values for certain key nutrients.

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Australian Defence Force Nutritional Requirements in the 21st Century (Version 1)

Executive Summary

This report addresses the determinants of military nutritional requirements—that is, the relevant variables that determine the types and quantities of foods necessary to support ADF training and operations. It also examines the current state of knowledge about nutritional requirements, includes recommendations on nutritional standards for ADF rationing systems, and suggests areas of research that will help fill the gaps in our knowledge.

This is the second revision (i.e. the third iteration) of *Australian Defence Force Nutritional Requirements in the 21st Century*. However, although the two earlier documents were 'internal reports', i.e. they were not published in the DSTO Report Series, they were used by the Defence Materiel Organisation (DMO) to set standards for ADF combat ration packs (CRP) and by DSTO to assess the nutritional adequacy of CRP and of fresh-feeding systems.

The recent publication by the National Health and Medical Research Council (NHMRC, 2006) of Nutrient Reference Values for Australia and New Zealand provided an incentive and an opportunity to revise and update this report. It is intended to be a 'living document'—i.e. it will be available only in electronic form and not in hard copy—so it can be updated whenever new information becomes available.

The 2009 Defence White Paper (Department of Defence, 2009) imposes on the ADF a need for self-reliance, a high level of mobility, and an ability to operate in all terrains, climatic conditions and social situations. Therefore, there is a need for rationing systems (particularly ration packs) that will sustain troops during short-term, high-intensity operations (e.g. up to 72 hours) and also a need for rationing systems that will support long-term, low-intensity operations (lasting many weeks). In each case, operations could be conducted in the heat, cold and/or at altitude, in rainforest, desert or temperate regions.

Physical activity levels and gender are the two major determinants of nutritional requirements of ADF members, with age, stature, climate, altitude, terrain, and individual variation playing relatively minor roles. Each of these determinants exerts its effects predominantly via an influence on energy expenditure. Females have approximately 70–75% of the energy requirement that males have for the same activity. The only substantial purely gender-related difference in nutritional requirements is a greater need for iron by female ADF members.

However, the unique requirements of adolescent ADF members should be taken into account in messes where adolescents constitute a substantial proportion of the ADF

population being rationed. Adolescent ADF members have a slightly greater need than adults for energy for growth, and generally also for physical activity. Adolescents also have a significantly greater need than adults of the same gender for some micronutrients, particularly calcium (males and females), phosphorus (males and females) and iron (males only).

The nutritional requirements discussed for ADF members in this document will not necessarily apply to each individual. Although the ADF population is relatively homogeneous, there will always be some variation between individuals. This variation comes from two main sources—different body size and composition, and individual genetic variation in metabolism. However, largely because requirements will vary 'normally' (in the statistical sense) about the mean, it is considered appropriate to base nutritional standards on the nutritional requirements of average male and average female members of the ADF.

The extent of 'over-nutrition' (i.e. excess body fat levels) in the ADF needs to be investigated. The Australian Defence Health Status Report (published in 2000) found that 57% of ADF members were above the healthy weight range. Recommendations are made in the present report on how improvements may be made to monitoring and reporting of body fat levels and determining risk of ill-health through the addition of a simple measurement—waist circumference—to existing regular medical examinations.

It appears to be a near-universal finding that troops under-eat on operations when rationing is by CRP. When nutrient intake is less than ideal, the nutritional status of a subject prior to the period of low nutrient intake itself becomes a determinant of subsequent nutritional status. There is evidence from the military scientific literature (both Australian and overseas) that young service people are entering military service with sub-optimal nutritional status. The potential for this to impact adversely on health and performance can only be overcome by improvements in nutritional quality of diet during service. This implies a strong need for both availability of highly-nutritious food and guidance to ADF members on appropriate food selections to maximise nutritional status.

DSTO has conducted studies to determine the energy expenditure (and therefore nutritional requirements) of (predominantly male) ADF members across a wide range of land-based, and a smaller range of sea-based military activities. These results are summarised in Tables 1 and 2 of the present report. Knowledge gaps can be filled by conducting research on ADF groups not previously studied. There is also scope for resuming the development of an expert system that will allow commanders to determine the food and water needed to sustain troops in particular operational situations.

It is concluded that for the purposes of setting nutritional standards, the ADF can be divided into four population groups—*adult males, adult females, adolescent males* and *adolescent females*. Further, adult male ADF occupations can be conveniently assigned to five distinct categories of energy expenditure, while four categories apply to occupations involving adult females and adolescents. The highest category (*Category 5*) is believed to be a special case, applying largely to males attempting selection to the Special Air Service Regiment. Therefore, only categories 1–4 are regarded as being of practical significance to the vast majority of ADF rationing. However, further studies on the energy expenditures associated with SF training and operations are needed to confirm or alter this belief. Also, it is suggested that during a period of re-feeding following sustained under-consumption (e.g. when troops have been fed with combat ration packs for more than two weeks while engaging in very vigorous physical activities), *Category 5* entitlements are appropriate for the period of re-feeding.

Although there is a reasonable correlation between the defined categories of ADF activity levels and those of the NHMRC (2006), they do not correspond exactly. Consequently, it is recommended that DSTO attempt to add a category of energy expenditure (perhaps designated 'extreme activity') to the six existing NHMRC physical activity levels.

Nutritional quality of the diet of ADF members is critical in ensuring that optimal performance can be maintained as long as possible. This quality is in terms of macronutrients (protein, fat and carbohydrate), micronutrients (vitamins, minerals and trace elements) and dietary fibre.

Carbohydrate is considered to be the most important macronutrient for vigorous physical activity, with fat being of value mainly for acceptability. The important role played by protein in recovery from vigorous physical activity has been recognised only relatively recently. It is recommended that the standard for protein be set at 15–20% of total energy for situations involving light physical activity (*Category 1*), with the range of percentage contributions decreasing linearly as energy expenditure increases (from 14–19% for *Category 2* to 11–14% for *Category 5*). Conversely, the percentage of energy derived from carbohydrate should increase linearly with increasing physical activity from a range of 50–55% (*Category 1*) to 58–63% (*Category 5*), at the expense of fat (decreasing linearly from 27–35% (*Category 1*) to 23–31% (*Category 5*). The recommended ratios of protein to fat to carbohydrate (P:F:C ratios) are shown in Table 4.

As indicated in a footnote to Table 4, the only situation in which it is recommended that carbohydrate should provide more than 63% of energy is when operations are conducted at high altitude—here it is recommended that the P:F:C ratio should be approximately 15:20:65 respectively.

There is preliminary evidence that not only the quantity, but also the quality of carbohydrate may impact on both performance and health. Further research is warranted on the potential to enhance nutritional status by varying the glycaemic index and increasing resistant starch in rations (particularly in combat ration packs).

There is also scope for conducting research on the impact of combining protein with carbohydrate to enhance recovery from vigorous physical activity.

The previous two iterations of this report included Recommended Military Dietary Intakes (RMDIs) for all nutrients that had been assigned Recommended Dietary Intakes (RDIs) in 1991 by the NHMRC. The RMDIs corresponded very closely to the RDIs.

In 2006 the NHMRC published Nutrient Reference Values (NRVs) to apply to the population of Australia and New Zealand. These differ, often substantially, from the 1991 recommendations. It is recommended that the RDIs (or Adequate Intake if an RDI has not been established) of the NHMRC (2006) be adopted as Military Recommended Dietary Intakes (MRDIs) for all nutrients other than thiamin, riboflavin, niacin, vitamin B6, protein and sodium, and also for total energy. The reasons for these exceptions are detailed in the body of this report. It is also recommended that MRDIs be defined for carbohydrate, even though NRVs were not published by the NHMRC for carbohydrate. It is recommended that military-specific Estimated Average Requirements (MEAR) be calculated for the B-group vitamins thiamin, riboflavin, niacin and vitamin B6 as 70% of the respective MRDIs.

Finally, it is argued that nutritional standards should take into account age (adult versus adolescent), gender and activity level. Table 5 shows the MRDIs for *adult males* for five categories of physical activity; Tables 6–8 show the MRDIs for the *adult females*, *adolescent males* and *adolescent females* of the ADF for four categories of activity.

Nutritional standards are recommended for general purpose (i.e. not mission-specific) CRP. These are based on *Category 3* requirements for energy (~16 MJ), protein and carbohydrate for adult males and the MRDI that constitutes the 'worst case' situation for each micronutrient (i.e. the sub-group that has the greatest requirement for each specific micronutrient) for ADF members working at *Category 3* That is, the nutritional requirements of practically all ADF members working at *Category 3* will be met by the basic ration pack if it is eaten in its entirety. Table 9 details the recommended nutritional criteria for general purpose ration packs.

Further, it is recommended that fortification to three times the MRDI should occur for four key vitamins—thiamin, riboflavin, vitamin B6 and vitamin C—to counteract storage losses and the discarding of ration pack items. It is also recommended that more research be conducted into vitamin stability during storage of ration packs, and on how bioavailability of micronutrients from combat ration packs affects nutritional status of ADF members.

It is recommended that a small range of mission-specific ration packs be developed; that consideration be given to adopting a modular, just-in-time process for procuring, packing and distributing CRP; and that investigation be conducted into the need for, and most appropriate form of a group-feeding pack.

Recommendations are provided on how entitlements to fresh rations should be determined.

Tables 5–8 show the MRDIs that apply for homogeneous groups of ADF members (i.e. all members are of the same gender and age group—adult or adolescent).

For a mixed ADF population (a mixture of genders and age groups) the entitlements to energy and macronutrients for fresh feeding should be based on the number to be fed and the MRDIs that apply to the 'worst case' situation (i.e. the sub-group that has the greatest requirement for each specific nutrient). Table 10a shows these recommended entitlements. Appendix B provides an example of how the entitlements to total energy can be determined for a mixed ADF population to be fed freshly-cooked food at a mess.

In designing ration scales for fresh feeding, it is recommended that a basic scale be devised based on the MRDIs for energy, protein and carbohydrate for adolescent males working at *Category 1*. For the remaining nutrients, the MRDI that applies to *Category 4* physical work output for the population sub-group that constitutes the 'worst case' situation should apply. Table 10c shows the recommended nutritional basis of the basic fresh-feeding scale. Allowance should also be made for inevitable food discarding. It is suggested that this allowance be 15%—i.e. food availability should be 15% above the estimated requirement.

To feed troops working above *Category 1*, it is recommended that between-meal snacks be devised in modular form, with each module providing 1–2 MJ.

Dietary modelling should be conducted to determine the ability of 'real world' diets based on these entitlements to meet the MEARs of ADF members. Table 10b shows the nutritional criteria for this dietary modelling for mixed population groups of ADF members. Table 10d shows the nutritional criteria for modelling the adequacy of the basic ration scale (*Category 1*, mixed population).

In assessing the nutritional adequacy of intake of ADF groups it is also the MEARs that apply. Table 10b applies in relation to assessing the adequacy of intake for mixed population groups; Tables 11–14 apply to the four categories of homogeneous groups of ADF members.

When determining the adequacy of nutritional intake of an individual ADF member, it is appropriate to use the MRDIs applicable to that individual's population group and activity category (Tables 5–8 apply).

The recommended entitlements in this report are also considered to be an appropriate basis for the development of military core food groups and a military guide to healthy eating.

It is also suggested that the nutritional entitlements supporting 'hot-boxed meals' (used for fresh feeding in the field) should be based on the appropriate work category (3 or above) for adult male ADF members.

The implications of under-consumption in the field, specifically when feeding is by CRP, are addressed. The origins of 'negative energy balance', how this affects military performance, and steps that may be taken in an attempt to overcome any perceived problems are critical factors affecting nutritional status of ADF members. It is concluded that previously well-nourished troops should suffer no decrement to performance for at least 16 days when rationing is solely by CRP. It is also concluded that more research is needed in this area.

Following an extended period of negative energy balance, it may be appropriate to aim for a recovery period equal to about half the period of negative energy balance. Until further information is available, it is considered prudent to attempt to limit the rate at which recovery is attained to a maximum of ~8 MJ per day. That is, the tentative recommendation is that the excess of intake over expenditure during the recovery period should be no more than 8 MJ per day. It may also be appropriate to seek advice from military Medical Officers on how recovery feeding can be safely conducted if troops have undergone an extensive period of severe under-consumption.

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Chris graduated from the Australian National University with BSc (Hons) in 1972. He has 35 years experience in food science, nutrition and exercise physiology, including extensive research into food acceptability, food intake, energy expenditure and physical performance enhancement of ADF members. For ten years Chris was the Australian National Leader of an international defence technical panel under The Technical Cooperation Program (TTCP). This panel conducted collaborative and cooperative research into performance enhancement for special and conventional military operations. Currently Chris is continuing his research into aids to military performance and nutritional promotion of health and military fitness. In 2006 he was appointed Assistant Site Manager of DSTO-Scottsdale. In 2007 Chris became the Australian member of a NATO Research Technical Group that aims to develop optimal standards for combat ration packs.

Contents

Glossary of Terms

Abdominal Obesity – Excess body fat in the region of the abdomen. This is the form of obesity most strongly associated with increased risk of type 2 diabetes and cardiovascular disease.

Adequate Intake (AI) – The average estimated or experimentally-determined daily intake of a nutrient in a group (or groups) of apparently healthy people. Because the observed population is healthy, the average intake is assumed to be adequate (NHMRC, 2006).

Adiposity – Degree of body fatness.

Acceptable Macronutrient Distribution Range (AMDR) – An estimate of the range of intake for each macronutrient for individuals (expressed as per cent contribution to energy), which would allow for an adequate intake of all the other nutrients whilst maximising general health outcome (NHMRC, 2006).

Adolescent ADF Member – A recruit undergoing recruit training, or a serving soldier, sailor or airman who is less than 19 years of age.

Adult ADF Member – For the purposes of determining nutritional requirements, an 'adult ADF member' is assumed to be in the age group 19–31 years.

Annual Health Assessment (AHA) – A component of the ADF health promotion program, the AHA includes a general health questionnaire, age- and sex-specific screening, measures of body weight and height, blood pressure, results of recent serology and fitness testing, vaccination status, hearing test and lifestyle counselling.

Basal Metabolic Rate (BMR) – The minimum rate of metabolism (i.e. rate of energy expenditure) compatible with survival. BMR roughly equates with the metabolic rate during deep sleep.

Body Mass Index (BMI) – An indication of 'weight category', BMI is defined as weight (kg)/height (m)-squared. The National Health and Medical Research Council (NHMRC, 2003) recognises the following definitions: BMI < 18.5 is defined as *underweight*; BMI in the range 18.5–24.9 is *healthy weight range*; BMI in the range 25.0–29.9 is *overweight*; BMI ≥ 30.0 is *obese*. The Director General Defence Health Services (Department of Defence, 2002) recognises three classes of obesity — Class 1 is BMI in the range 30.0–34.9; Class II is BMI in the range 35.0–39.9; Class III is BMI ≥ 40.0.

***Cis* fat** – A polyunsaturated fat that, unlike the *trans* form (see separate entry below) has the normal spatial configuration and therefore does not behave in the body like a saturated fat.

Combat Ration Packs (CRP) – Also known as 'ration packs', 'operational ration packs' and 'combat rations', these are packs of processed foods and other items associated with rationing (e.g. matches, cutlery, can-opener). They may be for individual or group feeding, and may be general-purpose or mission-specific (i.e. designed to support operations in a particular climate or missions of a special nature, such as short-term/high-intensity operations).

Comprehensive Preventive Health Examination (CPHE) – Conducted every five years, the CPHE is similar to the Annual Health Assessment (see above) but more comprehensive, addressing, *inter alia*, smoking, alcohol consumption, sexual behaviour, stress exposure, sun protection, diet and physical activity. The CPHE replaces the AHA for that year.

Defence Materiel Organisation (DMO) – The Defence agency that purchases new platforms and equipment (including combat ration packs) and conducts through-life support for equipment currently in service.

Defence White Paper – The highest-level policy document used by the ADF and Australian government for planning long-term capability development.

Energy Balance – A state of 'energy balance' is achieved when energy intake from food equals energy expenditure. Negative energy balance occurs when body energy reserves are being depleted and weight is being lost; positive energy balance involves increase in energy reserves (usually body fat) and body weight.

Ergogenic Aid – An aid to physical performance. An ergogenic aid may be nutritional (e.g. carbohydrate loading), pharmacological (e.g. amphetamines), mechanical (e.g. a swimming costume that aids buoyancy) or psychological (e.g. hypnosis).

Estimated Average Requirement (EAR) – A daily nutrient level estimated to meet the requirements of half the healthy individuals in a particular life stage and gender group (NHMRC, 2006).

Estimated Energy Requirement (EER) – The average dietary energy intake that is predicted to maintain energy balance in a healthy adult of defined age, gender, weight, height and level of physical activity, consistent with good health (NHMRC, 2006).

Glycaemic Index (also spelled **glycemic index**) **(GI)** – A measure of the rate at which carbohydrate is released from ingested food into the blood; high GI foods lead to rapid increase in blood glucose, low GI foods are slow-release foods.

Healthy Weight Range – See Body Mass Index.

Hyponatraemia (also spelled **hyponatremia**) – A dangerously low level of sodium in the blood. Hyponatraemia can result from drinking plain water while sweating profusely (and thereby losing sodium).

Iron Deficiency – Iron deficiency occurs in three stages. The first stage—*iron deficiency*—is characterised by low iron stores. In the second stage—*iron deficiency erythropoiesis*—red blood cell production decreases. The final and most severe stage—*iron deficiency anaemia*—involves abnormally low haemoglobin in the blood. Symptoms of anaemia include impairments to physical and cognitive performance, immune function and thermoregulation.

Joule (J) – The fundamental unit of energy in the Système International (SI, also known as the metric system of measurement). One joule is the work done when one kilogram is accelerated at one metre per second-squared across a distance of one metre.

Kilojoule (kJ) – One thousand joules (i.e. 1 kJ = 1000 J). One Calorie (or 1 kcal) = 4.184 kJ.

Maximal Oxygen Uptake ($\dot{V}O_{2max}$) – The maximal rate at which oxygen can be used by the body to release energy. $\dot{V}O_{2max}$ is considered to be the best general measure of physical work capacity.

Megajoule (MJ) – One MJ is the equivalent of 1000 kJ (see Kilojoule above).

Metabolic Equivalent (MET) – The metabolic rate associated with a physical activity expressed as a multiple of BMR (see Basal Metabolic Rate). For example, an activity that involves energy expenditure at twice BMR is rated as 2.0 METs.

Military Estimated Average Requirement (MEAR) – The military equivalent of the Estimated Average Requirement.

Military Nutrient Reference Value (MNRV) – The military equivalent of the Nutrient Reference Value defined by the National Health and Medical Research Council (NHMRC, 2006). MNRVs include, *inter alia*, Military Estimated Average Requirements (MEARs) and Military Recommended Dietary Intakes (MRDIs).

Military Recommended Dietary Intake (MRDI) – The recommended daily intake level of a nutrient for ADF members engaged in training or operations at a particular level of work output. MRDIs are recommended for four ADF subgroups—*adult males, adult females, adolescent males* and *adolescent females*. In this context an 'adult' is assumed to be in the age group 19–31 years, and 'adolescent' implies those aged less than 19 years (ADF adolescents will be 17 or 18 years).

NATO HFM RTG 154 – A Research Technical Group in NATO. RTG 154 *Nutrition Science and Food Standards for Military Operations* consisted of Defence science representatives of NATO member nations and Australia (which is not a NATO nation but comes under the category 'Miscellaneous'). RTG 154 conducted its program of work from 2006 to 2009. One of the key activities of RTG 154 was the development of benchmark nutritional standards for combat ration packs.

Nutrient Reference Values (NRVs) – A collective term for a series of recommended nutrient intakes published by the National Health and Medical Research Council (NHMRC, 2006). NRVs include Estimated Average Requirement (EAR), Adequate Intake (AI), Upper Level of

Intake (UL), Recommended Dietary Intake (RDI) and Suggested Dietary Target (SDT). Each of these terms is defined elsewhere in this Glossary.

Obese/Obesity – See Body Mass Index.

Osmolality – A measure of the osmoles of solute per kilogram of solvent. In lay terms, there will be a net flow of water in the direction of the solution with the higher osmolality. For example, water will flow initially from the blood to the intestine if a carbohydrate drink is consumed that has higher osmolality than the blood, thereby exacerbating dehydration.

Overweight – See Body Mass Index.

Physical Activity Level (PAL) – The mean daily energy expenditure of an individual or group expressed as a multiple of BMR (see Basal Metabolic Rate). For example, an individual or group whose mean daily expenditure is 75% above BMR has a PAL of 1.75.

P:F:C – The ratio of the contributions of protein, fat and carbohydrate respectively to total energy, expressed as percentages.

Polyunsaturated Fat – A type of fat that has more than one double bond along the fatty acid chain. Polyunsaturated fats are generally liquid at room temperature (so are called 'oils'). Most naturally-occurring polyunsaturated fatty acids have the *cis* configuration; some manufactured products contain the *trans* form (see separate entries for *cis* and *trans* fats). From the perspective of human nutrition, the two major categories of polyunsaturated fats are those in which the first double bond is found on the third carbon atom from the methyl end of the chain ('n-3' also known as 'omega-3') and those in which the first double bond is on the sixth carbon atom ('n-6' or 'omega-6').

Ration Scales – Scales of entitlements to fresh food for garrison (also known as barracks or mess) feeding, and when fresh feeding can take place in the field.

Recommended Dietary Intake (RDI) – The average daily dietary intake level of a nutrient that is sufficient to meet the nutritional requirements of nearly all (97–98 per cent) healthy individuals in a particular life stage and gender group (NHMRC, 2006).

Resistant Starch – A form of starch that resists mammalian digestive enzymes in the small intestine. As a result it passes to the large intestine, where bacteria convert some of the starch to short-chain fatty acids (SCFA). These SCFA are believed to have health benefits.

Saturated fat – A type of fat in which there are no double bonds along the length of the fatty acid molecule (i.e. all the carbon atoms are 'saturated' with hydrogen). Saturated fat is found in large quantities in fats that are solid at room temperature (e.g. butter, lard, tallow) and also in whole milk and cream. High intakes of saturated fats are associated with increased blood cholesterol, and therefore with increased risk of heart disease.

Suggested Dietary Target (SDT) – A daily average intake from food and beverages for certain nutrients that that may help in prevention of chronic disease (NHMRC, 2006).

TTCP-HUM-TP14 – A technical panel under Group HUM (Human Resources and Performance) of The Technical Cooperation Program (TTCP). TTCP consists of Defence representatives of five member nations — the US, UK, Canada, New Zealand and Australia — who collaborate on non-atomic military research and development. The title of HUM-TP14 is *Protection and Sustainment of Physical and Cognitive Performance.*

***Trans* fat** – A polyunsaturated fat that does not have the usual *cis* configuration (see 'Polyunsaturated Fat' above). As a result it behaves more like a saturated fat in the body, and is therefore believed to have deleterious health effects.

Underweight – See Body Mass Index.

Upper Level of Intake (UL) – The highest average daily nutrient intake level likely to pose no adverse health effects to almost all individuals in the general population (NHMRC, 2006). As intake increases above the UL, the potential risk of adverse effects increases.

Watt (**W**) – SI unit of power output. One watt = 1 joule/second (see 'Joule' above).

1. Introduction

This is the second revision (i.e. the third iteration) of *Australian Defence Force Requirements in the 21st Century*. The first document was written in 1993 (Forbes-Ewan, 1993) and the second in 2002 (Forbes-Ewan, 2002a). However, although the two earlier documents were 'internal reports', i.e. they were not published in the DSTO Report Series, they were used by the Defence Materiel Organisation (DMO) to set standards for ADF combat ration packs (CRP) and by DSTO to assess the nutritional adequacy of CRP and of fresh-feeding systems.

The recent publication by the National Health and Medical Research Council (NHMRC, 2006) of Nutrient Reference Values for Australia and New Zealand provided an incentive and an opportunity to revise and update this report. Also, the strategic situation has altered appreciably since 2002. It was considered appropriate to take into account the evolution of the role played by the ADF in the last seven years, combined with the new nutrition recommendations (NHMRC, 2006), and publish the present report in the formal DSTO Report Series. However, rather than publish this report in 'hard copy' it is intended to be a 'living document' which can be updated whenever new information becomes available. Therefore, the aim is to make the present report accessible only in electronic form to members of the Australian Defence Organisation, and to other approved recipients.

The 2009 Defence White Paper (Department of Defence, 2009 p. 22) recognises that:

> … it would be premature to judge that war among states, including the major powers, has been eliminated as a feature of the international system. While growing economic and other interdependencies between states will act as a brake on the resort to force between them, and high-intensity wars among the major powers are not likely over the period to 2030, such wars cannot be ruled out.

Therefore, the ADF must maintain or even build on its capability (including appropriate feeding systems) to take part in conventional warfare.

The Defence White Paper (Ibid, p. 23) also recognises that:

> ADF deployments into situations of armed conflict short of conventional war may be required. These could be in the form of humanitarian, stabilisation, counter-insurgency, peacekeeping and reconstruction interventions, such as we have undertaken over recent years in Cambodia, Namibia, Bougainville in Papua New Guinea, Somalia, Rwanda, East Timor, Solomon Islands, southern Iraq and Afghanistan.

Further, the ADF is playing a greater role at home in general security, such as the security and protection provided for the Melbourne Commonwealth Games in 2006 and the APEC meeting in Sydney in 2007.

In all cases, a high level of individual operational readiness will be a pre-requisite to the successful completion of operations. Clearly, there is also a need for rationing systems that not only support conventional operations in all terrains and climates, but also support operations in all 'social' conditions—e.g. during humanitarian missions potable water may not be available, and locally-available food may not be wholesome. This implies a need to provide 'complete' rations and also a means for disinfecting water.

The Defence White Paper (Ibid; p.12) states that a high degree of self-reliance is required for the defence of Australia:

> Australia's defence policy should continue to be founded on the principle of self-reliance in the direct defence of Australia and in relation to our unique strategic interests …

Therefore, it would be advisable for the ADF to continue to source ration pack components only from the local region (specifically Australia and New Zealand).

However, Australia should also be prepared to:

- Lead military coalitions where we have shared strategic interests at stake with others, and in relation to which we would be willing to accept a leadership role, in part to compensate for the limited capacity or engagement of others; and
- Make tailored contributions to military coalitions where we share wider strategic interests with others and are willing to accept a share of the burden in securing those interests. (Ibid, p. 13).

Therefore, there will be some reliance on rationing by allies, implying a need to acquire knowledge of nutritional and non-nutritional characteristics of other nations' rations. In addition, there will be a requirement to determine the effects of exposure to non-defence food outlets, e.g. the 'fast food' establishments available at some overseas US bases.

Through its effects on physical and cognitive performance, and immune status, nutrition plays a fundamental role in ensuring that troops are operationally ready. Hence, there is a need for rationing systems, particularly combat ration packs (CRP) that will sustain troops during short-term, high-intensity operations (e.g. up to 72 hours) and also a need for rations that will support long-term, low-intensity operations (lasting many weeks) in the heat, cold, and (perhaps) at altitude. The East Timor experience suggests that CRP may be needed to sustain troops for at least 45 days (Forbes-Ewan, 2001).

There is also a need for ration scales that promote a high level of nutritional status of ADF members before, during and after operations when rationing is with freshly-cooked food ('fresh feeding').

Before the nutritional requirements of ADF members can be satisfied—and nutritional strategies can be devised to enhance performance—those requirements must be determined. Reference to the international military scientific literature will provide some of the required information (see for example, Tharion *et al*., 2005), but our climate, terrain, and military doctrine are not exactly reproduced anywhere else. Therefore, there is a need for DSTO to determine the nutritional requirements of ADF members in operational and training scenarios where the Australian circumstances differ substantially from those of other nations.

Interpretation of the results of these studies must be based on a sound knowledge of the *determinants* of military nutritional requirements. That is, what aspects of the conditions under which a soldier, sailor or airman carries out his or her tasks need to be studied so that CRP and ration scales can be devised to satisfy the demonstrated nutritional needs of ADF members?

The previous version of this report (Forbes-Ewan, 2002a) was based on the published scientific literature to 2001 and the results of studies conducted in Australia prior to 2002 to determine food availability and intake, food discards and energy expenditure in a wide range of military situations. The present report takes into account the international military scientific literature that has become available since 2001, and the results of further studies that have been conducted in Australia. The report addresses not only nutritional requirements of ADF members, but also how those requirements might best be satisfied, and suggests additional research that may allow some knowledge gaps to be filled.

Caveat: This report includes recommendations for further research to create base level knowledge that will inform ADF catering policy and better support future ADF rationing. It is recognised that although DSTO has the capability to conduct much of this research, it does not currently have the necessary resources to carry out more than a small proportion of the recommended R&D. Consequently, much of this research could perhaps best be conducted collaboratively. Therefore, continued Australian membership of international organisations such as The Technical Cooperation Program (TTCP) and NATO will be of great value to Australia. Similarly, memorandums-of-understanding and other agreements with organisations such as CSIRO, the Australian Institute of Sport, NSW Institute of Sport, universities and the New Zealand Defence Force provide additional avenues for collaborative research.

2. Determination of Nutrient Requirements

It is argued in the Introduction to this report that the ADF cannot rely entirely on the results of studies conducted overseas to determine the nutritional requirements of ADF members—our standard operating procedures, range of climates, terrains, load carriage and so on are different to those of other defence forces. Therefore, although much valuable information can be obtained from the military scientific literature, ADF nutritional requirements are best determined by conducting studies on ADF members in typical training and operational situations.

Recommendation 1: *The nutritional requirements of ADF members should be determined by conducting studies of food intake and energy expenditure on ADF members engaged in normal training and operations, and not by relying entirely on overseas results.*

It is assumed in this report that ADF members engaged in training or operations will be between the ages of 17 and 55 years, and are neither pregnant nor lactating. The determinants of nutritional requirements of non-pregnant, non-lactating adult humans can be considered to include personal characteristics such as age, weight, height and gender, in addition to climate, geographic location, terrain, and intensity and type of activity. Psychological stress associated with combat or combat-related activities may also be a determinant of nutritional requirements, but one that is difficult to investigate in peace-time (and one that may not be appropriate to investigate during war, unless this can be done entirely non-invasively).

2.1 Age

The nutritional requirements of children and young adolescents differ from those of adults. In the context of ADF nutritional needs, age is of importance largely for officer cadets, recruits and young ADF members who have only recently completed recruit training. Using FAO:WHO:UNU (2004) as the reference, the National Health and Medical Research Council (NHMRC, 2006) stated that the additional energy requirement for growth 'falls to … 1–2% until mid-adolescence and zero by 20 years of age'. Assuming a requirement of 1.5% additional energy for growth in ADF members aged 17–18 years ('adolescent ADF members' in the remainder of this report), an allowance of ~150 kJ per day would apply to adolescent females, and 200 kJ/day to adolescent males. These figures are based on the NHMRC (2006) Estimated Energy Requirement of 12.2–14.0 MJ/day for males aged 17–18 who are moderately-to-very physically active, and corresponding figures of 9.6–10.9 MJ/day for females.

The additional requirement for growth *per se* is of only minor practical consequence in terms of total energy requirements of ADF members. For example, there is no need for a substantial food supplement to account for additional energy requirements for growth at messes where adolescents constitute only a small proportion of total ADF members. However, there are messes where adolescents constitute a substantial proportion of the ADF population, e.g. recruit training and initial employment training establishments. At such messes, it is appropriate to take into account the likely additional energy requirement not only for growth, but also attributable to the generally higher levels of physical activity of adolescents relative to adults.

Adolescents also have additional requirements for several minerals associated with growth (NHMRC, 2006). The most significant differences (those where the adolescent requirement is more than 20% greater than the corresponding adult requirement) are calcium (30% increase for adolescent males and females), phosphorus (25% for male and female adolescents) and iron (males only, 37%).

This indicates a need to increase the availability of foods that are rich in these specific nutrients at messes where there are substantial numbers of adolescents (e.g. recruit training and initial employment training establishments). An appropriate 'adolescent supplement' providing the additional micronutrients needed by adolescents could consist of extra lean meat, eggs, beans, and fresh fruits and vegetables (as sources of iron or for promotion of non-haem iron absorption through increased vitamin C intake) and dairy products, preferably low- or reduced fat (for additional calcium and phosphorus). Taking into account the likely higher levels of energy expenditure of young ADF members, it may also be appropriate to slightly increase the entitlement to 'carbohydrate' foods (bread, rice, pasta, potatoes and alternatives).

Recommendation 2: *The specific nutritional requirements of adolescents should be taken into account when determining food entitlements of ADF members in messes where adolescents constitute a substantial proportion of the ADF population being rationed.*

2.2 Weight/Height/Individual Variation

Weight and height influence nutritional requirements through their effects on energy expenditure. To maintain appropriate body weight, taller and/or heavier people usually have greater requirements for energy than do shorter/lighter people with similar activity patterns.

On average, men are taller and heavier and have a higher percentage of lean body mass than women. Each of these gender-specific physical characteristics is associated with higher energy requirement, as discussed in greater detail below in sub-section 2.3.

The nutritional requirements discussed for ADF members in this document will not necessarily apply to each individual. Although the ADF population is relatively homogeneous, there will always be some variation between individuals. This variation comes from two main sources—different body size and composition, and individual genetic variation in metabolism.

If individual nutritional requirements are to be determined, variation due to differences in body size and composition must be taken into account. Genetically-determined individual variation in energy expenditure cannot be accurately estimated without conducting exhaustive laboratory testing on each individual.

However, in the context of determining ADF nutritional requirements, it is the *mean* requirement of the group that is important, together with the extent of variation about the mean (commonly expressed as the 'standard deviation'). Individual variation will usually be normally distributed about the mean, so determining nutritional requirements of units, rather than individuals, can be based on easily collected group data such as mean age, gender and weight.

Therefore, in determining nutritional entitlements—in the form of ration scales—for ADF members it is appropriate to base the energy entitlement on the mean requirement. This is important from both the nutritional viewpoint and from the perspective of minimising waste (and therefore cost). Food availability substantially above the mean energy requirement would promote either excessive intake—and therefore overweight/obesity—or wastage of food. Provision of the mean energy requirement (with appropriate allowance for unavoidable food discarding) will allow those who have above-average needs for energy and/or micronutrients to be balanced by those with below-average needs.

Recommendation 3: *The nutritional standards for ration scales should be based on mean nutritional requirements of ADF members (with appropriate allowance for unavoidable food discarding).*

It is also appropriate to base energy entitlements on the mean requirement for combat ration packs (CRP). This is because feeding solely with CRP generally occurs only as a short-term measure. As described in greater detail in section 7, the resulting negative energy balance for those ADF members who have above-average energy requirements is unlikely to impact adversely on military performance, provided that the weight is lost gradually and total weight loss is less than ~5% of initial body weight.

However, where troops do not have control over the quantity of food they may take (e.g. when feeding is by combat ration packs) entitlements to micronutrients should take into account the extent of variation about the mean (i.e. standard deviation) because those whose needs are above average will not receive adequate nutrition if only the mean nutritional requirement is provided. Some micronutrients are not stored in the body, so inadequate micronutrient intake has the potential to adversely affect health and performance in the relatively short term.

Recommendation 4: *The nutritional standards for ration packs should be based on mean nutritional requirements of ADF members for energy (with appropriate allowance for unavoidable food discarding) but should allow sufficient micronutrients to meet the requirement of practically all ADF members.*

If, for any reason, it is considered necessary to estimate individual nutritional requirements, but laboratory testing is not feasible, it is possible to arrive at a reasonable estimate based on individual physical characteristics and observed level of physical activity (taking both occupational and leisure activity into account). Stature and weight both exert a significant effect on total energy requirement—an increase of 12 cm in height or of 10 kg in weight is associated with an increased energy requirement of approximately 1 MJ (= 1000 kJ) per day (calculated from NHMRC, 1991; Table 7). Using this information, together with Tables 3 and 4 of NHMRC (2006) will allow an estimate to be made of the total daily energy expenditure of an individual ADF member that is likely to be accurate to approximately ± 10%.

The importance of taking into account individual variation in specific circumstances is illustrated graphically by one of history's most famous adventurous treks—Robert Falcon Scott's attempt to lead the first expedition to the South Pole. Edgar Evans was the biggest and strongest of the five men who attempted the final dash to the Pole. He was expected to be the 'work horse', but he was provided with only the same quantity of food as the other members of the group. From being the strongest initially, he quickly became the weakest, and a liability because of this. He was first to die, his death almost certainly resulting from a combination of scurvy and general starvation because he was the most under-fed (Huntford, 1979). Had a ration plan been devised that made available the mean energy requirement of the group, with each man taking the quantities of food he needed, there is every reason to believe that Evans would have survived far longer, and would not have been the first to show a substantial loss of strength.

2.2.1 Body Energy Reserves

The other consideration with respect to weight is the effect of body energy reserves (partly muscle glycogen, mostly body fat) on endurance. During a period of negative energy balance (i.e. when energy intake is less than expenditure) a fit, well-nourished person will be able to continue to perform physical work longer than will an equally fit person who has less reserve body energy.

2.2.1.1 Excess Body Fat

However, energy reserves in the form of body fat are a 'double-edged sword'. Excessive body fat constitutes additional weight that may interfere with the individual's capacity to perform his/her military duties. There is also a cost (in both dollar terms and lost workdays) associated with excess body fat. For example, Robbins *et al.* (1997) reported that 20.4% and 20.5% of male and female US active duty Air Force (ADAF) personnel respectively had weight-for-height above the allowable maximum. Based on health care costs and lost workdays in the overweight group compared to normal-weight ADAF members:

> Total body-weight attributable costs … were estimated at $22.8 million per year … Attributable lost workdays were estimated at 28 351. The weight-attributable health conditions identified included hypertension, dyslipidemia, type 2 diabetes, coronary heart disease, congestive heart failure, stroke, gallstones, osteoarthritis, sleep apnea, various cancers, various reproductive health problems in women, and various behavioural health problems.

Following a comprehensive survey of the UK Armed Forces, involving more than 4500 personnel, Wood (2007) reported that '15% of Caucasian military males and 12.5% of Caucasian military females have a BMI[1] ≥ 30 kg/m^2'. A BMI ≥ 30 kg/m^2 is taken to indicate 'obesity' by the World Health Organisation (WHO, 1997).

Further, Wood (2007) found that '… 34.6% of Caucasian Service personnel (male and female) were at risk of obesity-related ill-health, of which 11.4% are at very high risk of ill-health.'

The Australian Defence Health Status Report (Department of Defence, 2000b) reported that 57% of ADF members were above the healthy weight range (BMI ≥ 25). In addition to health implications, being overweight or obese has the potential to impact adversely on physical performance and 'the quality of life by limiting mobility, physical endurance and other functional measures … studies in military populations have also demonstrated a significantly higher risk of musculoskeletal injury in obese individuals' (Department of Defence, 2002).

2.2.1.2 Optimal Body Fat Level

Optimal body fat level for military performance is not known, but it is likely to be within the range usually considered 'normal' for the general population. According to Durnin *et al.* (1985) 'normal' body fat levels are 10–20% of body weight for men, and 20–30% for women. This is consistent with findings that many elite sportsmen have 'moderate' levels of body fat (Norton and Olds, 1996, p. 332): 'For example, male sailors in the Montreal Olympics averaged 16.4% BF (body fat) (range 13–24%) across various sailing events … First-class Australian cricketers average about 11% BF with some players above 15% BF … '

Body fat is difficult to determine in a living organism. A surrogate measure, Body Mass Index (BMI), is used by the World Health Organisation (and many other authorities) to determine

[1] 'BMI' is Body Mass Index, defined as weight (kg)/height (m)-squared—see section 2.2.1.2 for a more detailed explanation of this term, particularly the limitations of using BMI alone as a measure of body fat levels.

whether an individual is in the healthy weight range, above or below this range. BMI is calculated as [weight in kg divided by height (m)-squared]. Although BMI has a place in screening individuals for possible excessive body fat, the index itself does not give a reliable estimate of body adiposity—it reveals only which weight category the individual is in. The ADF recognises the following weight categories based on BMI: *underweight* (< 18.5); *healthy weight range* (18.5–24.9); *overweight* (25.0–29.9); *obese* class 1 (30.0–34.9); *obese* class II (35.0–39.9) and *obese* class III (> 40.0) (Department of Defence, 2002). It is important to note that being *overweight* is not necessarily synonymous with being 'over-fat'. Overweight can result from excessive body fat, or from a high level of muscular development ('muscular hypertrophy'), or from a combination of these conditions.

With the popularity of 'body building', particularly among young men, it is important that the ADF not exclude suitable potential recruits whose BMI is in the range 25.0–29.9 on the basis that they do not fit into the healthy weight range. If their extra weight is mostly muscle, such young men are in fact more likely to have the upper body strength needed to cope with the arduous physical work—including carrying heavy loads—associated with many military occupations.

The National Health and Medical Research Council (NHMRC, 2003) pointed out that BMI has limitations, including its inability to 'distinguish fat mass from lean mass', and also to 'reflect body-fat distribution' (NHMRC, 2003: p. 44). For BMI < 35, the NHMRC (2003: p. 47) recommended the measurement of waist circumference together with weight and height as a 'valid measure of abdominal fat mass and disease risk … ' Recommendations were published by the NHMRC (2003) on the how BMI and waist circumference could be combined to assess obesity and the risk of type 2 diabetes and cardiovascular disease (Table 3.3, p. 48).

In summary, from Table 3.3 the risk categories for males of varying BMI and waist circumference are:

> BMI in the range 18.5–24.9 (*healthy weight range*), and waist circumference ≥ 102 cm constitutes 'Increased' risk;
>
> BMI in the range 25–29.9 (*overweight*), and waist circumference in the range 94–102 cm – 'Increased risk'
>
> BMI in the range 25–29.9 (*overweight*) and waist circumference ≥ 102 cm – 'High risk';
>
> BMI ≥ 30 (*obese*) and waist circumference in the range 94–102 cm – 'High risk'; and
>
> BMI ≥ 30 (*obese*) and waist circumference ≥ 102 cm – 'Very high risk'.

For females, the BMI categories are the same as for men, but the corresponding waist circumference cut-offs are 80 cm and 88 cm respectively.

2.2.1.3 ADF Policy on Overweight and Obesity

The ADF has a policy for managing obesity (Department of Defence, 2002). This policy details the procedures to be used to determine weight categories of individual members, and recommended actions to be taken by medical officers. It includes reference to 'abdominal obesity' (as measured by waist circumference) as an additional guide to the risk of morbidity in ADF members with BMI above the healthy weight range. It also recognises that some members may be able to carry out their duties even if their BMI is in the obese range ($\geq$ 30 kg/m^2). Appropriately, such members are to be classified as having 'uncomplicated obesity'. For these individuals, 'Physical fitness … will be assessed by the individual Service's operational readiness requirements.'

However, there is no reference to a need to *monitor* the levels of overweight and obesity in the ADF. Without this data, it is not possible to determine if these levels are stable, increasing or decreasing.

Some of the required data are available from the Annual Health Assessment (AHA) and Comprehensive Preventive Health Examination (CPHE) that apply to all ADF members (Department of Defence, 2007). These assessments include the measurement annually of weight and height to allow calculation of BMI. However, there is no requirement to measure waist circumference.

It is recommended that measurement of waist circumference be added to the suite of measurements taken at the AHA and CPHE. It is further recommended that the resulting data be used to monitor and report annually on trends in overweight/obesity and disease risk according to the recommendations of the NHMRC (2003) to inform future policy on overweight and obesity in the ADF. This would be consistent with the aims of the AHA and CPHE, which are to 'provide an efficient system of verification of a member's individual readiness, from a medical perspective, on an annual basis' (AHA) and 'to promote medical fitness and health by identifying and recording all significant medical conditions, detecting and modifying factors known to adversely affect health or predispose to disease' (CPHE).

Recommendation 5: *Measurement of waist circumference should be added to the Annual Health Assessment and Comprehensive Preventive Health Examination to allow calculation of ADF members' risk of cardiovascular disease.*

2.3 Gender

Gender influences nutritional needs, but it does so predominantly through the different sizes of males and females. Females are generally shorter and lighter than males. Between them, these two characteristics account for most of the difference of ~25–30% in energy requirements between men and women. The other major contributor is the lower lean body mass of females. As a result of these differences, the basal metabolic rate (BMR) of females is lower, and the typical adult female needs approximately 1.2–1.5 MJ less energy per day than does the typical adult male of the same height and weight and with a similar activity level (NHMRC, 1991). The other major gender-related nutritional requirement is an increased need by females of child-bearing age for iron, due to menstrual loss of iron.

2.4 Stress

'Stress' can have many meanings and causes. It can be used to refer to the effects on military performance of environmental stressors such as extreme physical activity, sleep deprivation, and adverse climatic conditions (e.g. heat, humidity, cold and altitude). The effects of climatic stressors on nutritional requirements are discussed in the next subsection.

In the military context, the term 'stress' can also be used to refer to psychological stress, the most important of which is combat stress—the debilitating effects on military performance of the constant threat of contact with a hostile enemy during war.

The effect of combat-related stress on nutritional requirements is not known. Morrissey *et al*. (1989) found that soldiers engaged in the descent phase of parachute training used more energy than during ground training, despite an apparently lighter physical workload during the descent phase. It was hypothesised that this may be due to a stress-induced increase in metabolic rate associated with a potentially life-threatening activity. This hypothesis received some support from the finding by Schmidt *et al*. (1996) that resting metabolic rate was significantly higher in 'high trait anxious' than 'low trait anxious' students. Until more evidence is available, no firm conclusions can be made on the nature or extent of the effects of combat stress *per se* on nutritional requirements.

2.5 Climate

Climate may exert an effect on energy requirements either directly or indirectly. Direct effects include the influence of heat on the need for sodium and water, and of cold on total energy requirements (particularly if cold exposure leads to shivering). An example of an indirect effect is a possible need for more energy when marching or patrolling in the wet season compared to the dry season in northern Australia, because of the difficulty associated with walking through mud.

There has been a substantial increase recently in the range of environments in which ADF operations occur. For example, ADF members can now be subjected to intense cold and altitude, e.g. during operations in the mountainous areas of Afghanistan in winter.

However, because most ADF operations still occur in hot climates, the effects of heat on nutritional requirements will receive somewhat more attention than those in cool or cold climates and/or at high altitude.

2.5.1 Hot Climates

The major likely effects of heat on nutritional requirements are discussed briefly in this section. For more detailed information, the reader is referred to Kullen (2008).

Perhaps the major consideration in the heat is hydration status. Sweat rates of over 1 L/h have been measured among ADF members patrolling in hot-wet and hot-dry climates (Amos *et al.*, 1998). Current guidance to the ADF is that fluid intakes up to 1.25 L/h may be required, with a limit of 10 L per day (Department of Defence, undated a.).

Note that it is total body *water* level that is critical to hydration status. However, intake of fluids other than water can contribute to maintaining euhydration (optimal hydration status), and some fluids are superior to plain water in this regard. For example, adding small quantities of sodium to drinking water will result in greater retention of the water compared to drinking the same volume of plain water (Shirreffs and Maughan, 1998). And although there is a common belief that caffeinated beverages have a diuretic effect, the scientific evidence does not support this (Armstrong *et al*., 2007). These authors conclude that 'Caffeinated fluids contribute to the daily human water requirement in a manner that is similar to pure water'. Because many fluids contribute similarly to hydration status, in the remainder of this report, the terms *water intake* and *water requirements* will be used synonymously with *fluid intake* and *fluid requirements* respectively.

There is evidence that carbohydrate is preferentially used as the source of energy for physical work in the heat (Burke, 2001), suggesting that the requirement for carbohydrate increases when physically arduous operations are conducted in hot weather. Kullen (2008) recommended that carbohydrate intake should be supplemented via beverages providing 4–8 g carbohydrate per 100 mL. This would have the dual beneficial effects of enhancing intestinal absorption of water *and* providing supplementary energy. Beverages with carbohydrate concentrations greater than ~10% should be avoided because they may exacerbate the effects of dehydration due to their high osmolality (Gisolfi and Ryan, 1995).

Exercise in the heat may also increase protein requirements (Burke, 2001), especially during recovery after endurance activity (see, for example, the review by Forbes-Ewan, 2005). However, Burke (2001) stated that 'there is insufficient evidence to make specific dietary recommendations … ' Combining carbohydrate with protein during recovery has been reported to speed up the recovery process, and reduce health problems (Flakoll *et al*., 2004).

Preliminary evidence also exists for increased requirements of zinc (Lukaski, 2000; US CMNR, 2006) and iron (Booth *et al*., 2002; Booth, Coad, Forbes-Ewan, Thomson, Niro, 2003; US CMNR, 2006). The possibility has also been raised that there is an increased requirement for calcium due to previously unrecognised losses of calcium in sweat (NHMRC, 2006). US CMNR (2006) concluded that the strength of evidence suggests that 'only requirements for copper, iron, and zinc are adjusted on the basis of increased sweat losses … '. Further study was recommended to assess the effects of stressors such as heat on mineral losses and the resulting effects on performance.

An increased requirement for antioxidants during exercise in hot environments has been suggested (Burke, 2001). The Australian Institute of Sport (AIS, undated) suggested that, with respect to the antioxidants vitamin C and vitamin E, 'While studies do not provide evidence of substantial benefits or performance enhancements following antioxidant supplementation, there is logic to support a period of supplementation of (1–2 weeks) at the commencement of a period of increased training stress.' Stressful situations are stated to include 'moving into hot environments or undertaking acclimatisation training'. The quantities suggested by the AIS are 500 mg vitamin C and 500 IU (~335 mg) of vitamin E. These are respectively of the order of ten and fifty times the RDIs (NHMRC, 2006).

The other major increased nutritional requirement in the heat is for salt (i.e. sodium) under certain circumstances as described immediately below.

2.5.1.1 Salt Requirements during Heat Acclimatisation

There is much controversy surrounding the nutritional requirement for sodium. Although recent data are not available on sodium intakes for the Australian population, Beard (1997) found that adults in Hobart were consuming approximately 3450 mg of sodium per day. This equates to about nine grams of salt, and is 50% greater than the currently recommended Upper Limit (above which there is increasing potential for harm) recommended by the NHMRC (2006) for Australians and New Zealanders.

Perhaps of even greater relevance, the daily Adequate Intake (AI) is now defined as being in the range 460–920 mg of sodium (~13–26% of likely current intakes). These recommendations are aimed mainly at reducing the risk of hypertension, a major risk factor for cardiovascular disease. The NHMRC (2006) recognised that 'This AI may not apply to highly active individuals, such as endurance athletes or those undertaking highly physical work in hot conditions, who lose large amounts of sweat on a daily basis.'

A further complication is the increased need for sodium that may occur during the process of acclimatisation to the heat. The scientific literature on salt requirements for heat acclimatisation is somewhat equivocal. For example, Denton (1982) describes a study reporting sweat losses of up to 24 g of salt per day in unacclimatised people working in hot climates. On the other hand, Armstrong *et al.* (1993) found that both 4 g and 8 g of salt intake per day were sufficient to effect heat acclimation while participants were engaging in vigorous treadmill activity in a laboratory setting. However, during this period there were increased symptoms of heat exhaustion in the low-salt group (US CMNR, 1993, p. 18). Largely as a result of this finding, the US Committee on Military Nutrition Research (*Ibid*) recommended maintaining sodium levels in US Army operational ration packs similar to those of the current civilian population, rather than reducing them in accordance with US health recommendations (which were similar to those at the time of the NHMRC in Australia).

This is also considered to be an appropriate position for the ADF with respect to sodium intake in both barracks and field feeding. That is, the recommended sodium intakes for the Australian population generally may not be appropriate in the context of military nutritional requirements. Because ADF operations and training occur mainly in hot climates, sodium intakes may have to be greater than those of the general population, to take into account likely greater sodium losses in sweat.

Forbes-Ewan (2002b) provides advice to commanders on nutrition for optimal performance in hot climates, including recommendations on sodium intake.

Recommendation 6: *Determination of the nutritional requirement for sodium should be based on the 'worst case' situation – i.e. likely need for heat acclimatisation – and not on the Adequate Intake defined for civilians.*

2.5.2 Cold

Provided that troops are not subject to the debilitating effects of extreme cold (e.g. they are not required to shiver for warmth), cold weather *per se* exerts only relatively minor influence on nutritional requirements directly (see for example, Burstein *et al.*, 1996).

It is largely through two indirect effects that a significantly increased requirement for energy may occur. First, more energy is required for locomotion because of the greater weight and 'hobbling' effect of thick protective clothing. This can result in a 5–15% extra need for energy (Askew, 1989). Second, the energy expended in walking on snow is about twice that for walking on dry ground (Brotherhood, 1973).

Because high sweat rates are relatively uncommon in cold climates, water requirements are likely to be less than when in the heat. Baker-Fulco *et al.* (2001) recommend that 'Soldiers should drink at least 2–6 canteens (~2–6 L) of water each day'. Consistent with this recommendation, Engell *et al.* (1987)—whose study participants were Special Forces troops engaged in a ten-day cold-weather field training exercise—reported that only two litres of water were drunk per day. However, 'specific gravity data indicated that (the) soldiers ... were moderately dehydrated in the field', leading to the conclusion that two litres of water intake may have been insufficient. Also, Roberts *et al*. (1987) reported that on the same ten-day cold-weather field training exercise 'water discipline was not good, and less dehydration ... could be encouraged if soldiers were instructed and expected to force fluids up to the level of 4 liters per day or more'. This is supported by the finding of Edwards *et al.* (1992) who reported that water intakes of ~3.5 L/day were associated with adequate hydration status during an 8-day winter field exercise in Alaska.

The conclusion drawn in this report from the limited evidence available on water requirements in the cold is that water availability of 3–4 L per day will be sufficient for the range of likely activity levels when operations are conducted in cold climates.

Recommendation 7: *For troops who are engaged in vigorous training or operations in very cold climates, water availability for drinking should be at least three litres per person per day.*

2.5.2.1 Altitude

Altitude exerts an effect on nutritional requirements independently of any effect on energy expenditure. Above an altitude of about 3000 m the contribution made by carbohydrate to total energy intake should be appreciably increased, to reduce the risk of altitude sickness (Hickson and Wolinsky, 1989) and to maximise physical work capacity (Askew *et al.*, 1987a). In addition to supplementary carbohydrate, Hoyt and Honig (1996) also recommend reduced salt intake during the first few days at altitude, with increased water intake to encourage natriuresis (excretion of sodium). They hypothesise that reducing body sodium levels may assist in the process of physiological acclimatisation to altitude.

Hoyt and Honig (1996) suggest that ~500 g of carbohydrate per day is needed to meet the nutritional requirement when vigorous work is conducted at high altitude. However, they also point out that anorexia (loss of appetite) leads to carbohydrate intakes closer to

300 g per day. By making easily-consumed sources of carbohydrate available (e.g. as gels, beverages) daily intake may increase to ~400 g. This is still sub-optimal, but is probably the maximum that can be achieved. The issue of food intake and optimal nutritional availability at altitude is discussed further in section 4.1.2.4. Forbes-Ewan (2002c) provides advice to commanders on nutrition for optimal performance in cold climates and at altitude.

2.6 Physical Activity

Many aspects of operations or training influence the nutritional needs of ADF members. Foremost is the volume of physical work output. As the total quantity of work increases, so does the need for more total energy intake. Increased total work output also leads to alterations in the appropriate macronutrient mix (i.e. the relative contributions of protein, fat and carbohydrate to energy intake).

Elevated total energy expenditure occurs most commonly through one of three types of activity: endurance, ultra-endurance, and intermittent arduous activity. These types of activity do not necessarily lead to identical nutritional requirements. Because all three are common to both the military and to athletic competition, lessons appropriate to military scenarios can be learned from sports nutrition research.

(i) *Endurance* activities involve moderately sustained (up to several hours) of arduous work, often at 80% or more of maximal oxygen uptake ($\dot{V}O_{2max}$). Endurance activity is commonly seen in athletic training and competition; examples include marathon running, triathlon and long-distance swimming. An equivalent military activity would be the Army's combat fitness assessment.

(ii) *Ultra-endurance* activity involves many hours of relatively low-level activity (e.g. running races that last for several days or longer). A military example (albeit at a lower level of physical activity than the typical ultra-endurance race) would be a sustained field exercise that involves many hours per day of moderately-to-very vigorous physical work.

(iii) *Intermittent Arduous* sports include rugby, soccer, basketball and Australian Rules Football. In the military context, relevant operations are those involving repetitions of arduous activities such as fire-and-movement, with intervening periods of relatively low activity or inactivity.

2.6.1 Fitness Training

The effect of physical fitness training on total energy requirement will vary greatly, depending on how sustained and vigorous the training is. For example, a daily 30-minute PT session including light jogging, stretching and callisthenics, or based on intermittent team games such as volleyball or 'touch' football adds no more than ~1 MJ (1000 kJ) to the daily energy expenditure of most ADF members (calculated from Astrand and Rodahl, 1986; Fig. 11 and 12). This is of the order of 8% above the normal energy requirement of a relatively sedentary adult male ADF member (Forbes-Ewan and Waters, 1991). By way of contrast, two sailors at HMAS Albatross who were in training for an inter-Service triathlon competition had daily energy expenditures of ~17 000 kJ, about 40% greater than would be expected for sedentary males of their age and weight (Forbes-Ewan *et al*., 1990).

2.6.2 Load Carriage and Speed of Locomotion

Total work output and rate of work are influenced by factors such as load carriage and speed of locomotion. For example, Smith *et al.* (1989) reported that the energy expended by foot soldiers undergoing simulated patrolling on a treadmill increased by approximately 10% for each additional 15 kg load. Loads carried were representative of typical infantry scenarios, i.e. 3 kg ('clean fatigues'), 20 kg ('patrol order') and three 'marching orders' (25, 35 and 50 kg). There was an even greater response to increased patrolling speed. With angle of inclination and load carriage held constant, soldiers' energy expenditure rose by between 30 and 50% with each 2.5 kph increase in patrolling speed (from 2.5 to 7.5 kph). The effects of these components were found to be additive. Thus, increasing load by 15 kg, speed by 2.5 kph and angle of inclination by 3 degrees led to an approximate doubling in the rate of energy expenditure.

2.6.3 Terrain/Vegetation

Another determinant of total daily work output—through its effects on the energy cost of locomotion—is the nature of the terrain and vegetation cover. For example, soldiers patrolling in a tropical rainforest in mountainous terrain will have a greater need for energy than those patrolling at the same speed and for the same duration on level grassland. Pandolf, Givoni and Goldman (1977) devised an algorithm that takes into account the nature of the terrain to estimate the energy cost of patrolling. Demzcuk (2001) used this algorithm to investigate the likely effects on energy requirements of patrolling in different terrains.

For example, Figure 1 shows a comparison of energy expenditures for different conditions. The soldier’s load is 65 kg and walking speed is 2 kph. On a flat bitumen road the power output is 400 watts (W). If the slope is increased to 10%, the energy expenditure rises to 700 W. If the march is through scrub (10% slope), the energy expenditure rises to 730 W.

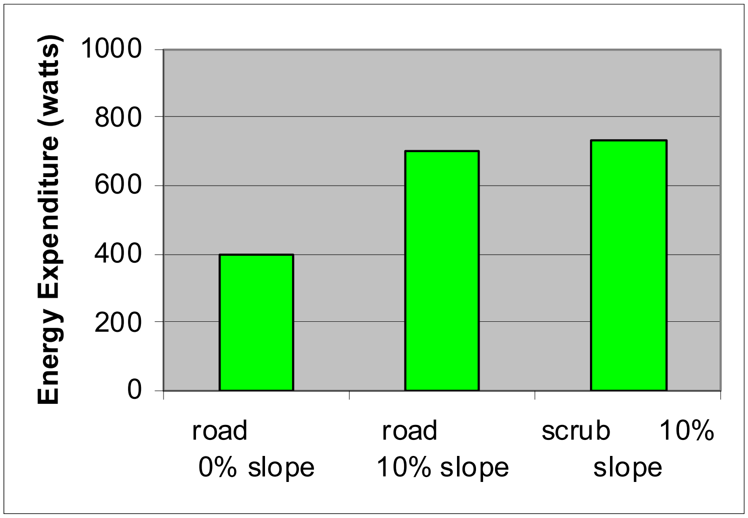

Figure 1: Effects of slope and vegetation on energy cost of walking at 2 kph, with load carriage of 65 kg, as predicted by the algorithm of Pandolf et al. (1977)

2.7 Pre-Operational Nutritional Status

As detailed below, it appears to be a near-universal finding that troops under-eat on operations when rationing is by CRP. Although this phenomenon is usually attributed to factors such as monotony and acceptability, Smith and Miles (1986) speculated that there may be operational advantages to this under-consumption, including reducing the drop in vigilance and reaction time that typically occurs after eating a large meal. Hoyt and Honig (1996) further suggested that the benefits associated with reduced load carriage and increased time available for non-food-related military tasks may outweigh the nutritional disadvantages of under-eating.

Regardless of the cause of under-consumption, it is a genuine and widespread phenomenon.

When nutrient intake is less than ideal, the nutritional status of a subject prior to the period of low nutrient intake itself becomes a determinant of subsequent nutritional status. This applies particularly to energy reserves and to the water-soluble vitamins, which are not stored in the body in appreciable quantities.

Reference has already been made in this report to Robert Scott's failure to take individual variation in nutritional requirements into account in his attempt to lead the first team to the South Pole. This expedition also provides a graphic illustration of the effect of previous inadequate nutrient intake on subsequent physical performance. Raoul Amundsen's Norwegian party included the Arctic cloudberry (now known to be a potent source of vitamin C) in their rations for the over-wintering period preceding their trek to the South Pole (Huntford, 1979). By way of contrast, Scott's group had little intake of vitamin C during this period. Furthermore, Scott depleted the vitamin C levels of his men by taking 35 000 cigars for the over-wintering period (Nicholson, 1994). [Cigarette and cigar smoke add to the oxidation stress and therefore deplete vitamin C—the first line in the body's antioxidant defence system (Alberg, 2002)]. As a result, scurvy is believed to have played a role in the failure of Scott's group to return from the Pole, resulting in the deaths of all five team members, while Amundsen and his men returned to the Antarctic coast in good health (Feeney, 1989).

Perhaps of more immediate relevance to the ADF are the findings of Booth and Coad (2000), who conducted a questionnaire investigation of the nutritional quality of the (previous) civilian diet of recruits on their first day at the Army Recruit Training Centre. The recruits' self-reported diet was 'too high in fat and unbalanced with respect to the recommended core food groups'. Booth and Coad (2000) reported that recruits were also:

> … at risk of eating insufficient calcium, magnesium and zinc. Female recruits were at risk of eating insufficient iron. Biochemistry results revealed a significant prevalence of folate, thiamin and riboflavin deficiency for males and females and iron deficiency amongst the females. Up to half of the recruits had at least one risk factor for cardiovascular disease, namely elevated cholesterol, triglycerides, apolipoprotein B or homocysteine concentration.

These findings are supported by those of Booth, Clark and Fenn (1998), whose survey of civilian blood donors revealed that an apparently healthy cohort (first-time blood donors) of the Australian civilian population—from which ADF members are recruited—did not have optimal nutritional status, including a significant prevalence of low blood levels of thiamin (13%) and folate (24%).

Iron status is also of concern, particularly in female service people. According to the US Army Medical Research and Materiel Command (USAMRMC, 1999) approximately 22% of female US soldiers were iron-deficient at the time of their study. Similarly, Carins, Booth and Coad (2005) reported that approximately 20% of female ADF officer cadets had either iron-deficiency erythropoiesis (Stage 2) or outright iron-deficiency anaemia, with a further 35% showing Stage 1 iron deficiency (low iron stores). McClung *et al.* (2006) stated that 'Changes in immune function, cognitive development and behavior, energy metabolism, and work capacity have been described in animals and humans with suboptimal iron status.'

However, McClung *et al.* (2006) found that iron status improved among female US soldiers during the early stages of their military career, being significantly poorer at time of entry than either following basic training or six months after their initial posting. This could be considered to support the contention that exposure to military feeding can lead to improved nutritional status compared to pre-military (i.e. civilian) feeding.

Calcium status is also of concern: Booth and Carins (2006) reported that '… 20% of female officers-in-training (are) at risk of not meeting their calcium requirements—mostly due to not enough dairy foods.' Further, lower bone mineral density (a condition that leads to greater risk of bone fracture) has been found among athletes whose loss of calcium in sweat is not matched by calcium intake (Klesges *et al.*, 1996). From this, Booth and Carins (2006) concluded that 'this could be an important consideration when considering the calcium requirements and bone health of ADF personnel operating in tropical environments.'

The findings of Booth and Coad (2000) described above suggest that many male ADF members have marginal nutritional status on entry to the ADF. The low reported intakes of calcium, magnesium and zinc suggest potential sub-optimal immune function. The high levels of deficiency in thiamin and riboflavin suggest potential sub-optimal physical performance (these vitamins are involved in energy release for physical work). Finally, the low reported folate intakes imply increased risk of heart disease.

Vitamin D status of particular groups is also of potential concern, particularly those who live in southern states and submariners (Booth and Carins, 2006)[2]. A 68-day submarine voyage—during which there was no exposure to sunlight—was associated with a substantial decrease in serum vitamin D among submariners (Dlugos *et al.*, 1995).

Finally, eating disorders are becoming increasingly common in Western nations, particularly among young, active women (Sundgot-Borgen, 1993). The extent of eating disorders in the ADF is not known, but 8% of a cohort of 423 female soldiers in the US Army had an eating disorder (Lauder *et al.*, 1999).

Further research is needed into the nutritional status of ADF members and how this status varies with training and participation in operations.

Recommendation 8: *Further research should be conducted into the nutritional status of ADF members, and on how participation in training and operations impacts on nutritional status.*

In summary, *sustainability* of operations may be compromised unless optimal (or near-optimal) nutritional status is assured before operations commence. Poor nutritional status of the civilian population, from whom the ADF recruits its members, has implications for the importance of ensuring that high nutritional standards apply to all ADF rationing systems. This implies a strong need both for availability of highly-nutritious food and guidance to troops (or recruits), instructors and caterers on appropriate food provision and food selections to maximise nutritional status.

The *Defence Catering Manual* is expected to be published in 2009 (LTCOL D Caldwell, Defence Catering Policy Cell, pers. comm. 22 Jul 08). This development, combined with revision of the way in which fresh food entitlements are determined (one of the major aspects of the present report) should contribute to improved catering practices in all Defence messes. In turn, this should assist in reducing the incidence of nutritional deficiencies such as those described in the discussion immediately above.

With respect to the provision of guidance on appropriate food selections, because food habits are difficult to alter once they have been formed, it would be appropriate to start any nutrition improvement program with recruits, and gradually extend the program to the wider ADF.

Recommendation 9: *Develop and implement a nutrition promotion program, starting with recruits, but extending to all ADF groups in the long term.*

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[2] In addition to dietary sources of vitamin D, sunlight acts as the energy source for the production of vitamin D in the body. Without exposure to sunlight, the diet is the sole source of vitamin D, so diets low in vitamin D will lead to deficiency of this vitamin.

3. Categorisation of ADF Nutritional Requirements

The determinants discussed above affect nutritional requirements largely through their influence on energy expenditure. A complete database of ADF nutritional requirements would involve determination of the energy expended by representative groups engaged in operations or training in all possible situations and including all possible permutations and combinations of all the determinants. This is impractical because there are many thousands of such permutations and combinations. It is also unnecessary, because many operational scenarios will lead to similar nutritional requirements, and modelling can be used to estimate the nutrient/energy requirements based on the likely parameters of each operation.

3.1 Approach used to Categorise Nutritional Requirements

The approach adopted by DSTO was to seek advice on what are the most common operational and training situations faced by ADF units. Under various tasks sponsored by HQADF in the 1980s/1990s, the food intakes and energy expenditures associated with the highest priority military scenarios were determined. Other related scenarios similar to those studied were then assigned to appropriate categories according to the level and type of physical work conducted, as described later in this report.

Gaps in the knowledge of nutritional requirements associated with as yet undefined situations can be filled in accordance with the priorities assigned by the appropriate client groups. These gaps can only be identified with the assistance of ADF subject matter experts.

At the time of writing this report (May, 2009) DSTO is planning to complete the determination of the nutritional requirements of ADF groups across the spectrum of military scenarios. This will be conducted as an activity under Task 07/082, sponsored by Chief of Joint Logistics.

One element of this activity will be identifying the high priority gaps. And because the existing suite of results is based on studies that were conducted up to twenty years ago, another aspect will be reviewing the currency and relevance of the results already obtained. Although these activities are being conducted under Task 07/082, it is considered appropriate to reiterate their importance by including them in a formal recommendation in this report. It is also considered appropriate to suggest that regular revision of the database of energy requirements of ADF groups should occur, preferably at intervals of no more than ten years.

Recommendation 10: *Complete the determination of the nutritional requirements of the full spectrum of ADF occupations, and repeat this process regularly at intervals of no more than ten years.*

However, when ADF nutritional requirements have been adequately characterised, there will be a need for a means by which commanders can rapidly and readily determine suitable combinations of rations that will sustain troops on specific operations. A start has been made on the development of a computer-based system that may allow this, as described immediately below.

3.1.1 Development of REAP™

In 1999 a computer modelling system, devised for the US Army Natick Soldier Center (Natick, Mass.) was shown to be effective in predicting energy requirements associated with an ADF training exercise. The Ration Expert Advisor Program (REAP™) takes information on likely operational variables such as temperature, humidity, distance to be walked, load carriage, terrain, altitude and so on, and determines requirements for rations and water. Booth *et al.* (2001) used REAP™ to predict the energy requirements of ADF members (Airfield Defence Guards) prior to a study of the effects of feeding with combat ration packs (CRP) on military performance during Exercise Northern Awakening (EX NA). REAP™ accurately estimated the food energy required (15 MJ, which was also the measured energy expenditure of the subjects, as determined by doubly-labelled water technique). REAP™ appeared to have potential as a means of determining ADF food and water requirements.

However, development of REAP™ appears to have ceased. The author of this report believes that REAP™ or a similar program has a place in determining food (and water) requirements. Consequently, it may be appropriate to consider resumption of development of this or a similar program.

It is unlikely that Australia would have the resources to conduct the R&D required to complete development of the program. However, a multi-national approach (e.g. through The Technical Cooperation Program) may be feasible. TTCP-HUM-TP14 includes a relevant Key Collaborative Area, KCA 3: *Nutrition and Hydration for Sustaining and Enhancing Physical and/or Cognitive Performance during Training and Operation*s. One of the objectives of KCA 3 is:

> Provision of data for modeling the energy and nutritional requirements of military personnel in all likely scenarios and the effects of nutritional interventions or inadequate nutrition on performance.

It may be appropriate for the Australian National Leader of HUM-TP14 to suggest expansion of KCA 3 to include the actual 'development' of modelling of energy and nutritional requirements, not simply provision of *data* for modelling.

Recommendation 11: *Resume development of the Ration Adviser Expert Program (REAP™); this might best be achieved through a multi-national approach, e.g. as part of KCA 3 within TTCP-HUM-TP14.*

3.2 Research Basis for Categorising Nutritional Requirements

The findings of Pennefather *et al*. (1980), Forbes-Ewan (1988), Morrissey (1988), Forbes-Ewan *et al.* (1988), Morrissey (1989), Forbes-Ewan and Morrissey (1989), Morrissey *et al.* (1989), Forbes-Ewan (1990), Forbes-Ewan *et al*. (1990), Morrissey *et al.* (1990), Forbes-Ewan and Waters (1991), Waters *et al.* (1992), Forbes-Ewan *et al.* (1995), Booth e*t al.* (2001); Skiller *et al.* (2005), and Forbes-Ewan *et al.* (2007) were used to determine categories of nutritional requirements according to mean total daily energy expenditure. These studies involved soldiers, sailors and airmen in a wide range of training and operational scenarios, from sedentary training (e.g. soldiers undertaking a clerical course, and sailors with desk jobs at a large Naval base), through to military activities that are believed to approach the limits of human physical endurance (ADF members attempting selection to the Special Air Services Regiment).

Earlier in this report it was argued that age and gender are two significant determinants of nutritional requirements. Therefore, a comprehensive categorisation of nutritional requirements involves determining the specific requirements of *adult males*, *adolescent males*, *adult females* and *adolescent females*.

Recommendation 12: *The categorisation of ADF nutritional requirements should separately address the needs of four groups – adult males, adult females, adolescent males, and adolescent females.*

In this context an 'adult' ADF member is assumed to be over the age of 19 years (with the majority being in the age range 19–31), and an 'adolescent' ADF member is aged less 19 years (generally 17–18 years inclusive).

3.3 Categories of Nutritional Requirements

Table 1 presents the results of all food intake/energy expenditure studies so far conducted to determine ADF nutritional requirements. Energy requirement is reported as the mean energy expenditure (MJ/person/day). It should be noted that the energy expenditures shown in Table 1 apply only to adult male soldiers.

From Table 1, all ADF activities studied so far can be assigned to one of five categories:

Category 1	'low physical activity': involves largely sedentary occupations or training schedules (mean daily energy expenditure 11–13 MJ for the average adult Serviceman).
Category 2	'moderately active' (13–15 MJ)
Category 3	'very active' (15–17 MJ)
Category 4	'extremely active' (17–21 MJ)
Category 5	believed to approach the limit of human endurance (≥ 25 MJ)

Category 5 is considered to be a special case that will occur only rarely during operations or training. It is based on the energy expended by ADF members attempting selection to a Special Forces (SF) unit, specifically the result obtained by Forbes-Ewan *et al.* (1995) for the 'Cadre Course' for entry to the Special Air Service Regiment (SASR). Because SASR selection includes some food deprivation as an integral aspect of the barrier test, it could be considered that *Category 5* has little practical implication for ADF feeding.

However, there are several caveats to this conclusion. Firstly, although feeding will not match the energy expenditure during the SASR selection course, recovery feeding following completion of (or cessation of involvement with) the course will need to take the extra energy expenditure into account, if the affected number of ADF members is significant. Secondly, there is a gap between the high end of *Category 4* (21 MJ) and the low end of *Category 5* (25 MJ). If any other training or selection courses or operations involve energy expenditures > 21 MJ per day, the upper limit for *Category 4* may have to be raised. For example, it is possible that engaging in some other SF related activities—e.g. attempting the current Special Forces selection course or the Commando Selection course, and some SF operations—also involves energy expenditure above the current maximum of the range for *Category 4*, and perhaps even approaches *Category 5*. This is as yet unresolved and requires further research.

Recommendation 13: *The energy expenditure associated with Special Forces selection and Special Forces operations should be investigated.*

There is a third caveat to the suggestion that *Category 5* may not have practical applications to ADF feeding. Rationing ADF members with CRP has been shown to almost inevitably lead to under-consumption (see, for example, Booth *et al.*, 2005). Following a period of extended feeding with CRP, troops will need a period of recovery feeding. That is, they must have access to more fresh food than usual so that body energy reserves and lean body mass can be replenished. The implications of this for Defence catering are explored in more detail in section 7.

Finally, as discussed in section 3.1 above, the list of ADF training and operational situations shown in Table 1 is not exhaustive. Further research is needed to allow the nutritional requirements of ADF members to be characterised for the full range of ADF occupations. Recommendation 9 also refers to this.

In conclusion, the vast majority of ADF occupations can be divided conveniently into four categories (categories 1–4 shown above). These are considered to be the most appropriate categories for determination of food entitlements.

Recommendation 14: *For the purposes of defining nutritional needs of nearly all ADF members, military occupations should be assigned to one of four categories (applicable to each of the ADF population subgroups male adults, female adults, male adolescents and female adolescents).*

4. Basis for Recommended Military Nutrition Standards

4.1 Suitability of the NHMRC Nutrient Reference Values

As mentioned briefly at the start of the Introduction to this report, in 2006 the National Health and Medical Research Council published *Nutrient Reference Values for Australia and New Zealand* (NHMRC 2006). It may be expected that these Nutrient Reference Values (NRVs) would apply to ADF members as well as the civilian populations of Australia and New Zealand. However, there are grounds for suggesting that this would be inappropriate, as detailed in section 4.1.1 immediately below for energy, in section 4.1.2 for macronutrients, and in section 4.1.3 for micronutrients.

4.1.1 Energy

With respect to energy, the NHMRC (2006) recognised six categories of estimated energy requirements (EERs), according to 'Physical Activity Level' (PAL)[3]. The six levels are shown below, with descriptions of the activity levels in parentheses:

1.2 (bed rest);

1.4 (very sedentary);

1.6 (light activity);

1.8 (moderate activity);

2.0 (heavy activity); and

2.2 (vigorous activity).

Mean body weight of male ADF members who took part in the studies that led to the development of the ADF physical activity categories 1–5 was ~78 kg, age range was predominantly 18–30 years, and mean stature was ~1.80 m. Using the equation of Schofield (1985), BMR in MJ/day for a such an adult is estimated to be:

[(0.063 x 78) – (0.042 x 1.80) + 2.953] MJ

= ~7.8 MJ.

Taking the mid-point of each category of ADF physical activity, PALs for categories 1–4 are:

Category 1 PAL = 12/7.79= 1.54;

Category 2 PAL = 14/7.79= 1.80;

Category 3 PAL = 16/7.79 = 2.05;

Category 4 PAL = 19/7.79= 2.43; and

Category 5 PAL = 25/7.79 = 3.21.

To the nearest decimal place, PALs for categories 1–4 (those that apply to the vast majority of ADF members) are 1.5, 1.8, 2.1 and 2.4, respectively, while that for *Category 5* is 3.2.

Although there is a reasonable correlation between the defined categories of ADF activity levels and those of the NHMRC (2006), they do not correspond exactly. Of particular significance is the lack of an NHMRC PAL corresponding to *Category 4* (and even more so to *Category 5*) ADF activity level.

Therefore, the six levels of EER of the NHMRC (2006) do not address the full range of demonstrated activity levels of ADF members. Consequently, it is recommended that DSTO attempt to add a category of energy expenditure with a PAL of 2.4 (perhaps designated 'extreme activity') to the six existing NHMRC activity levels. This additional category may

[3] PAL is the mean daily energy expenditure expressed as a multiple of basal metabolic rate (BMR).

also apply to some athletic activities, e.g. elite endurance training and competition, and ultra-endurance competition or adventurous activity.

Recommendation 15: *DSTO should attempt to collaborate with the National Health and Medical Research Council to introduce a further level of physical activity ('extreme activity', with a PAL of ~2.4) to the six existing NHMRC levels.*

Table 2 shows the data of Table 1 rearranged according to category of activity for ADF scenarios that have been studied. Table 2 can be used, *inter alia*, to determine appropriate victualling for several naval activities—including sea- and shore-based occupations—for setting ration entitlements for many Army activities involving base training or operations, and for one Air Force activity—Airfield Defence Guards engaged in a typical operational activity. For each situation in Table 2, the results apply to adult males.

Ensuring that total energy requirements are met is not the only nutritional aspect that needs to be considered when specifying nutritional needs. Nutritional *quality* of the diet is also critical in ensuring that optimal performance can be maintained for as long as possible. In this context 'quality' refers to the suitability of the mix of macronutrients (protein, fat and carbohydrate), the quantities of micronutrients (vitamins, minerals and trace elements) and dietary fibre.

4.1.2 Macronutrients

The contributions made by the macronutrients protein, fat and carbohydrate to total energy intake are believed to have major influences on both physical work capacity (see, as examples, Simopoulos and Pavlou, 1993; Coyle, 1995) and long-term health outcome (NHMRC, 2006).

Guidelines are provided by various health authorities on appropriate contributions by protein, fat and carbohydrate to total energy intake. These can be expressed as the 'P:F:C ratio', where 'P' is the percentage of energy derived from protein, 'F' the percentage from fat, and 'C' the percentage from carbohydrate.

The NHMRC (2006) NRVs include recommendations for protein intakes, but not for those of fat or carbohydrate. However, the NRVs include an *Acceptable Macronutrient Distribution Ratio* (AMDR) as described in sub-section 4.1.2.1 immediately below.

4.1.2.1 Protein

Recommendations for protein intake are most commonly expressed in grams (g) of protein per day, as grams of protein per kilogram of body weight per day (g/kg/day), or as a percentage of total energy intake.

Absolute protein intake will increase with increasing energy expenditure if the recommendation is expressed as a percentage of total energy intake. Taking into account a likely increase in protein requirements with greater energy expenditure, Simopoulos and Pavlou (1993) recommended that 12–15% of energy should be derived from protein, regardless of the level of energy expenditure. Lemon (1996) recommended 1.2–1.4 g/kg/day for individuals regularly active in endurance exercise, and 1.6–1.7 g/kg/day for individuals who regularly engage in strength training. Because strength training is increasingly being seen as important for military performance, particularly activities involving load carriage, the higher recommendation is thought to be relevant to ADF groups such as SF troops, infantry soldiers and artillery.

Although the recommendations of Lemon (1996) have been questioned (Millwood, 1998), protein intakes up to 2.0 g/kg/day are unlikely to have adverse health consequences (Burke and Deakin, 2006) and may be of benefit to ADF members who engage in strength training.

However, Burke and Deakin (2006) suggested that protein intakes above about 2.0 g/kg/day may not be appropriate. Firstly, they stated that very high protein intake increases the risk of untoward health consequences such as increased urinary excretion of calcium (and therefore impaired bone mineral density). Secondly, referencing Brenner (1982) they stated that it may accelerate the progression of pre-existing renal disease. Thirdly, referencing Tarnopolsky *et al*. (1992) they provided evidence that 'protein intake above the requirement is merely oxidised for energy'.

The Australian Institute of Sport (Burke *et al.*, 2008) recommends protein intakes for different groups of athletes. Table 3 of the present report shows these recommendations. From Table 3, recommendations vary from 1.2–2.0 g/kg/day depending on age (e.g. adolescent versus adult) and the type/intensity of activity.

Finally, the AMDR recommended by the NHMRC (2006) includes an acceptable range for protein intake as being one in which 15–25% of total energy is derived from protein. The NHMRC (2006) also sets RDIs for protein at 64 g for adult males and 46 g for adult females.

There appears to be an anomaly here. For example, an Australian adult male, aged 19–33 years, 180 cm tall, with a BMI at the mid-point of the healthy weight range, and with a PAL compatible with good health (≥ 1.75) has an EER of ~13 000 kJ (NHMRC, 2006: Table 3). To adhere to the AMDR, protein should provide no less than 15% of the 13 000 kJ. That is, for this adult male, daily protein intake should be *no less* than 114 g (equivalent to 1.6 g/kg/day), yet according to the RDI, daily protein intake need be *no more* than 64 g.

The NHMRC (2006), p. 260 resolves this apparent paradox as follows:

> … dietary modelling, using linear modelling with commonly consumed foods, has shown that it is not possible to design diets based on commonly eaten foods at 10% energy from protein that reach the EARs for the micronutrients at energy intakes below about 15,000 kJ/day.

That is, 64 g is *sufficient* protein, but it is very difficult to devise a diet using commonly-eaten foods in Australia that provides no more than 64 g of protein, yet also provides adequate levels of other essential nutrients.

This argument can be taken further—as energy expenditure increases above a PAL of 1.75 (the NHMRC recommended 'minimum for good health'), maintaining protein at the minimum of the AMDR (15% of total energy intake) will result in protein intakes increasing above 1.6 g/kg/day if a nutritious diet is consumed.

Therefore, it is probably appropriate to conclude that athletes and other very active people, many of whom have PAL levels above 2.0, should have protein intakes well above 1.6 g/kg/day when their diets are based on commonly-eaten foods. For example, the 71.3 kg man used in the example above would have a protein intake of 1.82 g/kg/day if he were to increase his PAL to 2.0 and maintain his protein intake at 15% of total energy intake.

A corollary of this is that as daily energy expenditure increases, the percentage contribution of protein to total energy intake can be reduced. In fact, as energy expenditure increases, it may be *preferable* to reduce the percentage energy derived from protein, so that protein intakes do not greatly exceed 2.0 g/kg/day for typical ADF members.

Another consideration in setting a minimum recommendation for protein availability for ADF members is the possible value of protein intakes above the RDI during periods of negative energy balance, a common occurrence during military training and operations. For example, Alemany *et al.* (2008) found that providing the US RDA (0.9 g/kg body weight, similar to the Australian RDI) for protein did little to mitigate the adverse protein-related effects of a low-energy diet (6.5 MJ/day) combined with high energy expenditure (16.5 MJ/day) during an 8-day military activity. The authors speculated that 'better maintenance of fat-free mass and nitrogen retention may occur during energy restriction when dietary protein is 1.5 g/kg body wt.'

Based on the above discussion, it is recommended that the minimum standard for protein be set at approximately 15% of total energy for ADF members engaged in occupations within *Category 1* physical activity. And although the NHMRC (2006) set a maximum of 25% of energy from protein as the upper end of the acceptable range, this is not seen as appropriate as the upper end of the range for ADF nutrition standards. This is because high protein availability can occur only at the expense of one or both of the other macronutrients, carbohydrate and fat. Carbohydrate is the key fuel for vigorous muscular activity, and fat—although of relatively low importance for vigorous activity—has the dual advantages of supporting light–to-moderate activity, and being 'energy dense'; that is, it provides more than twice as much energy per gram as either carbohydrate or protein. This is of considerable importance in the case of ration pack design. Finally, fat is also important in the diet for its effects on 'mouthfeel' and acceptability.

Although this report addresses predominantly 'nutritional' requirements of ADF members, it is considered appropriate to also take other considerations into account when setting protein entitlements—specifically the expectations of ADF members (i.e. food acceptability), current ADF catering practices, and the feasibility of devising a wide range of diets that meet nutritional requirements.

With respect to acceptability, Forbes-Ewan and Waters (1991) reported that soldiers with sedentary occupations (undertaking a clerical course) were deriving up to 19% of energy from protein when eating in the mess. Such protein intakes do not reflect nutritional requirements—rather they indicate acceptability of high-protein diets. Because acceptability is an important contributor to morale, there is an argument for an entitlement of up to 20% of energy from protein.

It can also be argued that, with respect to catering practices, it would be preferable for all troops being fed at the mess to have access to similar size serves of 'protein foods' (i.e. the meat, fish or other food that constitutes the centre piece of the meal). As discussed above, as energy expenditure increases so too does the absolute need for protein (largely for muscle repair following vigorous activity). This means that relatively large serves of protein foods are appropriate for ADF members working at the higher categories (i.e. *Category 3* and above). From the catering viewpoint, it is far more convenient for all troops to have access to this large serving size, rather than try to identify those who have a genuine nutritional need for the extra protein. This argues for a relatively high entitlement to protein for ADF members whose work rate is relatively low.

Finally, with respect to developing nutritious diets, nearly two decades ago the author of this report devised a 'Nutritional Basis for Naval Feeding' (Forbes-Ewan, 1991). I came to the same conclusion as the NHMRC (2006: p. 260)—that it is very difficult to model a diet that provides less than 15 000 kJ per day *and* is based on nutritious foods (particularly a diet that includes appropriate quantities of cereal foods) in which protein provides less than 15% of total energy. The feeding basis that was suggested to Navy (Forbes-Ewan, 1991) provided energy at 14 500 kJ per person per day, with protein contributing 18% of total energy.

Taking into account all the above discussion, it is suggested here that a reasonable position would be to set 20% of total energy as the upper limit for protein in diets of ADF members engaged in low levels of physical activity. Combining this with the recommendation described earlier in this section—that protein should provide at least 15% of energy—leads to Recommendation 16.

Recommendation 16: *The nutritional standard for protein should be set at 15–20% of energy intake for ADF members engaged in Category 1 physical activity.*

From the discussion above it is also concluded that as the level of physical activity increases, the percentage of energy derived from protein should be reduced to allow protein intake to be maintained approximately in the range 1.5–2.0 g/kg/day.

For extremely high energy intakes, protein intake could be as low as 11% of energy (e.g. for a 76 kg male expending 25 000 kJ/day, 11% of energy from protein equates to ~2.0 g/kg/day).

It is suggested here that a reasonable approach to determining protein entitlements as physical workload increases would be to decrease the contribution of protein to total energy by one percentage point for each rise in energy expenditure category. That is, with protein entitlement set at 15–20% of energy for *Category 1* (Recommendation 16, above), the protein entitlement for *Category 2* would be 14–19% of energy, for *Category 3* it would be 13–18%, *Category 4* entitlement would be 12–17%, and for *Category 5* it would be 11–16%.

Recommendation 17: *As energy expenditure increases across five designated categories of energy expenditure, the percentage contribution of protein to total energy intake should decrease linearly from 15–20% of energy (Category 1) to 11–16% of energy (Category 5).*

4.1.2.2 Carbohydrate versus Fat

Two major considerations need to be taken into account when deciding on the appropriate contributions of fat and carbohydrate to total energy intake—health effects and physical activity. With respect to health, the NHMRC (2006) recommends that fat contribute to total energy in the range 20–35%, while the corresponding range for carbohydrate is 45–65%. Although these ranges may be appropriate when considering the huge variety of diets that exist within the Australian and New Zealand civilian populations, they may be too wide to be acceptable as the standards for ADF nutritional adequacy. In section 4.1.2.1 immediately above, the recommendation is made that protein should contribute 15–20% of energy intake for ADF members engaged in light physical activity, and that the percentage contribution by protein to total energy should decrease as energy expenditure increases. In this section it is argued that the contribution of carbohydrate to total energy intake should also depend on the level of physical activity, while the contribution of fat is of less importance than that of carbohydrate, so fat levels can be set 'by difference'. That is, the energy to be derived from fat will be calculated as [100 - (*Pro%* + *CHO%*)] where *Pro%* is the percentage of energy derived from protein and *CHO%* is that derived from carbohydrate.

When a high rate of power output must be maintained for relatively long periods (i.e. the activity is 'endurance'), carbohydrate is the critical macronutrient (see, for example, Coyle, 1995). Similarly, the ability to continue to perform intermittent, relatively high-level physical work depends on replenishing carbohydrate stores (muscle and liver glycogen) between bouts of work. When work intensity is high, depletion of muscle glycogen leads to reliance on fat metabolism, resulting in a noticeable reduction in performance. Marathon runners are familiar with this phenomenon, which is sometimes called 'hitting the wall', because of the fatigue and inability to maintain the initial pace that follow depletion of muscle glycogen.

Hawley and Burke (1998) recommend 5–7 g of carbohydrate per kilogram of body mass per day (g/kg/day) 'to meet fuel needs and general nutrition goals in a less fuel-demanding program—for example, < 1 hr of moderate intensity exercise, or many hours of predominantly low intensity exercise.' The same authors recommended 7–10 g/kg/day 'to maximize daily muscle glycogen recovery in order to enhance prolonged daily training, or "load" the muscle with glycogen before a prolonged exercise competition'.

Similarly, Kreider *et al.* (2003) recommended for 'athletes involved in moderate amounts of intense training (e.g. 2–3 hours per day of intense exercise performed 5–6 times per week)... a diet consisting of 55–65% carbohydrate (i.e. 5–8 g/kg/day...). Research has also shown that athletes involved in high volume intense training (e.g. 3–6 hours per day of intense training in 1–2 workouts for 5–6 days per week) may need to consume 8–10 g/kg/day of carbohydrate.' As described elsewhere in this report, many ADF members engage in similar levels of physical activity during training and operations.

Carbohydrate is also important in that, except during semi-starvation, glucose is the only fuel that can cross the blood-brain barrier and so is essential for optimal cognitive function. The potential importance of carbohydrate as an aid to cognitive performance is illustrated by the study of Lieberman *et al.* (2002). In a double-blind, placebo-controlled study, these researchers showed that supplementing with carbohydrate beverages enhanced vigilance and mood during 10 hours of physically demanding tasks, including a 19.3-km road march and two 4.8-km runs, interspersed with rest and other activities.

The well-nourished adult male has a body fat level in the range 10–20% of body weight (Durnin *et al.,* 1985). This constitutes an energy reserve in the order of 400 000 kJ. By contrast, carbohydrate reserves are unlikely to exceed 500 g, constituting an energy reserve of ~8000 kJ. Consequently, fat provides a vastly greater reserve of energy than carbohydrate. Stroud (1998) pointed out that because ultra-endurance activities must be performed at lower intensities than endurance activities (e.g. marathon running, triathlon), this should allow for a higher use of fat as the major fuel for the muscular work involved in ultra-endurance activity. In fact, according to Stroud (1998) the nature of many ultra-endurance activities is such that fat *must* provide a substantial proportion of the required energy. This is because, unlike endurance activities, many ultra-endurance events or military operations continue beyond the time that muscle glycogen is exhausted. Further, Stroud (1998) stated that exogenous carbohydrate can be metabolised only at a rate of about 60 g per hour (equivalent to a total power output of ~265 watts, or external power output of ~53 watts, assuming ~20% mechanical efficiency of the human body). If Stroud is correct, and the activity is conducted at an external power output greater than ~50–55 watts, the work can be sustained only if fat is available to make up the difference.

Fat also has the advantage over carbohydrate of being 'energy dense'—fat provides 37 kJ per g compared to only 16 kJ per g from carbohydrate. One implication of this is that when load carriage is a consideration, high intake of fat provides the same energy availability for a lower total load compared to a diet based largely on carbohydrate.

Investigations have been conducted to determine if 'fat loading' can be used to enhance endurance performance, perhaps by sparing body glycogen reserves and thereby extending the time to glycogen depletion.

The results of these investigations have been equivocal at best. Venkatraman *et al.* (2001) and Lambert *et al.* (2001) reported increased time-to-exhaustion (i.e. beneficial effects) following fat loading, while Helge *et al.* (1996), Keins and Helge (2000), Stepto (2002), Fleming *et al.* (2003) and Hargreaves *et al.* (2004) all reported either no effect or impairment of performance.

Burke and Kiens (2006) concluded that the 'glycogen sparing' that appears to result from a period of fat adaptation may in fact be 'glycogen impairment'. As a result, the athlete's ability to perform short-term very vigorous work (e.g. a sprint at the finish) is impaired because of a reduction in the efficiency of utilisation of carbohydrate for the high-intensity activity. Burke and Kiens (2006) stated that 'those at the coal-face of sports nutrition can delete fat loading and high-fat diets from their list of genuine ergogenic aids for conventional endurance and ultra-endurance sports.'

Although ADF activities are not 'conventional sports', there is often a need (and one that cannot always be predicted) for short-term high-intensity activity such as fire-and-movement, rapid advance or rapid withdrawal. The reported impairment in short-term high-intensity activity when the diet is habitually high in fat suggests that high-fat rations may have little, if any, place in ADF rationing.

Although this conclusion applies to ADF rationing generally, it may have particular significance to the design of CRP, because when rationing is with CRP, ADF members generally have no other available source of food. This differs from the situation in barracks, where supplementary feeding is often available from commercial outlets.

It is concluded that, while fat is a significant and useful source of energy for the working muscle at relatively low levels of physical work intensity, it is of less importance in ADF rationing than carbohydrate. Further, it is critical for optimal performance that carbohydrate intake increases as the rate of energy expenditure rises. Consequently, it is suggested that the contribution of carbohydrate to energy availability should rise from a range of 50–55% to a range of 58–63% from *Category 1* to *Category 5,* with the balance of energy coming from fat. These ranges are consistent with the recommendations found in the nutrition/exercise literature, e.g. those of Kreider *et al.* (2003).

Recommendation 18: *The contribution of carbohydrate to energy availability should increase from 50–55% to 58–63% as energy expenditure increases across five designated categories of physical activity.*

4.1.2.3 How best to express carbohydrate standards for feeding groups?

Hawley and Burke (1998) stated that expressing carbohydrate requirements in terms of percentage of total energy intake is inappropriate, because it does not address the muscles' absolute need for carbohydrate and is also not 'user-friendly'. Rather, Hawley and Burke (1998) recommended that the requirement for carbohydrate should be expressed in terms of grams of carbohydrate per kg body weight (g/kg). As the level of activity increases, the requirement for carbohydrate will increase from 5–7 g/kg ('< 1 hr of moderate intensity exercise, or many hours of predominantly low intensity exercise') to 10–12+ g/kg ('very high total energy requirements, daily muscle glycogen recovery, and continued refueling during exercise').

The recommendations of Hawley and Burke (1998) are appropriate when devising recommendations for individual athletes (or other very active people), but they are inappropriate when devising recommendations for large groups (e.g. ADF members engaged in particular military activities). It would be entirely impractical to attempt to determine food entitlements or nutritional standards for operational ration packs for each individual ADF member, based on his or her body weight. Therefore, in this report the recommended contributions of carbohydrate to total energy intake are based on percentages of total energy intake, not on grams of carbohydrate per kilogram body weight.

4.1.2.4 Recommendations for P:F:C

The NHMRC (2006) recommends appropriate contributions of protein, fat and carbohydrate to total energy in the form of an Acceptable Macronutrient Distribution Ratio (AMDR). In sections 4.1.2.1 and 4.1.2.2 recommendations are given separately for the percentage contributions of protein, fat and carbohydrate to total energy availability. Combining these recommendations leads to a 'P:F:C' ratio (where P, F and C refer respectively to protein, fat

and carbohydrate), analogous to the AMDR. The recommended P:F:C ratios are shown for each category of ADF physical activity in Table 4.
There is one circumstance in which the P:F:C values in Table 4 may not be entirely appropriate. At high altitudes it is believed that eating a diet that is even higher in carbohydrate may be beneficial (Askew *et al.*, 1987a). Therefore, Note 1 to Table 4 includes a recommended P:F:C ratio of 15:20:65 specifically for operations that are conducted at high altitude (above 3000 m).

Recommendation 19: *For operations at high altitude (above 3000 m) protein, fat and carbohydrate should contribute to total energy availability approximately in the ratio 15:20:65.*

However, it is recognised that intake of food is often severely impaired by 'altitude anorexia', which can be expected to increase as the altitude increases above 3000 m. As briefly discussed in section 2.5.2.1, it may be that consumption of ~400 g of carbohydrate is the most that can be expected at very high altitudes. It may be appropriate for commanders and medical officers to be aware that troops operating at very high altitudes are unlikely to eat the entire ration, so there is scope for reducing load carriage by choosing mostly high-carbohydrate items from ration packs and either discarding or leaving some of the high-protein/high fat components at base camp for consumption on return.

4.1.2.5 Glycaemic Index

Another aspect of carbohydrate that may be important is the potential for performance enhancement by varying the type of carbohydrate eaten. It has been suggested that the rate at which carbohydrate is digested and absorbed into the blood (expressed as 'glycaemic index', abbreviated to GI) may influence subsequent performance.

One early study (Thomas *et al.*, 1991) suggested that pre-event feeding with low-GI carbohydrate may improve endurance performance. By way of contrast, Burke *et al.* (1998) found that the GI of the pre-event meal did not affect endurance performance—rather, carbohydrate intake at a rate of about 60 g/h (in the form of sports drinks) *during* the activity swamped any effect that might have occurred as a result of the GI of the pre-event meal.

Further, Febbraio *et al.* (2000) reported that pre-feeding with a high-GI meal augmented carbohydrate utilisation during subsequent endurance activity, but had no noticeable effect on performance.

Siu and Wong (2004) stated that:

> … research had shown a low-GI CHO-rich[4] meal is a suitable CHO source before prolonged exercise in order to promote the availability of the sustained CHO (while) a high-GI CHO-rich meal appears to be beneficial for glycogen storage after the exercise by promoting greater glucose and insulin responses.

The results of a study by Stevenson *et al.* (2005) provided support for this—plasma glucose concentrations were better maintained during subsequent exercise following low-GI carbohydrate consumption compared to high-GI.

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[4] CHO is the abbreviation for carbohydrate.

However, recent research has provided conflicting results on performance effects of modifying GI. Wu and Williams (2006) found that ingestion of a low-GI meal three hours before exercise resulted in a greater endurance capacity than after the ingestion of a high-GI meal. Conversely, no beneficial effects were found on performance for intermittent high-intensity activity (shuttle running) (Erith *et al.*, 2006), on endurance performance (Lancaster *et al.*, 2004) or on immune response to vigorous activity (Chen *et al.*, 2008) when food intake (and especially carbohydrate intake) was not restricted.

Although the GI of the diet prior to or during activity may be of little practical value to athletic performance, it may not be appropriate to conclude that the same applies to military performance. This is because military operations are associated very strongly with under-consumption, while athletes (other than some extreme ultra-endurance athletes, e.g. trans-Antarctic trekkers) rarely experience periods of under-eating. In the presence of chronic under-consumption of total energy and carbohydrate, factors such as GI may play more important roles. However, there appears to have been little or no research on this. It is recommended that research be conducted into the effects of low- versus high-GI carbohydrate on performance of activities relevant to military operations and/or training, particularly during periods of sustained negative energy balance.

Recommendation 20: *Investigate the effect of glycaemic index on military performance in the presence of chronic under-consumption of total energy and carbohydrate.*

4.1.2.6 Protein plus Carbohydrate

Many studies have been conducted to test the common belief (among athletes) that combining carbohydrate with protein (CHO + protein) will lead to beneficial alterations in metabolism, and that these in turn may enhance performance. Forbes-Ewan (2005) reviewed the scientific literature on the effect of this combination on muscle glycogen replenishment, and concluded that:

> … a reasonable assumption is that CHO + protein may be no more effective than carbohydrate alone for glycogen replenishment if carbohydrate intake at ~1.2 $g.kg^{-1}$ body $wt.h^{-1}$ commences soon after the completion of exercise. If carbohydrate availability is limited during the recovery period, CHO + protein may be more effective than carbohydrate alone.

However, there are other potential benefits from combining carbohydrate with protein. With respect to military health and performance, the most positive study was that of Flakoll *et al.* (2004) who reported statistically significant reductions in perceived muscle soreness, fewer total presentations for medical problems, for infectious illness and for heat illness in US Marine Corps recruits who received CHO + protein compared to those taking either CHO alone or placebo. Flakoll *et al.* (2004) concluded that:

> Post exercise protein supplementation may not only enhance muscle protein deposition but it also has significant potential to positively impact health, muscle soreness, and tissue hydration during prolonged intense exercise training, suggesting a potential therapeutic approach for the prevention of health problems in severely stressed exercising populations.

If these results were to be confirmed, they suggest a substantial potential for better training and operational outcomes by the simple practice of providing beverages containing CHO + protein for recruits and ADF members who are required to engage in repeated bouts of vigorous physical activity. It is suggested that this is an area ripe for further research. It is further suggested that DSTO may not have the resources to conduct research unilaterally in this area. Rather, it may be an area of research that could be conducted in collaboration with the Australian Institute of Sport, which has an active program in this area.

Recommendation 21: *Investigate the potential for conducting collaborative research with the Australian Institute of Sport on the value of combining carbohydrate and protein as a recovery beverage.*

4.1.3 Micronutrients

Requirements for vitamins, minerals and trace elements are believed to be generally independent of energy expenditure (NHMRC, 2006). However, the relevance of this belief to ADF rationing is challenged in this report, as described in detail in section 5.2.1.

4.1.4 Dietary Fibre

Although it is not universally accepted as a nutrient, there is considerable scientific evidence that adequate quantities of dietary fibre must be ingested for optimal health to be maintained.

The National Health and Medical Research Council (NHMRC, 2006) established 'Adequate Intakes' of 30 g for men and 25 g for women. These recommendations are accepted as being appropriate for ADF members who are rationed with freshly-cooked food.

Recommendation 22: *A minimum of 30 g per day should be adopted as the criterion for adequacy of dietary fibre intake of male ADF members, and 25 g for female ADF members eating freshly-cooked food in static messes or in the field.*

The definition of 'dietary fibre' now includes a form of starch that is resistant to mammalian digestive enzymes ('resistant starch', abbreviated to RS). Topping *et al.* (2007) described the potential benefits to health from increased consumption of RS. In brief, short-chain fatty acids (SCFA) are produced by bacteria as a result of fermentation of RS in the colon. SCFA have several beneficial effects on bowel function, including suppressing the growth of pathogenic bacteria, promoting colonic blood flow and stimulating uptake of fluids and electrolytes (including sodium, potassium and calcium). In this regard, RS may be of value in reducing both the risk and the severity of diarrhoea, a common occurrence in the field (see for example Steele *et al.*, 2005). Topping *et al.* (2007) suggested that increasing the RS content of military rations may be particularly useful.

Recommendation 23: *Research should be conducted into the effects of resistant starch on intestinal health of ADF members engaged in field exercises or training where a high level of diarrhoea or other gut disturbances commonly occur.*

5. Recommended Military Nutrient Reference Values

5.1 Background

Forbes-Ewan (2002a) suggested Recommended Military Dietary Intakes (RMDIs) for use by the ADF as the nutritional basis for fresh feeding of ADF members and in the development or assessment of ration packs. These RMDIs were based on the Recommended Dietary Intakes (RDIs) published by the National Health and Medical Research Council (NHMRC, 1991), but also taking into account the results of studies of the energy requirements of ADF members across a wide range of operational and training situations. They detail the recommended nutrient intakes for the range of nutrients for which RDIs were recommended by the NHMRC (1991). These RMDIs have been used by DSTO as unofficial standards for nutritional adequacy of fresh feeding and feeding with CRP, and also by DMO in CRP design.

As previously discussed in this report, the NHMRC (2006) published revised recommendations on nutrient intakes for Australians and also (for the first time) the people of New Zealand. The 2006 recommendations differ in several ways from the 1991 recommendations. Firstly, the term 'Nutrient Reference Value' (NRV) is now used to describe a range of recommended nutrient intakes. As applied previously, these include the RDI, but there are now also 'Adequate Intake' (AI), 'Upper Level' (UL), 'Estimated Energy Requirement' (EER) and 'Estimated Average Requirement' (EAR). Secondly, the 2006 RDIs differ from those published in 1991, and NRVs now exist for a much wider range of nutrients. Of particular relevance to ADF rationing, there has been a substantial reduction in the NRV for sodium from the 1991 RDI. Thirdly, the basis for the determination of NRVs for several key vitamins of the B group has altered—previously, the requirements for thiamin, riboflavin and niacin were believed to increase as energy expenditure rose, while the requirement for vitamin B6 was believed to increase with protein consumption. The 2006 NRVs for these vitamins do not increase with energy expenditure (thiamin, riboflavin, niacin) or protein intake (vitamin B6). Fourthly, the NHMRC has, for the first time, set 'Suggested Dietary Targets' (SDTs) for some nutrients. SDTs are levels of intakes of certain nutrients from food and beverages that may help in prevention of chronic disease.

It is considered appropriate to adopt similar terminology as the NHMRC for military NRVs, but with the term 'Military' included in the name of the NRV to distinguish it from the NHMRC NRV. As examples, the 'Military Recommended Dietary Intake' (MRDI) is the military equivalent of the NHMRC RDI, while 'Military EAR' (MEAR) is the military equivalent of the NHMRC EAR. (*However, Note that where the* EAR *is identical to the* MEAR*, the terms* EAR *and MEAR will be used synonymously in the remainder of this report).* Tables 5–8, 10a and 10c show recommendations for military intakes of micronutrients based on MRDIs, while Tables 10b, 10d and 11–14 relate to EARs/MEARs. The background to the development and *raison d'être* of these tables is discussed in Section 6.

It is considered advisable to adopt the appropriate[5] NRV of the NHMRC (2006) as the MRDI for energy and for each nutrient, with the exceptions of thiamin, riboflavin, niacin, vitamin B6, protein and sodium. The reasons for these exceptions have been briefly alluded to previously, and are argued in greater detail in section 5.2 below.

Recommendation 24: *The appropriate 2006 Nutrient Reference Values (Recommended Dietary Intake where one exists, otherwise the Adequate Intake) of the National Health and Medical Research Council should be adopted as the Military Recommended Dietary Intakes (MRDIs) for all nutrients other than thiamin, riboflavin, niacin, vitamin B6, protein, sodium, and total energy.*

It is also argued above that MRDIs should take into account age (adult versus adolescent), gender and activity level. Tables 5–8 show the MRDIs for each activity level for the four ADF population subgroups *adult males*, *adult females*, *adolescent males*, and *adolescent females.*

It is also recommended that the ULs and SDTs published by the NHMRC (2006) be adopted for use with ADF rationing, with the exception of the UL for sodium (see section 5.2.4 for the rationale for this exception).

Recommendation 25: *The Upper Limits and Suggested Dietary Targets of the National Health and Medical Research Council should be adopted for use with ADF rationing, with the exception of those for sodium.*

Table 15 shows the SDTs for all nutrients for which the NHMRC (2006) recommends an SDT, other than that for sodium.

Table 16 shows the ULs for those nutrients assigned a UL by the National Health and Medical Research Council (NHMRC, 2006) for each of four groups of ADF members—*adult males*, *adult females*, *adolescent males* and *adolescent females*. These ULs are identical to those of the NHMRC (2006) other than for sodium.

5.2 MRDIs that differ from the NRVs

5.2.1 Thiamin, Riboflavin and Niacin

The reduction from 1991 to 2006 in the RDIs for thiamin, riboflavin and niacin occurred because the reviewers apparently rejected the previously-held assumption that the requirements for these vitamins are energy-dependent. For example, the 1991 RDI for thiamin was 0.10 mg/MJ, while the 2006 RDI for thiamin is 1.2 mg for an adult male regardless of energy expenditure.

[5] In this context, 'appropriate' is interpreted as:
- (i) The RDI where one exists; or
- (ii) The AI if no RDI has been established for a particular nutrient.

However, the rationale for this is not clear. In the chapter on 'Thiamin' in the NHMRC document (NHMRC, 2006) it is stated that:

> (Thiamin) plays an essential role in the supply of energy to the tissue, in carbohydrate metabolism and in the metabolic links between carbohydrate, protein and fat metabolism … Although there is a lack of direct evidence, it is thought that a relationship exists between thiamin requirement, energy supply and energy expenditure.

Because many ADF operational and training situations involve high energy expenditures as described above, until the situation with respect to energy-dependence of thiamin requirements is resolved, it may be appropriate to retain the existing RMDI (based on the 1991 RDI) as the new MRDI, rather than adopt the revised RDI. Similar considerations apply to riboflavin and niacin.

Further, thiamin is one of the least stable vitamins (along with vitamin C) in combat ration packs. James *et al.* (1993) reported that more than 50% of the thiamin in a wet dish (canned chicken and vegetables) and a dry food (beef noodle soup powder) had been degraded following two years storage at 30 °C. Setting higher standards would help to reduce the risk of deficiency—at least when rationing is by CRP—that could result from consuming combat rations that are nearing the end of their shelf-life. The implications of these considerations for setting standards for CRP are discussed in greater detail in section 6.1.1.3 below.

Recommendation 26: *Rather than adopt the Nutrient Reference Values recommended by the National Health and Medical Research Council, the MRDIs for thiamin, riboflavin and niacin should continue to increase linearly with energy expenditure.*

The NHMRC (1991) used the following relationships to estimate requirements for thiamin, riboflavin, niacin, based on energy expenditure:

(i) 0.1 mg of thiamin for each MJ of energy;

(ii) 0.15 mg of riboflavin per MJ; and

(iii) 1.6 mg of niacin per MJ.

The MRDIs shown in Tables 5–8 for these B group vitamins reflect this recommendation.

5.2.2 Vitamin B6

The NHMRC (1991) RDI was 0.02 mg of vitamin B6 per gram of protein. The 2006 RDIs are age- and gender-specific and no longer increase with protein intake. The most applicable RDI in the military context is that for men aged 19–33; this is 1.3 mg/day. The appropriateness to members of the ADF of the current basis for setting the RDIs for vitamin B6 is not clear. The NHMRC (2006) stated that:

> It has been proposed that vitamin B6 requirements may be increased at higher protein intake (Baker *et al.*, 1964, Hansen *et al.*, 1996a, Linkswiler 1978), although other studies have not shown this (Pannemans *et al.*, 1994). Nevertheless, protein intake is generally taken into consideration in setting requirements for vitamin B6.

Despite this, the NHMRC (2006) NRV for vitamin B6 does not take protein intake into consideration in setting requirements for this vitamin.

As applies to the MRDI for thiamin, until the question of the relationship between protein intake and the requirement for vitamin B6 is resolved, a prudent course would be to take protein intake into consideration and base the MRDI for vitamin B6 on protein intake at the minimum recommended level of protein intake. This is 15% of energy for *Category 1*, 14% for *Category 2*, 13% for *Category 3*, 12% for *Category 4* and 11% of energy for *Category 5.*

Recommendation 27: *The MRDI for vitamin B6 should continue to be calculated as 0.02 mg of vitamin B6 per gram of protein (using the minimum value of the range that constitutes the MRDI for protein) within each energy expenditure category.*

The MRDIs for vitamin B6 shown in Tables 5–8 reflect this recommendation.

5.2.3 Protein

The NHMRC (2006) RDI for protein for men is 64 g; for a 75 kg man (typical of Australian male ADF members), this corresponds to ~0.8 g/kg body weight. However, as previously discussed (section 4.1.2.1), it is very difficult to achieve adequate intakes of other essential nutrients when diets provide only the RDI for protein. There is also evidence for a greater requirement for protein with increasing levels of physical work (see, for example, McArdle, Katch and Katch, 2005, pp. 201–204). Further, the 2006 RDI of 64 g is well below the minimum level of the Acceptable Macronutrient Distribution Range (AMDR) for protein (15–25% of total energy intake).

Recommendations 15 and 16 (above) are that the nutritional standard for protein for ADF rationing should be set at a range of 15–20% of energy intake for low levels of physical work activity (*Category 1*), with the percentage of energy derived from protein decreasing linearly (to 11–16% of energy) as physical activity category increases. It is suggested here that it would be appropriate to set the MRDI for protein for ADF members as the 'gram equivalents'[6] of these recommended ranges of protein intake (e.g. for adult male ADF members working at *Category 1* the MRDI is the gram equivalents of 15–20% of 12 000 kJ, or 106–127 g of protein). Intakes below the level of the MRDI—although possibly still well above the RDI of the NHMRC (2006)—may be considered as being sub-optimal for ADF members.

Therefore, it is recommended that the MRDI for protein should be a range that varies according to the category of energy expenditure for each of the four ADF population groups *adult males, adult females, adolescent males* and *adolescent females.* Tables 5–8 show these MRDIs.

Recommendation 28: *The MRDIs for protein should be expressed as the gram equivalents of the recommended ranges of adequate intakes shown in Recommendation 16 and Recommendation 17, for each of the ADF work level categories, also taking into account age (adult or adolescent) and gender.*

[6] One gram of protein provides 17 kJ, so one gram of protein is the 'gram equivalent' of 17 kJ.

5.2.4 Sodium

The situation with sodium is perhaps even more problematic. The NHMRC (1991) RDI was a range of sodium intake of 920–2300 mg. There is no longer an RDI for sodium; rather, the NHMRC (2006) established an AI in the range 460–920 mg per day for sodium intake, with an upper level (UL) of 2300 mg.

As discussed in section 2.5.1.1, high sweat rates are common during ADF training and operations, largely because much of this activity occurs in hot climates, and sodium losses in sweat can be substantial. For example, Amos *et al.* (1998) reported sweat rates between 1.0 and 1.5 L/h for soldiers in training situations in Far North Queensland during summer. Clearly, fluid intakes of > 1 L/h must be maintained during these periods. Under these circumstances there would be a high risk of hyponatraemia if sodium intake were to be maintained at or below 460 mg/day. To minimise the risk of hyponatraemia, the 2002 RMDI for sodium was set at 2300 mg (the top of the range for the 1991 RDI).

The major reason given by the NHMRC (2006) for reducing the RDI to an AI of 460–920 mg is the association between high sodium intakes and hypertension (excessive blood pressure). However, the NHMRC (2006, p. 291) recognises that 'Physical activity can potentially affect sodium chloride balance, mostly from increased losses in sweat. People who regularly undertake strenuous activity in the heat can lose substantial amounts of sodium'. The US Army (2001) also recognises that 'Hard physical work in a hot environment increases the amount of sodium lost in sweat. The need for extra salt (a source of sodium) depends on the severity of sweat loss and the degree of acclimatization ...' The US military recommendations are 5000 mg (approximately the mid-point of the range 4550–5525) of sodium for men, and 3600 mg (range 3220–3910) for women, '… based on 1400 to 1700 milligrams of sodium per 1000 kcal (~4.2 MJ) of food served (and) calculated using energy intakes for moderate activity of 3250 kcal (13.6 MJ) for men and 2300 kcal (9.6 MJ) for women' (US Army, 2001).

In addition to replacing salt lost in sweat in acclimatised individuals, there may be a specific situation in which high salt intakes are appropriate. When troops deploy to a hot climate from a cool climate, and are required to engage in vigorous physical work before they are heat acclimatised, supplementary sodium may be required for the first few days of the acclimatisation period, as discussed in section 2.5.1.1.

Taking all these factors into account, it is recommended that the MRDI for sodium be set within the range 920–2300 mg for ADF rationing at *Category 1* work level, with an increase of approximately 10% (rounded to the nearest 50 mg) in the upper end of the range for each increase in work category (i.e. the recommended ranges are: *Category 2* 920–2500 mg; *Category 3* 920–2750 mg; *Category 4* 920–3000 mg; *Category 5* 920–3200 mg). This constitutes a compromise between the (relatively) very high recommendations of the US Army and the relatively low AI of the NHMRC (2006). It is further proposed that the upper end of the range of the adequate intake of sodium be extended to 4600 mg, applicable only in the circumstance that troops who are not acclimatised to the heat move to a hot climate and are required to take part in vigorous and sustained physical activity before they have acclimatised to the heat.

Recommendation 29: *The MRDI for sodium should be set as a range of 920–2300 mg for Category 1 work level, with an increase of approximately ten percent in the upper end of the range for each increase in work category.*

Finally, as mentioned briefly in section 5.1, it is recommended that the NHMRC (2006) upper level (UL) for sodium not be adopted for use by the ADF. Rather, it is suggested here that an appropriate Military UL (MUL) under normal circumstances would be the highest MRDI (3200 mg), with a MUL of 4600 mg in the sole circumstance where troops from a cool climate deploy to a hot climate and are required to engage in vigorous and sustained physical activity before they have acclimatised to the heat.

Recommendation 30: *A Military Upper Level for sodium should be set at 3200 mg under normal circumstances, or 4600 mg where unacclimatised troops must engage in arduous physical activity in hot environments.*

Recommendations 29 and 30 are reflected in the MRDIs for sodium shown in Tables 5–8.

5.2.5 Energy

Energy is not strictly a 'nutrient'. Rather, the macronutrients are used as sources of energy in the body. However, for the purposes of this report, it is considered appropriate to treat energy in the same way as nutrients, and to develop an MRDI for energy. This is to allow the same terminology to be used for energy and all nutrients when setting nutritional standards. The MRDI for energy corresponds to the Estimated Energy Requirement (EER) defined by the National Health and Medical Research Council (NHMRC, 2006).

As discussed in section 3.3, the EERs of the NHMRC (2006) do not encompass the full range of physical activity levels that apply to the ADF. Recommendation 11 of this report is reiterated and expanded here—that is, the energy requirements of ADF members should be based on gender, age (adult or adolescent) and category of physical activity (categories 1–4 for nearly all ADF situations).

Recommendation 31: *The categories of energy expenditure of ADF groups defined in this report (ADF energy expenditure categories 1–5 for male adults, categories 1–4 for female adults, male adolescents and female adolescents) should be adopted as the basis for determining standards for total energy for ADF rationing.*

This recommendation is reflected in the MRDIs for energy shown in Tables 5-8.

5.2.6 Carbohydrate

There is no NRV for carbohydrate. However, the NHMRC (2006) stated that 'The lack of an RDI or AI for total carbohydrates in no way reflects a lack of value as a key component of the diet.' As previously discussed, carbohydrate is the nutrient of most importance when vigorous physical work is conducted, and the higher the work rate, the greater the need for carbohydrate. Although the NHMRC (2006) does not include an NRV for carbohydrate, the AMDR range for carbohydrate is set at 45–65% of total energy intake.

In section 4.1.2.2 of this report it is proposed that carbohydrate availability should increase from a range of 50–55% to a range of 58–63% of energy through the categories of energy expenditure (as shown in Table 4). Each of these ranges is within the AMDR recommended by the NHMRC (2006). It is recommended that an MRDI for carbohydrate be defined for each gender and activity category as the 'gram equivalents' (see Footnote 6 to section 5.2.3 for an explanation of this term) of the recommended range of carbohydrate intake for each category of energy expenditure (e.g. for adult male ADF members working at *Category 1* the MRDI is the gram equivalents of 50–55% of 12 000 kJ, or 394–413 g of carbohydrate).

Recommendation 32: *The MRDIs for carbohydrate should be expressed as the gram equivalents of the recommended ranges of adequate intakes shown in Recommendation 17 for each of the ADF work level categories, also taking into account age (adult or adolescent) and gender.*

The MRDIs for carbohydrate shown in Tables 5–8 reflect this recommendation.

5.2.7 Fat

As also applied to carbohydrate, the NHMRC (2006) did not set an NRV for fat. As shown in Table 4, and as previously argued in this report, it is considered that military standards for total fat intake should remain within the NHMRC (2006) AMDR recommendation for fat, and should be determined 'by difference', when protein and carbohydrate percentages have been specified. That is, the energy to be derived from fat will be calculated as [100 – (*Pro%* + *CHO%*)] where *Pro%* is the percentage of energy derived from protein and *CHO%* is that derived from carbohydrate. Consequently it is not recommended that MRDIs be defined for fat.

However—and although this does not involve setting an MRDI—it may be prudent to recognise the suggestion by NHMRC (2006, p. 263) that the combined total of saturated and *trans*[7] fat be limited to 8–10% of total energy intake. To allow an exact standard to be set, it is recommended that the upper limit of this range be adopted as the standard for ADF rationing.

Recommendation 33: *ADF rationing systems should provide no more than ten percent of total energy as saturated fat plus trans fat.*

5.3 Summary of MRDIs

In summary, tables of 'Military Recommended Dietary Intakes' (MRDIs) for ADF members have been devised according to activity level, age and gender, as described in greater detail in section 5.4 below. This has been achieved by combining the known energy expenditure levels of ADF activities (as detailed in Tables 1 and 2) with the recommended percentage contributions to total energy from protein, fat and carbohydrate (Table 4) and the recommendations of the National Health and Medical Research Council (NHMRC, 2006) for Australian men, women, adolescent males and adolescent females.

[7] *Trans* fat is polyunsaturated fat that does not have the usual *cis* configuration. As a result it behaves like a saturated fat in the body, and may actually have more deleterious effects than saturated fat (NHMRC, 2006, p. 262).

As discussed above, the MRDIs are adopted directly from the NRVs for all nutrients except thiamin, riboflavin, niacin, vitamin B6, protein and sodium. In addition, the MRDIs for energy are derived from studies conducted on ADF groups rather than adoption of the NHMRC's EERs. Further, MRDIs are presented for carbohydrate.

5.4 MRDIs for Specified ADF Population Groups

5.4.1 Adult Male ADF Members

Table 5 shows the recommended energy, protein and micronutrient intakes for adult male members of the ADF for each of five categories of energy expenditure. For *Categories 1–3*, the recommended energy intake is shown as the mid-point of the range for that category (e.g. *Category 2* ranges from 13–15 MJ, with a mid-point of 14). The MRDIs in Table 5 for those micronutrients that may be 'energy dependent' (i.e. whose requirement may increase directly with increasing energy expenditure) or 'protein dependent' are based on the mid-point of the energy range for each category.

Where differences occur in recommended nutrient intakes across the energy expenditure categories, these are highlighted by 'bolding' all such recommendations. As can be seen in Table 5, this applies to energy, the macronutrients protein and carbohydrate, the B group vitamins that are associated with energy release from food (thiamin, riboflavin, and niacin) and vitamin B6, which is involved in protein metabolism.

5.4.2 Adult Female ADF Members

As discussed previously, gender exerts a major influence on nutrient requirements, albeit largely through its effects on energy expenditure. The data in Tables 1 and 2 apply to male members of the ADF. Females were either not represented or did not form a large proportion of the study group in any of the studies that led to those tables. This is partly because over the period these studies were conducted (1987–2005) females constituted only a small proportion (~10–13%) of the ADF, and also because females were not permitted to engage in many of the activities that were studied (which were mostly combat or combat-related).

Investigation of the nutrient requirements of female members of the ADF, and how well the current feeding systems meet those requirements, is recommended for inclusion in the future research program. Until definitive studies are conducted, recommendations must be based on theoretical considerations, on published recommendations for civilians, and on the limited data obtained in studies involving female subjects already conducted by DSTO and overseas Defence nutrition research organisations, as described immediately below Recommendation 33.

Recommendation 34: *Further studies should be conducted to determine the specific nutritional requirements of female ADF members.*

Females generally expend less energy than males in performing a given task. According to the National Health and Medical Research Council (NHMRC, 1991), on average females need 25–30% less energy than do males to perform similar work. This is supported by the results obtained by Forbes-Ewan *et al.* (1990) who found that female sailors at a large Naval base, female soldiers engaged in a course at the Royal Australian Army Ordnance Corps Centre, and female Staff Cadets at RMC Duntroon had energy expenditures approximately 70% of those of males doing the same activities. Similarly, Tharion *et al.* (2005) reported that mean energy expenditure (11.9 MJ) of female military personnel engaged in a wide variety of activities was substantially less than for males (19.3 MJ). According to Tharion *et al.* (2005) this is '… presumably due to their lower lean body mass, resting metabolic rate, and absolute work rates … '

The major difference between the genders in micronutrient requirements is a greater need for iron by females: 18 mg per day compared to 8 mg for males (NHMRC, 2006). Therefore, if females on operations or in training are subjected to a period of low or poor-quality food intake, iron availability may be performance limiting.

Friedl *et al.* (1990) provided evidence that iron status of female members of the US defence force may be borderline, even during barracks feeding—almost 37% of female West Point cadets had ferritin < 12 ng/mL, 22% had Fe saturation < 16% and 5% had haemoglobin < 12 g/dL. At least in theory, borderline iron deficiency of this magnitude could quickly translate into anaemia in the field if iron intake is less than adequate. Similarly, Carins *et al.* (2005) reported that more than 50% of female officers-in-training at the Royal Military College and Australian Defence Force Academy exhibited some degree of iron deficiency.

There is evidence that some female members of the ADF may also be at risk of calcium deficiency. Newman (2000) reported that 29% of female Officer Cadets at the Australian Defence Force Academy had self-reported calcium intakes less than two-thirds of the RDI for calcium (RDI at that time = 800 mg per day). With the recent increase of the RDI to 1000 mg (NHMRC, 2006) the percentage of female officers-in-training at risk of calcium deficiency would be even higher. This finding indicates a possible increased risk of musculoskeletal injuries and osteoporosis, and suggests the need for directed nutrition education on appropriate food choices for female ADF members.

Table 6 shows the MRDIs for adult female members of the ADF for each of the four categories of energy expenditure. As with the MRDIs shown in Table 5 for adult males, the recommendations for females are the mid-points of the range of energy expenditures for each category, based on the assumption that female requirements are approximately 70–75% of those for male ADF members in the same category (rounded to the nearest 0.5 of a MJ). The recommended micronutrient levels are calculated on the same basis as those for adult males. Figures that differ between categories of energy expenditure are bolded.

5.4.3 Adolescent ADF Members

As discussed previously in this report, in the context of defining ADF nutritional requirements, age is considered to be of practical importance only for adolescent members (defined here as < 19 years).

Table 7 shows the recommended dietary intakes for adolescent male members of the ADF. Table 8 shows the corresponding figures for adolescent female members. Figures that differ between categories of energy expenditure are bolded.

In Tables 7 and 8, an allowance of 0.5 MJ per day is made, partly for growth, but mainly to allow for the generally higher physical activity levels of adolescents than adults.

6. ADF Nutritional Requirements and Feeding Systems

6.1 Combat Ration Pack Feeding

6.1.1 Typical Operational and Training Situations

The results provided in this report show that ADF members have a wide range of nutritional requirements, with reported daily energy expenditures ranging from less than 7 MJ/day (a small female with a sedentary occupation) to more than 25 MJ/day (males attempting SASR selection). Therefore, a decision needs to be made on the most appropriate basis for determining how much food energy should be made available in combat ration packs (CRP). In making this decision, several factors need to be considered, including:

- The type of CRP and the situations in which it will be used
- The relevant activity category for typical users of that CRP
- The need to minimise load carriage
- The possibility that supplementary issue can be used to increase food availability under extreme circumstances (e.g. if *Category 4* or *Category 5* training or operations are expected)

6.1.1.1 Energy, Macronutrients and Micronutrients

Because ADF members have no choice on either quantity or type of food they consume when fed with CRP, the MRDI is the appropriate NRV for determining nutritional adequacy of CRP. This is because provision of the MRDI will ensure that the nutritional requirements of the vast majority (approximately 97.5%) of the ADF population will be met if the ration is consumed in its entirety).

ADF policy does not allow females to take part in ‘direct combat duties’, i.e. to be placed in situations where direct physical contact with an armed adversary is likely to occur (Department of Defence, 1994). Therefore, the vast majority of users of CRP are male ADF members. This suggests that male requirements should be paramount as the criterion for total energy in CRP. Because females have only about 70% of the energy requirement of males, if male requirements for energy are met, female requirements will also be satisfied.

From Table 1 the mean energy expenditures of male soldiers on typical field exercises in relatively warm climates (soldiers engaged on a field exercise involving vital assets protection in a desert environment; Airfield Defence Guards engaged in a field exercise in a hot climate; and soldiers on a field exercise in a tropical rainforest) were all in the range 15–16 MJ per man per day. This range is within *Category 3* (15–17 MJ) for adult male and adolescent male ADF members. It would therefore appear to be appropriate to set the standard for energy availability in general purpose CRP at 16 MJ. This corresponds to the MRDI for energy for adult males engaged in *Category 3* activities.

Because CRP may be consumed by ADF members other than adult males, it is recommended that the 'worst case' situation be applied to determining nutritional standards for each nutrient other than energy. That is, the MRDI at *Category 3* for the population group that has the greatest nutritional requirement for a specific nutrient should constitute the nutritional standard for that nutrient in general purpose CRP.

Note that these standards apply to 'general purpose' CRP, i.e. those that will be issued when extremes of climate and physical work output are unlikely to be experienced. Therefore, these standards do not necessarily apply to 'mission-specific' situations, e.g. those involving short-term/high-intensity activity, or where troops may be subject to extreme heat, cold and/or altitude.

Recommendation 35: *The nutritional standard for energy for general purpose (i.e. not mission-specific) combat ration packs (CRP) should be 16 MJ, and the standards for all other nutrients should be the MRDIs that apply to the population sub-group with the greatest estimated requirements at Category 3 activity level.*

The standards recommended for micronutrients apply at the time of consumption, *not* at the time of packing. The rationale for this is provided in section 6.1.2.1 below.

6.1.1.2 Dietary Fibre

It is also considered appropriate to set a standard for dietary fibre in CRP. This is because considerable anecdotal evidence exists that constipation is very common when feeding is by CRP, and this is commonly attributed to a lack of dietary fibre in the packs.

Lichon and James (1991) reported that the mean value for dietary fibre in the Combat Ration One Man of the late 1980s was 22 g (range 17–30 g). The corresponding values for the Patrol Ration One Man were: mean 22 g, range 18–29 g. Although below the NRV of 30 g, these values are not inconsequential.

However, a recent analysis of ADF CRP (Topping *et al.*, 2007) suggests that currently CRP are relatively low in non-starch polysaccharides, the major component of dietary fibre. As pointed out in section 3.2.7, Topping *et al.* (2007) also recommend increasing the level of resistant starch in military rations, on the basis that this may lead to substantial reduction in the incidence of diarrhoea in the field.

Recent research suggests that long-term consumption of ration packs does not lead inevitably to constipation. For example, Steele *et al*. (2005) reported that there was little or no relationship between consumption of combat rations and constipation among US troops involved in Operation Enduring Freedom in Afghanistan who were subsisting on a combination of Meals, Ready-to-Eat (MRE) and Unitized Group Rations (UGR). Steele *et al.* (2005) also found that no workdays were lost to gastrointestinal (GI) disturbances among these troops. However, the authors pointed out that the participants in their study were Special Forces soldiers—it is possible that other troops would be less motivated to continue despite suffering from GI symptoms.

A lack of dietary fibre is not the only potential cause of constipation in the field. Manz (2007) stated that 'Maintaining good hydration status has been shown to positively affect … constipation … ' In this regard, it is worth noting that physical activity in the heat is known to suppress the sense of thirst. It has been reported that, through an effect known as 'voluntary dehydration', replacement of only 66–75% of nett water loss will commonly occur, despite access to adequate fluids (Maresh *et al*., 2004). Therefore, it can be concluded that inadequate water intake may also play a major role in the onset of constipation on operations in hot environments.

Despite (or perhaps because of) the multiple origins of constipation, it would appear to be prudent to monitor dietary fibre levels in CRP, including resistant starch, and to attempt to maximise fibre content (within the constraints imposed by the necessity to exclude all perishable foods from CRP).

There is also the potential for prophylaxis against diarrhoea and other gastrointestinal illness by the use of probiotics. Because this is not a 'nutritional' area as such, there will be no further discussion of this subject, however continued research on the potential health benefits resulting from supplementation of ration packs with probiotics is recommended.

In brief, more research is needed on the potential for dietary fibre (including resistant starch) and probiotics as prophylactic measures against gastrointestinal illness when rationing is by CRP.

Recommendation 36: *Research should be conducted into the minimum level and most appropriate form (or forms) of dietary fibre (including resistant starch) for inclusion in CRP, and the potential for probiotics to optimise bowel health when rationing is by CRP.*

It is also suggested that, until more information becomes available, a suitable interim criterion for dietary fibre in CRP is 80% of the MRDI. This equates to 24 g of dietary fibre.

Recommendation 37: *Analysis should be conducted to determine dietary fibre and resistant starch content of ADF CRP, which should provide a minimum of 24 g of dietary fibre per person per day.*

6.1.2 Special Considerations with respect to Micronutrients

With respect to the nutritional effects of rationing with CRP, two other key considerations need to be addressed—the storage stability of micronutrients, and their bioavailability. These are addressed separately in the next two sub-sections.

6.1.2.1 Storage Stability

Because storage impacts on vitamin stability, Recommendation 35 above refers to nutritional standards of CRP at the time of consumption, not at the time of packing.

The reason for making this distinction is that, as discussed briefly in section 5.2.1, several key vitamins undergo degradation during storage. Vitamin C and thiamin in particular were found to be unstable in several vitamin-fortified ration pack items during storage (James *et al.*, 1993). Although these authors reported that riboflavin was relatively stable during storage, a preliminary report from the US Army Research Institute of Environmental Medicine noted significant reductions in riboflavin and folic acid, and trends towards reduced vitamin B6, thiamin and vitamin C following six months storage at 100 ºF (38 ºC) for 17 ration components analysed from the US Army Meal-Ready-to-Eat (MRE) XXVI menu (H McClung, pers. comm. 4 June, 2008). However, despite these vitamin losses, the ration menus still exceeded the US Nutritional Standards for Operational Rations (NSOR) for these nutrients. Additional analysis is under way to better determine the extent to which high temperature storage affects ration vitamin levels in US combat rations.

The apparently conflicting results of James *et al.* (1993) and McClung (H McClung, pers. comm. 4 June, 2008) may be at least partly explained by the different effects of food matrices on storage stability of vitamins. For example, James *et al.* (1993) found that vitamin C was stable in hard-boiled candy, but degraded readily in ration chocolate. Clearly, more research is required into storage stability of vitamins in combat ration packs.

This may be best achieved as a cooperative research program with allied nations, e.g. through TTCP-HUM-TP14. The objectives of Key Collaborative Area 3 (KCA 3) of HUM-TP14 include engaging in 'collaborative information exchange and research on:

> 1. Optimal micro-and macro-nutrient composition of field rations, including stability, fortification and availability of fresh food supplements.'

Recommendation 38: *Further investigation should be conducted into the storage stability of vitamins in CRP, perhaps through a multi-national approach, e.g. as part of KCA 3 within TTCP-HUM-TP14.*

It is also important to recognise that provision of the MRDI in ration packs does not imply that intake will necessarily be at the MRDI level. As discussed in section 6.1.2, ADF members almost invariably discard a substantial proportion of their CRP. To ensure that micronutrient requirements are met, it would be appropriate to fortify CRP food items with key micronutrients to well above the level of the MRDI. It would also be appropriate to fortify a wide variety of food items, so that even if discarding occurs, it is less likely to lead to vitamin deficiency.

Until the situation is resolved with respect to storage stability of vitamins in CRP items, as an interim measure it is recommended that ADF CRP be fortified with considerably more thiamin, vitamin C, riboflavin and vitamin B6 than the MRDIs. It is suggested that a reasonable level of fortification would involve providing three times the MRDI for each of these vitamins at the time of packing, and that the vitamins be distributed among a wide variety of food items.

Recommendation 30: *Until more information is available on storage stability of vitamins in CRP generally, fortification with thiamin, vitamin C, riboflavin and vitamin B6 should occur so that ADF CRP contain three times the MRDI for each of these vitamins at the time of packing, and a wide variety of ration items should be fortified.*

Table 9 presents a summary of the recommended criteria for nutritional adequacy at the time of packing of CRP for use in typical operations and training situations.

It should be noted that the standards in Table 9 address only the theoretical basis for adequate total energy and nutrients in CRP; they do not take into account actual consumption rates of ration packs. Elsewhere in this report, evidence is provided that ADF members discard a significant proportion of the food made available in the form of CRP.

Booth, Coad, Forbes-Ewan, Thomson, Niro (2003) found that carbohydrate was the macronutrient at greatest risk of under-consumption when ADF members were rationed with CRP on a field exercise. Coad (2001) suggested possible means of increasing the consumption of CRP items while simultaneously enhancing the nutritional value of the pack.

6.1.2.2 Bioavailability of Vitamins and Minerals

Vitamins and essential minerals must be provided in appropriate quantities in CRP, either naturally-occurring in ration items, or in the form of fortificants. However, provision of vitamins and minerals at the level of the MRDI may not be sufficient. If micronutrients are not well absorbed, then the nutritional value of the ration packs may still be inadequate to optimally sustain training and operations. For example, the absorption rate of iron is extremely variable, ranging from ~5% for 'non-haem' iron (in foods of plant origin) to ~25% for haem iron (found in red meat) (Mahan and Escott-Stump, 1996: p. 139). Even the absorption of non-haem iron can vary greatly, depending on variables such as nutritional status, the simultaneous presence or absence of vitamin C, the presence of phytate (from plants), tannin (tea), calcium and many other food components. As a result, absorption of non-haem iron can vary from 2% (from vegetables) to as high as 50% (in cases of deficiency) (Ibid: p. 140).

When fortification of CRP food items takes place, technical aspects of the fortification process, such as quantity of the fortificant, its chemical form, and method of addition need to be considered to ensure optimal bioavailability.

While some research has been conducted on iron and calcium bioavailability in mixed meals, there is little literature about other micronutrients. There are no Australian research groups and few international groups working on this aspect of nutrition. There are several ways in which the absorption of test micronutrients can be determined, including the use of foods fortified with compounds labelled with stable isotopes in nutrient balance studies.

Because this is an area of great significance to ADF nutritional status, but about which little is known, research needs to be conducted into the bioavailability of micronutrients from ration packs.

Initially the effect of single fortificants would be tested. However, on conclusion of these studies, the effects of fortificant interactions—in particular of iron/zinc, calcium/iron, vitamin C/iron, vitamin E/oils and calcium/magnesium interactions—and the effects of different food combinations could be investigated.

Recommendation 40: *A program of research should be developed and implemented to determine the bioavailability of a wide range of micronutrients from CRP, and the implications of the findings for ADF nutritional status should be investigated.*

6.1.3 Mission- or Climate-Specific Ration Packs

As discussed briefly in the Introduction:

> … there is a need for rationing systems (particularly ration packs) that will sustain troops during short-term, high-intensity operations (e.g. up to 72 hours) and also a need for packs that will support long-term, low-intensity operations (lasting many weeks) in the heat, cold, and (perhaps) at altitude.

Decisions will have to be made on how troops will be rationed under these circumstances. In all instances, the emphasis should be on providing freshly-cooked food as often as possible, to maximise acceptability and morale, but also to achieve optimal nutritional status.

However, there will be occasions when fresh food cannot be provided. This will usually be at the commencement of operations, before field kitchens can be established. The ADF experience in East Timor in 1999 suggests that complete reliance on ration packs may extend for many weeks (Forbes-Ewan, 2001). It will also occur when operations are conducted in remote localities or by Special Forces units.

There is evidence that the primary individual ration pack, Combat Ration One Man, may not be meeting troops' nutritional needs or expectations. For example, high discard rates are consistently reported (see, for example, Booth *et al*., 2003). This problem may be exacerbated by the operational or climatic conditions (see, for example, Kullen, 2008).

It may be appropriate to develop a range of ration packs tailored to specific operational or climatic conditions. However, this range may have to be somewhat limited—it is unlikely that a small defence force such as the ADF could support a wide range of specialised CRP, such as the range produced by the US Army.

Recommendation 41: *CRP should be developed for a restricted range of mission- or climate-specific situations, with specific nutritional criteria determined for each situation.*

A potential solution to the problem of having to procure components and pack a relatively small number of components for each of a wide range of ration pack types might be the use of a 'modular' system, one that also employs a just-in-time packing program and combines commercial-off-the-shelf and military-specific ration pack components.

Recommendation 42: *Consideration should be given to adoption of a modular, just-in-time system of ration procurement, packing and distribution.*

A prototype Hot-Weather Ration Pack (HWRP) has already been developed. The effect of heat on nutritional requirements is discussed in section 2.5.1 of this report. The report by Carins *et al.* (2007) describes the background to the development of the HWRP, and also details the nutritional standards recommended for this pack. These are that the HWRP should provide:

(i) Total energy of 15 MJ;

(ii) P:F:C = 15:25:60;

(iii) Minimum of 7.5 g of salt (= 2950 mg sodium) with 4 g of additional salt (= 1570 mg sodium) in sachets, with further options to supplement while troops are acclimatising to the heat;

(iv) Includes 500 mg of vitamin C and 335 mg of vitamin E; and

(v) Provides 20% more calcium, copper, iron and zinc than CRP for temperate climates.

Other nutritional standards are the same as for the CRP for use on typical operations or training situations (see Table 9).

Appendix A provides a template that is consistent with the current structure of ADF ration packs and can be used to build a CRP that meets the MRDIs.

6.1.4 Group-feeding ration pack

The extent of usage of the current group-feeding ration pack (Combat Ration Five Man) has been reported to be well below forecast requirements (P Harris, SO1 Capability Resources, DLOG-A, pers. comm. 14 Jun 07), casting doubt on its success as a group-feeding pack. There is scope for investigating the suitability of the Combat Ration Five Man as the group-feeding pack and examining alternatives to the configuration of the group-feeder (and whether there even needs to be a group-feeding ration pack—for example, would a wider range of individual 24-hour packs, as recommended above, preclude the need for a group-feeding pack?).

Recommendation 43: *Investigate the most appropriate configuration of a group-feeding ration pack and the suitability of alternative approaches to feeding groups of ADF members on operations where fresh feeding cannot be provided.*

6.1.5 NATO HFM RTG 154

At the time of writing this report (May 2009), a Research Technical Group (RTG) within the Human Factors and Medicine group of NATO is nearing completion of a review of member nations' CRP with respect to, *inter alia*, nutritional standards. NATO HFM RTG 154 *Nutrition Science and Food Standards for Military Operations* is developing benchmark standards for CRP. These standards will be published in the final report of the RTG, due to be published in late 2009.

Australia has membership of the RTG and will have full access to all its outputs. It would be appropriate for the nutritional standards pertaining to ADF CRP in this report to be reviewed when the final report of RTG 154 becomes available.

Recommendation 44: *The Final Report of NATO HFM RTG 154 should be used as a basis for determining the appropriateness of the nutritional standards pertaining to ADF CRP.*

6.2 Scales of Entitlement to Fresh Food

6.2.1 Energy

ADF members exhibit a wide range of energy expenditure levels, even at the same base. For example, Forbes-Ewan *et al.* (1990) found daily energy expenditures ranging from 7 MJ (female with sedentary occupation) to 17 MJ (Navy representative triathletes in training) at a large naval shore base. Sailors with relatively sedentary occupations, and who did not take part in vigorous physical activity in their leisure time, had mean daily energy expenditures of ~12 MJ.

There are even greater differences between bases and/or training or operational situations. Forbes-Ewan and Waters (1991) reported mean daily energy expenditure of just below 13 MJ for male soldiers who were undertaking a clerical course at the RAAOC Centre, Bandiana, while soldiers training for jungle warfare were expending energy at a rate of 19 MJ (Forbes-Ewan *et al.*, 1988). The highest reported level of energy expenditure was 28 MJ/day reported for ADF members attempting selection to the Special Air Service Regiment (Forbes-Ewan *et al.*, 1995).

Forbes-Ewan (2002a) recommended that one set of nutritional standards be adopted as the criteria for an ADF Ration Scale, and that this scale should be a 'maximum' scale—i.e. it should provide adequate food for the vast majority of ADF rationing situations. The current basic scale of entitlement, published as SUPMAN 4 (Department of Defence, undated b.) uses this approach. However, recent studies (Skiller *et al.*, 2005; Forbes-Ewan *et al.*, 2007) suggested that for some groups, this 'maximum' scale may still be borderline, or actually provide insufficient food to meet nutritional requirements.

Rather than retain a 'one scale fits all' approach, it is argued here that food entitlements should better match nutritional requirements based on demonstrated physical workloads. In section 4, categories of energy expenditure were defined for each of four population groups, *adult males, adult females, adolescent males* and *adolescent females*. Tables 5–8 detail the MRDIs for each group at each category of physical workload. These are the tables on which nutritional entitlements should be based when groups of ADF members of the same gender and age group (adult or adolescent) are to be fed.

It is important to note that the energy levels shown in Tables 5–8 refer to recommended *intake*—they do not constitute recommended *availability*. This distinction is important because of the nature of institutional feeding, particularly when the clientele are free to attend the mess or eat elsewhere. A major outcome of this is that some food will always remain uneaten in the mess. This includes used cooking oil, food that has not been consumed after having been offered twice, and plate waste. (In the remainder of this report this uneaten food will be collectively referred to as 'discarded food'). Based on studies of food usage, food intake and energy expenditure conducted at various messes (see, for example, Morrissey *et al.*, 1989; Forbes-Ewan *et al.*, 1990), an efficient mess should be able to keep total discarded food to no more than 15% of total food availability. This indicates that, to account for unavoidable food discards, a margin of ~15% should be made available in addition to the amount of food needed to satisfy the average energy requirement of the group being rationed.

The recommended entitlements shown in Tables 5–8 apply when only one population sub-group is to be fed. Where mixed ADF populations are involved, it is recommended that energy availability from fresh feeding should be determined according to the group that has the greatest requirement, *adolescent males* (see Table 7). If the energy needs of adolescent males are met, those of all other groups will also be met. Therefore, it is recommended that the criterion for adequacy of energy for mixed ADF populations working at the same category should be the MRDI for energy for adolescent males appropriate to the work category, regardless of the gender or age mix of troops.

Recommendation 45: *The criterion for adequacy of energy of a fresh-feeding ration scale should be set at the MRDI for energy for adolescent males for each category (1–4) of physical activity.*

Although five categories of energy expenditure are identified in this report, as discussed in section 3.3 the extreme high end of the range (*Category 5*) is unlikely to be of practical value in setting nutritional standards for the vast majority of ADF feeding. This is because *Category 5* is a 'special case', involving the selection course for entry to the Special Air Service Regiment (SASR). Recommendation 13 above suggests that research is needed into the nutritional requirements of other Special Forces units or situations (e.g. Commando selection course) to determine whether the upper limit of the range of energy expenditures for training and activities other than SASR selection should be increased above 21 MJ. There may also be a need to use *Category 5* entitlements as the basis of feeding following an extended period of high energy expenditure during which troops were rationed with CRP (see section 7 for more on this).

Recommendation 46: *For ADF members working at Category 5, or undergoing re-feeding following an extended period of vigorous physical work while rationed solely with combat ration packs, the criteria should be the MRDI for energy for adult males working at Category 5.*

6.2.2 Macronutrients

Similarly to the situation with respect to total energy, the needs of all ADF members for protein and carbohydrate will be met if the needs of adolescent males constitute the criteria for nutritional adequacy of macronutrients in ration scales for mixed ADF populations. Therefore, in setting nutritional criteria for a fresh-feeding scale, it is recommended that the ranges shown in Table 7 for protein and carbohydrate are adopted, also taking into account the activity category of the troops (but regardless of age or gender).

Recommendation 47: *The criteria for adequacy of availability of protein and carbohydrate for a fresh-feeding scale that applies in messes rationing a mixed population of ADF members working at categories 1–4 should be the MRDIs applicable to adolescent males working at categories 1–4.*

For ADF members working at *Category 5*, or undergoing re-feeding following sustained and vigorous work while rationed solely with CRP, the criteria for protein and carbohydrate availability should be the acceptable ranges for these macronutrients that apply to adult males at *Category 5* (final column of Table 5).

Recommendation 48: *For ADF members working at Category 5, or undergoing re-feeding following an extended period of vigorous physical work while rationed solely with combat ration packs, the criteria should be the acceptable ranges for adult males working at Category 5.*

6.2.3 Micronutrients

The MRDI is the appropriate NRV to use as the criterion for availability of micronutrients when developing a fresh-feeding scale. Where the group to be fed consists entirely (or nearly entirely) of one population sub-group, the nutritional entitlements that apply are those shown in Tables 5–8 (appropriate to the population sub-group).

Where a mixed ADF population is to be fed, it may be appropriate to set the nutritional entitlement for each micronutrient at the level applicable to the ADF population sub-group with the greatest estimated requirement when working at *Category 4*. The reasoning behind this is that such a basic scale would provide the micronutrient intakes required by the vast majority of ADF members fed according to this scale, regardless of their physical activity level. This would allow those troops who need additional energy (because they are working above the basic entitlement of 12.5 MJ) to obtain that energy in a form that does not necessarily provide high levels of micronutrients. Because the additional need is for energy for light, moderate or hard physical work, this supplementary feeding needs to consist predominantly of carbohydrate and fat, with some protein (for recovery). This concept is further developed in the next sub-section (6.2.4)

Recommendation 49: *The criteria for adequacy of availability of each micronutrient for a fresh-feeding scale that applies in messes rationing a mixed population of ADF members working at categories 1–4 should be the MRDI that applies to the ADF population sub-group with the greatest requirement for that micronutrient while working at Category 4.*

For all vitamins and minerals other than sodium, the criterion is regarded as the *minimum* acceptable value. In the case of sodium (where the MRDI also does not correspond to the NHMRC NRV) the MRDI for Category 4 is an acceptable range of 920–3000 mg. This range is seen as a compromise between the relatively low NHMRC (2006) AI (460–920 mg) and the current relatively high intakes of the Australian population. The high end of this range (3000 mg) is considered the *maximum* acceptable value.

As a long-term goal, the aim should be to gradually reduce the average daily sodium intake of ADF members towards the NHMRC SDT of 70 mmol (= 1600 mg).

Recommendation 50: *The criterion for sodium in the basic fresh-feeding scale should be the MRDI for Category 4 physical workload (920–3000 mg), with a long-term goal of reducing sodium availability to the Suggested Dietary Target of 1600 mg.*

6.2.4 Nutritional Entitlements for Fresh Feeding

In the previous sub-section it was recommended that an appropriate approach to the provision of fresh food would be to develop a fresh-feeding scale that meets the MRDIs for energy and macronutrients of all ADF troops (i.e. regardless of age and gender) working at *Category 1*, but also meets the MRDIs for micronutrients for all ADF members working at *Category 4*. Table 10c summarises the recommended nutritional criteria for this basic scale.

Having designed the basic scale, the adequacy of the scale should be tested by modelling with 'real world' diets against the MRDIs for energy and macronutrients, and MEARs for micronutrients, as shown in Table 10d.

Supplements would be made available in the form of small meals or snacks for between-meal consumption to meet the requirements of troops working at higher energy expenditure categories. This approach is consistent with the conclusion of Tharion *et al.* (2004) with respect to meeting the nutritional requirements of a group of US Special Forces (SF) troops whose daily energy expenditure was found to be ~17 MJ/day. Tharion *et al.* (2004) stated that 'The nutrient intake goals of SF soldiers were not fully met by eating in the dining facility … providing additional meals or "take out" foods may allow energy needs of SF soldiers … to be met.'

The supplementary between-meal snacks used to feed ADF members working at higher categories of energy expenditure may be most appropriately provided in the form of 'modules' of ~1–2 MJ as morning tea, afternoon tea and/or supper.

Note that the values in Tables 10c and 10d do not account for inevitable food discarding. As discussed above, 15% of total food available is considered a reasonable allowance for wastage.

As also previously discussed, it is recommended that the entitlements in Table 10c should be independent of age and gender. The question then arises—how are food entitlements actually calculated in a mess with clientele engaged in a variety of activity levels?

The suggestion in this report is that the calculation be conducted so that a 'weighted average' of food is made available in the mess. Appendix B provides a hypothetical example of how the calculation is conducted to determine the total energy that should be made available, based on a given mix of activity categories.

6.2.4.1 Fresh Field Feeding: Hot-Boxes

When fresh feeding is provided in the field in the form of 'hot-boxed' meals—whereby troops do not have a choice in the type or quantity of their food—it is considered as a special case. The ADF members with the greatest nutritional requirements are adolescent males. It is likely that in most cases the activity level will be *Category 3* or above. Hence, it is suggested that the nutritional entitlements supporting hot-boxed meals should be based on the appropriate work category (3 or above) for adolescent male ADF members.

Recommendation 51: *The nutritional entitlements to fresh field feeding in the form of 'hot-boxed' meals should, as a minimum, be based on the MRDIs of adolescent males working at Category 3.*

6.2.4.2 Assessing Nutritional Adequacy of Groups of ADF Members

Although the scales of entitlement are based on the MRDIs, the NHMRC (2006) recommends that EARs should be used 'to estimate the prevalence of inadequate intakes within a group'.

For thiamin, riboflavin, niacin and vitamin B6, an estimation of the MEAR is required. It is suggested here that it would appropriate to estimate the MEAR as 70% of the MRDI. All other micronutrient MEARs are identical to the EARs published by the NHMRC (2006).

For groups of ADF members consisting of the same gender and age group (adult or adolescent) Tables 11–14 respectively show the appropriate criteria for assessing the adequacy of nutritional intakes using the MEARs.

For mixed population groups, the values shown in Table 10b apply.

Recommendation 52: *When investigating the nutritional adequacy of dietary intake of groups of ADF members, the MEARs should be used as the criteria.*

6.2.4.3 Determining Adequacy of Nutrient Intakes of an ADF Member

When investigating the nutritional adequacy of the diet of an individual ADF member, it is recommended that the MRDIs are used as the criteria, taking into account age and gender in addition to category of energy expenditure. Therefore, the MRDI shown in tables 5–8 for *adult males, adult females, adolescent males* and *adolescent females* respectively apply as the criteria for adequacy of intake of individual ADF members.

Recommendation 53: *When investigating the nutritional adequacy of dietary intake for an individual ADF member, the MRDIs should apply, taking into account age and gender, in addition to category of energy expenditure.*

For energy, the MRDI is shown as an exact number of megajoules (the mid-point of a range of ~2 MJ in each case). It is recommended that the criterion for adequacy with respect to energy intake should be the MRDI ± 1 MJ, but also taking into account the member's age, gender and body weight, using the equation of Schofield (1985) to calculate BMR.

6.3 Estimating Energy Expenditure of ADF Members from a Record of their Activities

There will be situations in which commanders, medical officers and other decision makers may need information on the likely work rates and daily energy expenditure levels of their units. Earlier in this report it is pointed out that the only accurate way of determining the energy requirement associated with a particular situation is to conduct food intake and energy expenditure studies on representative ADF members in that situation. However, a reasonable estimate can be made of total daily energy expenditure—adequate to allow assignment of units into one of the four (or, in the case of Special Forces troops, five) categories of energy expenditure and nutritional requirements.

From studies conducted by DSTO and from the scientific literature, a database of the energy costs of a wide range of military activities has been developed. Appendix C shows the energy costs for adult males of selected military and sporting activities categorised according to a six level system (*basal*, *sedentary*, *slightly active*, *moderately active*, *very active* and *extremely active*).

An overall determination of the daily energy requirement of an ADF member can be made based on the activity pattern using the information in Appendix C as described below:

The commander, medical officer or researcher notes the time spent by an ADF member (or group) in each level of activity (as described in Appendix C). Multiplying the time spent in each level of activity by the average energy cost of that level and summing for the 24-hour period gives an approximate estimation of 24-hour energy expenditure. This figure is then used to determine the category of energy expenditure (by reference to Table 5, 6, 7 or 8, depending on age and gender of the group).

Appendix D provides an example of how this method can be applied.

Appropriate software and database computer technology can be applied to conduct these analyses in the field; for example the field commander could use a palm-top computer for this.

7. Negative Energy Balance

Thus far the discussion has concerned the levels of energy intake needed to maintain energy balance. Military operations often involve periods of negative energy balance (i.e. when energy expenditure exceeds intake). This can occur for various reasons, including decreased appetite, poor ration palatability, menu boredom, inability to work on a full stomach, lack of water, lack of specific meal periods, lack of time to prepare meals, anxiety due to field conditions and intentional dieting (US CMNR, 1995).

The origins of negative energy balance, how this affects military performance, and steps that may be taken in an attempt to overcome any perceived problems are critical aspects of the consideration of ADF nutritional requirements.

7.1 Origins of Negative Energy Balance

When fed freshly-cooked food, adult humans have a remarkable capacity to unconsciously balance energy intake with energy expenditure over the long term; for example, many people maintain the same body weight throughout much of their adult life.

Even when imbalances occur, the daily excess (or deficit) in energy intake is usually minuscule when expressed as a percentage of the normal daily requirement. For example, an increase in body weight (as adipose tissue) of 1 kg over a period of one year implies an excess of intake over expenditure of about 0.1 MJ per day. This means that even during this period of weight gain, the balance between energy output and intake has been better than 99% in a sedentary adult male with typical daily energy expenditure of ~12 MJ.

However, when fed individual CRP, most service people discard a significant percentage of the food provided. Forbes-Ewan *et al.* (1988) found that 26% of the food energy provided by the Combat Ration One Man (CR1M) was discarded by soldiers who were going into the field for three days of hard physical work (jungle warfare training). Even when given the opportunity to select their CRP from a wide range of food choices, Airfield Defence Guards discarded 40% of the food energy available (Booth, Coad, Forbes-Ewan, Thomson, Niro, 2003).

The American experience is similar. For example, the Institute of Medicine (IOM, 2006: p. 1) stated that 'soldiers usually burn about 4,500 kcal (~18.8 MJ)/day, but consume only about 2,400 kcal (~10 MJ)/day during combat …'

7.2 Effects of Negative Energy Balance on Military Fitness

Studies have been conducted both in Australia (Booth, Coad, Roberts, 2003) and overseas (for a review, see Forbes-Ewan and Waters, 2000) to determine the effects on military performance of up to 30 days of moderately severe negative energy balance, resulting from under-consumption while being rationed with CRP. Booth, Coad, Forbes-Ewan, Thomson, Niro (2003) concluded that twelve days of feeding with CRP led to 'significant weight loss, suppressed immune function, loss of somatic protein, increased fatigue, loss of vigour, and increased feelings of confusion.'

Similarly, Moore *et al.* (1992), Kramer *et al.* (1997) and Nindl *et al.* (2007) reported extremely deleterious effects on the immunocompetence of US soldiers attempting the very arduous, 8-week Ranger (SF) selection course, in the presence of a daily energy deficit of about 5 MJ. For example, Nindl *et al.* (2007) observed physical performance decreases of 16% for vertical jump, 21% in explosive power output and 20% in maximal lifting strength accompanying a 13% loss of total body mass (consisting of 50% reduction in fat mass and 6% in fat-free mass).

Crowdy *et al.* (1969) fed British soldiers on a ration containing 7.93 MJ (leading to 7.85 MJ intake) for fourteen days, and compared them to a matched group given 15.3 MJ (mean intake was 14.5 MJ). The group fed the lighter ration experienced an overall energy deficit 92 to 96 MJ greater than that of the control group. There was no independent estimate made of energy expenditure or absolute energy deficit. Over the period of the experiment the experimental group lost an average of 2.2 kg of body weight, and the control group lost 1.3 kg. There was a noticeable reluctance of the low-energy group to exert themselves, but there was no measurable difference between the groups in maximal oxygen uptake ($\dot{V}O_{2max}$) as measured by a step test, and overall military efficiency, which included a timed mountain run.

Consolazio *et al*. (1979) assigned participants undertaking a field exercise to one of four diets—2.5 MJ/d (40 g protein, 110 g carbohydrate), 4.2 MJ/d (40 g protein, 210 g carbohydrate), 6.3 MJ/d (60 g protein, 315 g carbohydrate) or 14.6 MJ/d (110 g protein, 430 g carbohydrate). In each case, daily energy intake was greater than 90% of food availability, and was 5.7 MJ in the group that had access to 6.3 MJ. Daily energy expenditure was estimated to be 15 MJ. After 10 days, the three low-energy groups were found to be in negative nitrogen balance and there was evidence of ketosis. Mean $\dot{V}O_{2max}$ was 11% lower in the group that received 2.5 MJ/day, but did not drop in the other groups. While there were no statistically significant differences between dietary groups in the time to complete a 15-mile (24-km) march, there was a trend toward decreased time as food intake increased (i.e. performance may have been better with each increment in food intake). The investigators concluded that while energy intake of 5.7 MJ was insufficient to maintain nitrogen balance, it did prevent loss of physiological work performance in men during up to ten days of moderately vigorous work (typical field exercise). Note that an EI of 5.7 MJ/day combined with an EE of 15 MJ/day leads to an energy deficit of approximately 93 MJ after 10 days. That is, physiological work performance was not adversely affected by 93 MJ of total accumulated negative energy balance.

A loss of 5% of body weight has been shown to have no detectable effect on physical performance when the rate of weight loss was rapid (over a period of 5 days) or gradual (3 weeks) (Fogelholm *et al.,* 1993). Body fat mass has an energy value of approximately 30 MJ/kg (Westerterp *et al*., 1995). For a 75-kg man, a loss of 5% of body weight is approximately equivalent to an accumulated total energy deficit of ~112 MJ, assuming the body mass was lost entirely as body fat mass. In reality, some of the loss will be in the form of lean body mass, which has a lower energy value. Therefore, the results of Fogelholm *et al*. (1993) can be interpreted as implying that an energy deficit of ~100 MJ is unlikely to be associated with detrimental effects on physical performance.

However, loss of body mass is only one variable that is likely to affect physical performance. The nutritional quality of the diet is another factor that may have a powerful influence on physical performance during a period of negative energy balance. Guezennec *et al.* (1994) investigated the effects of three levels of energy intake on physical performance following 5 days of extremely vigorous field activity combined with relative sleep deprivation (French Army commando training). Energy expenditure was estimated to be greater than 21 MJ per day, while food availability was either 7.6, 13.4 or 17.6 MJ/day. Troops who received only 7.6 MJ/day 'exhibited a 14% decrease in power output at exhaustion in an incremental test and a significant decrease in $\dot{V}O_{2max}$ of 8%...' The intermediate (13.4 MJ) and high (17.6 MJ) intake groups 'demonstrated the same mechanical and metabolic performances on days 1 and 5.'

Guezennec *et al.* (1994) pointed out that lower energy availability also meant lower carbohydrate availability. The 7.6 MJ group received only 220 g of carbohydrate per day, contrasting with the 460 g and 660 g of carbohydrate available to the intermediate and high intake groups respectively. They concluded that 'progressive glycogen depletion' may have caused the impaired performance in the 7.6 MJ group.

Another factor (among many) that will affect physical and cognitive performance during a period of vigorous physical work combined with negative energy balance is the quantity and quality of sleep. For example, Rognum *et al.* (1986) found that providing adequate food to match energy expenditure did not lead to improved performance compared to providing grossly inadequate food during 107 hours of sustained hard work with less than two hours sleep. After four days, both groups 'were judged to be ineffective as soldiers'.

Forbes-Ewan and Waters (2000) and Booth *et al.* (2003) concluded that the provision of adequate carbohydrate is likely to be of primary importance in minimising decrements to military performance while ADF members are rationed with CRP. Unfortunately, the evidence from field studies (e.g. Thomas *et al.*, 1995; Booth *et al.* (2003) suggests that carbohydrate is the nutrient at greatest risk of being discarded. The implications of these findings for military physical and cognitive performance during sustained, moderately-arduous operations where CRP are the sole or predominant source of rations are not well understood, and are in need of further study.

Recommendation 54: *Further research should be conducted into the origins and implications of the under-consumption that results from feeding with CRP.*

7.3 Maximum Energy Deficit without Detriment

In the previous section, results were presented suggesting that total accumulated energy deficits of ~77 MJ (Askew *et al.*, 1987b), ~94 MJ (Crowdy, 1969) and ~93 MJ (Consolazio *et al.*, 1979) were associated with no decrements, or only relatively minor decrements in performance when carbohydrate intake was adequate.

On the basis of these results and the discussion in the previous sub-section, it is probably safe to say that an energy deficit of 100 MJ (corresponding to ~5% loss of body weight) can be tolerated by fit, motivated, male troops, provided that the deficit is accumulated gradually (i.e. not as a result of starvation or extreme levels of physical work output) and that the rations provide adequate carbohydrate to allow muscle glycogen levels to be maintained. This is consistent with the conclusion of Montain and Young (2003) that:

> … physical performance is preserved during several days of underfeeding provided sufficient carbohydrate and minerals are consumed to minimize the diuresis associated with semi-starvation diets and serial intake of carbohydrate is available to support metabolism during prolonged work.

It should also be noted that this conclusion assumes that the troops are well-nourished before the period of negative energy balance commences. Troops whose body energy reserves are significantly less than average will be affected by a period of negative energy balance sooner than those who have average or slightly above average energy reserves.

Recommendation 55: *Until further information becomes available, during normal field operations in peace time, an estimated total accumulated negative energy balance of ~100 MJ (corresponding to approximately 5% of body weight loss) should be adopted as the maximum allowable deficit before an ADF member is withdrawn from the field, and a period of recovery feeding occurs.*

7.4 Implications of Negative Energy Balance for CRP Rationing

Given that CRP feeding leads almost inevitably to negative energy balance, and that discard rates can lead to gross under-consumption of the available food, SUPMAN 4 (Department of Defence, undated b.) specifies that CRP may not be used as the sole source of rationing for more than 16 consecutive days in peace time. This recommendation is based on the following knowledge/assumptions:

(i) A total accumulated deficit of ~100 MJ can be tolerated with no substantial detriment to performance (see discussion immediately above);

(ii) Daily energy expenditure is ~15–16 MJ on typical field exercises where rationing is by CRP (Table 1);

(iii) Average energy availability from CR1M and PR1M is ~15–16 MJ (DSTO-Scottsdale in-house results);

(iv) It is assumed that ~40% of the available food energy is discarded.

Under this scenario, most ADF members can expect to have reached a total accumulated energy deficit of ~100 MJ by about day 16.

Recommendation 56: *Until further information becomes available, a maximum period of 16 days feeding with CRP during peace-time should be recommended for standard operations.*

7.5 Recovery from Negative Energy Balance

Recovery from an energy deficit can evidently be achieved very rapidly. Crowdy (1969) found that the mean energy intake exceeded 26 MJ per man per day over the first four days for the low energy group during the *ad libitum* feeding stage at the completion of his study, and exceeded 30 MJ on the second day. By the fourth day of recovery feeding, the difference in daily intake between the low and high energy groups had dropped to less then 0.7 MJ, although both groups were still consuming 7 MJ more per day than in the stabilisation period before the controlled feeding stage.

These rates of recovery feeding are exceptionally high and are not necessarily optimal. The time allowed to completely restore body energy reserves following a period of sustained and debilitating negative energy balance will have to take into account the operational situation (i.e. the urgency of getting troops back into the field). It may be appropriate to aim for a recovery period equal to about half the period of negative energy balance. If, for example, a unit had experienced a total negative energy balance estimated at ~60 MJ over a period of fourteen days, an appropriate recovery feeding regime may involve daily intakes of energy 8-9 MJ in excess of expenditure for seven days.

The conclusions and assumptions in this section should be viewed somewhat circumspectly—the military scientific literature on this subject is not comprehensive. It is recommended that further studies be conducted on the effects of prolonged energy deficit on military physical and cognitive performance, particularly in the context of rationing with CRP. Two aspects of this need to be addressed—operational scenarios involving relatively low-moderate daily negative energy balance, and those involving high daily negative energy balance (i.e. extremes of physical work output). It is also recommended that studies be conducted on the most effective and efficient means of ensuring that recovery from energy deficit has taken place before troops re-engage in operations.

Recommendation 57: *Research should be conducted on the most appropriate strategy to achieve recovery from severe energy deficit.*

Until these studies have been conducted, it is considered prudent to attempt to limit the rate at which recovery is attained to a maximum of ~8 MJ per day. That is, the tentative recommendation is that the excess of intake over expenditure during the recovery period should be no more than ~8 MJ per day.

Recommendation 58: *Until more information is available, the excess of energy availability over energy expenditure during recovery feeding should be restricted to no more than approximately 8 MJ per day.*

The major requirement during this time (and during the period of negative energy balance) will be for foods that provide the necessary carbohydrate to replenish muscle and liver glycogen, essential vitamins and minerals and adequate protein—i.e. a balanced diet derived from cereal foods such as bread, rice, pasta, breakfast cereals (preferably whole grain), vegetables (including legumes) and fruits, low- or reduced fat milk and milk products, and lean meat/fish. Additional easily-digested carbohydrates in the form of high energy drinks and snacks may also be necessary during this period to help ensure that the diet contains sufficient energy without excessive bulk. During this recovery feeding the energy intake will approximate that of ADF *Category 5* energy expenditure. However, it should be noted that if there has been a substantial period of under-consumption, and troops have experienced substantial weight loss, recovery feeding should commence relatively slowly and build up over several days. This is to avoid the possible onset of 'refeeding syndrome', a condition that leads to metabolic disturbances resulting from reinstitution of feeding at normal (or above normal) rates in people who are severely malnourished. It is recommended that under such circumstances, the advice of the unit Medical Officer should be sought before troops are assigned *Category 5* entitlements.

Recommendation 59: *If troops have been exposed to a prolonged period of severe under-consumption, medical advice should be sought to ensure that recovery feeding does not lead to 'refeeding syndrome'.*

8. Conclusions

Australia should not rely entirely on results obtained by overseas defence researchers on the nutritional requirements associated with military training and operations. Determination of nutritional requirements of ADF members should be based largely on studies conducted on ADF units engaged in ADF training and operations.

For the foreseeable future, the ADF will need rationing systems that promote self-reliance, a high level of mobility, an ability to operate in all terrains, climates, and in all social conditions (e.g. during humanitarian operations in developing nations).

There is a case for extending the monitoring program of levels of overweight and obesity in the ADF. The addition of one simple measurement—waist circumference—to the suite of analyses routinely conducted for the Annual Health Assessment and Comprehensive Preventive Health Examination would allow annual monitoring of trends in the risk of type 2 diabetes and coronary heart disease among ADF members.

Physical activity levels and gender are the two major determinants of nutritional requirements of ADF members, with age, stature, climate, altitude, and individual variation playing relatively minor roles. Each of these determinants exerts its effects predominantly via an influence on energy expenditure. Females have approximately 70–75% of the energy requirement that males have for the same activity. The only substantial purely gender-related difference in nutritional requirements is a greater need for iron by female ADF members.

However, the unique requirements of adolescent ADF members should be taken into account in messes where adolescents constitute a substantial proportion of the ADF population being rationed. Adolescent ADF members have slightly greater need than adults for energy for growth and generally also for physical activity. Adolescents also have a significantly greater need than adults of the same gender for some micronutrients, particularly calcium (adolescent males and females), phosphorus (males and females) and iron (males only).

There is scope to resume the development of computer-based expert systems for use by commanders to determine rationing options and hydration requirements for specific missions.

The range of ADF training and operational physical activity levels can be divided into five categories for adult males, and four categories for adult females and adolescents, based on the demonstrated energy expenditures associated with those activities (Tables 1 and 2). However, for most practical purposes the first four categories are adequate to define the nutritional requirements associated with ADF training and operations.

The results of field studies of food intake and energy expenditure, combined with published Nutrient Reference Values for macronutrients and micronutrients for the general population can be used to determine Military Recommended Dietary Intakes (MRDIs) for all ADF members (Tables 5–8), with some military-specific MRDIs being adopted that differ from the Nutrient Reference Values, as detailed in the body of this report. It is also concluded that it is appropriate to define MRDIs for carbohydrate and protein that differ substantially from the Recommended Dietary Intakes applicable to civilian Australians and New Zealanders.

The six 'physical activity levels' (PAL) within the published Nutrient Reference Values do not address all demonstrated ADF energy expenditure categories. There is need for one further PAL value (perhaps designated 'extreme activity') to cover the full range of ADF physical work levels.

The quantity (and possibly quality—e.g. glycaemic index, resistant starch level) of carbohydrate is the most important nutritional consideration for physically active people, including ADF members training or operating above a moderate level of activity (*Category 3* and above). As energy expenditure increases, so too should the percentage of energy derived from carbohydrate (at the expense of fat, with the percentage of energy derived from protein also decreasing in relative terms, but increasing slightly in absolute terms to about 2.0 g/kg body weight per day).

The value of combining carbohydrate with protein as a supplement to enhance recovery from vigorous activity deserves further investigation.

The nutritional requirements of female ADF members are not well understood and are worthy of more research.

Based on demonstrated energy expenditures on typical field exercises, it is considered appropriate to set the criterion for energy at 16 MJ for general-purpose (i.e. not mission-specific) combat ration packs, with the nutritional criteria based on the MRDIs of ADF members working at *Category 3*. For each nutrient the 'worst case' requirement should apply, so that the nutritional requirements of practically all ADF members working at *Category 3* are met if the ration pack is eaten in its entirety.

The storage stability of vitamins in ration packs is not well understood and needs further investigation. Until more is known about the effects of storage conditions on vitamin levels, fortification is recommended for key vitamins to approximately three times the MRDI.

The bioavailability of micronutrients will also impact on nutritional status of ADF members fed with CRP. Investigation is needed into the bioavailability of key micronutrients in ration pack foods.

There is a case for developing 'mission-specific' ration packs. Each pack would be designed to support operations in a particular climate (e.g. hot versus cold), or of a particular nature (e.g. short term, high intensity versus sustained, relatively low intensity).

The adoption of a modular, just-in-time process for procuring, packing and distributing ration packs may play a major role in allowing mission-specific ration packs to be provided as they are needed.

It is concluded that a new approach is needed for determining food entitlements when rationing troops with freshly-cooked food. The recommended approach is to determine food entitlements according to the number of ADF members to be fed (as occurs now), but also taking into account physical activity (normally *Categories 1–4*, but in a limited number of specific situations also *Category 5*). All ADF personnel would be provided with fresh food at the *Category 1* level for energy (and *Category 4* level for nutrients other than energy) at meal times. Additional fresh food should be provided for those working at higher categories in the form of modules of food to be consumed at morning tea, afternoon tea and supper. Entitlements should also take into account likely unavoidable food discarding (assumed to be about 15% of total food availability).

In determining the nutritional adequacy of diets of ADF groups it is appropriate to use EARs/MEARs (or Adequate Intakes if an EAR has not been established) and *not* MRDIs as the criteria for adequate intake of most nutrients. Exceptions include energy, protein, carbohydrate and sodium, for which the MRDIs are recommended as the criteria for adequate intake. In determining the adequacy of intake of an individual ADF member, the MRDIs are the appropriate criteria.

Under-consumption appears to be an inevitable consequence of feeding with CRP, leading to negative energy balance in the vast majority of ADF members.

A total accumulated loss of about 100 MJ of body energy may be supportable by previously well-nourished ADF members without significant detriment to military performance, provided that this loss occurs relatively slowly (i.e. over a period of weeks rather than days). When this situation is reached, it may be appropriate to withdraw the ADF member from the field (if the operational situation allows) for a period of 'recovery' feeding with fresh rations.

It is concluded that previously well-nourished troops should experience little or no decrement in performance for at least 16 days on typical operations if fed solely with CRP. Following an extended period of CRP feeding, recovery feeding will be required with fresh food. The most effective means of achieving recovery may be to feed for a number of days equal to half the period where feeding was by CRP (provided that the operational situation allows this).

During the recovery feeding phase, a daily intake of ~8 MJ in excess of expenditure is likely to effectively restore adequate nutritional status with no harmful side-effects. This implies that the appropriate level of food availability during the recovery period may approach the recommended food entitlements of adult males working at *Category 5* activity level.

9. Recommendations

It is recommended that:

1. The nutritional requirements of ADF members should be determined by conducting studies of food intake and energy expenditure on ADF members engaged in normal training and operations, and not by relying entirely on overseas results.

2. The specific nutritional requirements of adolescents should be taken into account when determining food entitlements of ADF members in messes where adolescents constitute a substantial proportion of the ADF population being rationed.

3. The nutritional standards for ration scales should be based on mean nutritional requirements of ADF members (with appropriate allowance for unavoidable food discarding).

4. The nutritional standards for ration packs should be based on mean nutritional requirements of ADF members for energy, but should provide sufficient micronutrients to meet the requirements of practically all ADF members.

5. Measurement of waist circumference should be added to the Annual Health Assessment and Comprehensive Preventive Health Examination to allow calculation of ADF members' risk of cardiovascular disease.

6. Determination of the nutritional requirement for sodium should be based on the 'worst case' situation—i.e. likely need for heat acclimatisation—and not on the Adequate Intake defined for civilians.

7. For troops who are engaged in vigorous training or operations in very cold climates, water availability for drinking should be at least three litres per person per day.

8. Further research should be conducted into the nutritional status of ADF members, and on how participation in training and operations impacts on nutritional status.

9. Develop and implement a nutrition promotion program, starting with recruits, but extending to all ADF groups in the long term.

10. Complete the determination of the nutritional requirements of the full spectrum of ADF occupations, and repeat this process regularly at intervals of no more than ten years.

11. Resume development of the Ration Adviser Expert Program (REAP™); this might best be achieved through a multi-national approach, e.g. as part of KCA 3 within TTCP-HUM-TP14.

12. The categorisation of ADF nutritional requirements should separately address the needs of four groups—adult males, adult females, adolescent males, and adolescent females.

13. The energy expenditure associated with Special Forces training and Special Forces operations should be investigated.

14. For the purposes of defining nutritional needs of nearly all ADF members, military occupations should be assigned to one of four categories (applicable to each of the ADF population subgroups male adults, female adults, male adolescents and female adolescents).

15. DSTO should attempt to collaborate with the National Health and Medical Research Council to introduce a further level of physical activity ('extreme activity', with a PAL of ~2.4) to the six existing NHMRC level.

16. The nutritional standard for protein should be set at 15–20% of energy intake for ADF members engaged in *Category 1* physical activity.

17. As energy expenditure increases across five designated categories of energy expenditure, the percentage contribution of protein to total energy intake should decrease linearly from 15–20% of energy (*Category 1*) to 11–16% of energy (*Category 5*).

18. The contribution of carbohydrate to energy availability should increase from 50–55% to 58–63% as energy expenditure increases across five designated categories of physical activity.

19. For operations at high altitude (above 3000 m) protein, fat and carbohydrate should contribute to total energy availability approximately in the ratio 15:20:65.

20. Investigate the effect of GI on military performance in the presence of chronic under-consumption of total energy and carbohydrate.

21. Investigate the potential for conducting collaborative research with the Australian Institute of Sport on the value of combining carbohydrate and protein as a recovery beverage.

22. A minimum of 30 g per day should be adopted as the criterion for adequacy of dietary fibre intake of male ADF members, and 25 g for female ADF members eating freshly-cooked food in static messes or in the field.

23. Research should be conducted into the effects of resistant starch on intestinal health of ADF members engaged in field exercises or training where a high level of diarrhoea or other gut disturbances commonly occur.

24. The appropriate 2006 Nutrient Reference Values (Recommended Dietary Intake where one exists, otherwise the Adequate Intake) of the National Health and Medical Research Council should be adopted as the Military Recommended Dietary Intakes (MRDIs) for all nutrients other than thiamin, riboflavin, niacin, vitamin B6, protein, sodium, and total energy.

25. The Upper Limits and Suggested Dietary Targets of the National Health and Medical Research Council should be adopted for use with ADF rationing, with the exception of those for sodium.

26. Rather than adopt the Nutrient Reference Values recommended by the National Health and Medical Research Council, the MRDIs for thiamin, riboflavin and niacin should continue to increase linearly with energy expenditure.

27. The MRDI for vitamin B6 should continue to be calculated as 0.02 mg of vitamin B6 per gram of protein (using the minimum value of the range that constitutes the MRDI for protein) within each energy expenditure category.

28. The MRDIs for protein should be expressed as the gram equivalents of the recommended ranges of adequate intakes shown in Recommendation 16 and Recommendation 17, for each of the ADF work level categories, also taking into account age (adult or adolescent) and gender.

29. The MRDI for sodium should be set as a range of 920–2300 mg for Category 1 work level, with an increase of approximately 10% in the upper end of the range for each increase in work category.

30. A Military Upper Level for sodium should be set at 3200 mg under normal circumstances, or 4600 mg where unacclimatised troops must engage in arduous physical activity in hot environments.

31. The categories of energy expenditure of ADF groups defined in this report (ADF energy expenditure categories 1–5 for male adults, categories 1–4 for female adults, male adolescents and female adolescents) should be adopted as the basis for determining standards for total energy for ADF rationing.

32. The MRDIs for carbohydrate should be expressed as the gram equivalents of the recommended ranges of adequate intakes shown in Recommendation 17 for each of the ADF work level categories, also taking into account age (adult or adolescent) and gender.

33. ADF rationing systems should provide no more than ten percent of total energy as saturated fat plus *trans* fat.

34. Further studies should be conducted to determine the specific nutritional requirements of female ADF members.

35. The nutritional standard for energy for general purpose (i.e. not mission-specific) combat ration packs (CRP) should be 16 MJ, and the standards for all other nutrients should be the MRDIs that apply to the population sub-group with the greatest estimated requirements at Category 3 activity level.

36. Research should be conducted into the minimum level and most appropriate form (or forms) of dietary fibre (including resistant starch) for inclusion in CRP, and the potential for probiotics to optimise bowel health when rationing is by CRP.

37. Analysis should be conducted to determine dietary fibre and resistant starch content of ADF CRP, which should provide a minimum of 24 g of dietary fibre per person per day.

38. Further investigation should be conducted into the storage stability of vitamins in CRP, perhaps through a multi-national approach, e.g. as part of KCA 3 within TTCP-HUM-TP14.

39. Until more information is available on storage stability of vitamins in CRP generally, fortification with thiamin, vitamin C, riboflavin and vitamin B6 should occur so that ADF CRP contain three times the MRDI for each of these vitamins at the time of packing, and a wide variety of items should be fortified.

40. A program of research should be developed and implemented to determine the bioavailability of a wide range of micronutrients from CRP, and the implications of the findings for ADF nutritional status should be investigated.

41. CRP should be developed for a restricted range of mission- or climate-specific situations, with specific nutritional criteria determined for each situation.

42. Consideration should be given to adoption of a modular, just-in-time system of ration procurement, packing and distribution.

43. Investigate the most appropriate configuration of a group-feeding ration pack, and the suitability of alternative approaches to feeding groups of ADF members.

44. The Final Report of NATO HFM RTG 154 should be used as a basis for determining the appropriateness of the nutritional standards pertaining to ADF CRP.

45. The criterion for adequacy of energy of a general fresh-feeding ration scale should be set at the MRDI for energy for adolescent males for each category (1–4) of physical activity.

46. For ADF members working at *Category 5*, or undergoing re-feeding following an extended period of vigorous physical work while rationed solely with combat ration packs, the criteria should be the MRDI for energy for adult males working at *Category 5*.

47. The criteria for adequacy of availability of protein and carbohydrate for a fresh-feeding scale that applies in messes rationing a mixed population of ADF members working at categories 1–4 should be the MRDIs applicable to adolescent males working at categories 1–4.

48. For ADF members working at *Category 5*, or undergoing re-feeding following an extended period of vigorous physical work while rationed solely with combat ration packs, the criteria should be the acceptable ranges for adult males working at *Category 5*.

49. The criteria for adequacy of availability of each micronutrient for a fresh-feeding scale that applies in messes rationing a mixed population of ADF members working at categories 1–4 should be the MRDI that applies to the ADF population sub-group with the greatest requirement for that micronutrient while working at *Category 4*.

50. The criterion for sodium in the basic fresh-feeding scale should be the MRDI for *Category 4* physical workload (920–3000 mg), with a long-term goal of reducing sodium availability to the Suggested Dietary Target of 1600 mg.

51. The nutritional entitlements to fresh field feeding in the form of 'hot-boxed' meals should, as a minimum, be based on the MRDIs of adolescent males working at *Category 3*.

52. When investigating the nutritional adequacy of dietary intake of groups of ADF members, the relevant MEARs should be used as the criteria.

53. When investigating the nutritional adequacy of dietary intake for an individual ADF member, the MRDIs should apply, taking into account age and gender, in addition to category of energy expenditure.

54. Further research should be conducted into the origins and implications of the under-consumption that results from feeding with CRP.

55. Until further information becomes available, during normal field operations in peace time, an estimated total accumulated negative energy balance of ~100 MJ (corresponding to approximately 5% of body weight loss) should be adopted as the maximum allowable deficit before an ADF member is withdrawn from the field, and a period of recovery feeding occurs.

56. Until further information becomes available, a maximum period of 16 days feeding with CRP during peace-time should be recommended for standard operations.

57. Research should be conducted on the most appropriate strategy to achieve recovery from severe energy deficit.

58. Until more information is available, the excess of food availability over energy expenditure during recovery feeding should be restricted to no more than approximately 8 MJ per day.

59. If troops have been exposed to a prolonged period of severe under-consumption, medical advice should be sought to ensure that recovery feeding does not lead to 'refeeding syndrome'.

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11. References

AIS (undated). Antioxidant Vitamins C and E. URL: http://www.ausport.gov.au/ais/nutrition/supplements/resources/supplement_fact_sheets/antioxidant_vitamins_c_and_e. (Site accessed on 20 May, 2008.)

Alberg, A. (2002). The influence of cigarette smoking on circulating concentrations of antioxidant micronutrients. *Toxicology* 180(2): 121–37.

Alemany, J.A., Nindl, B.C., Kellogg, M.D., Tharion, W.J., Young, A.J., Montain, S.J. (2008). Effects of dietary protein content on IGF-1, testosterone and body composition during 8 days of severe energy deficit and arduous physical activity. *Journal of Applied Physiology* 105: 58–64.

ABS (1998). *National Nutrition Survey: Nutrient Intakes and Physical Measurements*, *Australia, 1995*. Australian Bureau of Statistics.

Amos, D., Cotter, J.D, Lau,W-M., Forbes-Ewan, C.H. (1998). *A Methodology for Measuring the Physiological Strain of Enhanced Soldiers: The 1998 Soldier Combat System Enhancement Study*. DSTO-TR-0747. Defence Science and Technology Organisation.

Armstrong, L.E., Hubbard, R.W., Askew, E.W., Francesconi, R.P. (1993). Responses of Soldiers to 4-gram and 8-gram Diets During 10 Days of Heat Acclimation. In: *Nutritional Needs in Hot Environment,* Marriott, B.M. Editor. Chapter 12, pp. 247–258. National Academy Press, Washington, D.C.

Armstrong, L.E., Casa, D.J., Maresh, C.M., Ganio, M.S. (2007). Caffeine, Fluid-Electrolyte Balance, Temperature Regulation, and Exercise-Heat Tolerance. *Exercise and Sport Sciences Reviews* 35(3): 135–140.

Askew, E.W., Claybaugh, J.R., Hashiro, G.M., Sato, A., Cucinell, S.A. (1987a). *Mauna Kea III: Metabolic effects of dietary supplementation during exercise at 4,100 m altitude*. U.S. Army Research Institute of Environmental Medicine, Natick, Mass. *Technical Report T12-87.*

Askew, E.W., Munro, L., Sharp, M.A., Popper, R., Ross, W., Hoyt, R.W., Martin, J.W., Reynolds, K., Lieberman, H.R., Engall, D., Shaw, C.P. (1987b). *Nutritional Status and Physical and Mental Performance of Special Operations Soldiers Consuming the Ration, Lightweight or the Meal, Ready-to-Eat Military Field Rations during a 30-Day Field Training Exercise.* Report *T7-87* United States Army Research Institute of Environmental Medicine, Natick, Mass.

Askew, E.W. (1989). Nutrition for a Cold Environment. *The Physician and Sports Medicine* 17 (12): 77–89.

Astrand, P.-O., Rodahl, K. (1986). *Textbook of Work Physiology, 3rd Edition*. McGraw-Hill, Sydney.

Baker-Fulco, C.J., Patton, B.D., Montain, S.J., Liebermann, H.R. (2001). *Nutrition for Health and Performance: Nutritional Guidance for Military Operations in Temperate and Extreme Environments*. USARIEM Technical Report TN-01/4. US Army Research Institute of Environmental Medicine.

Beard, T.C., Woodward, D.R., Ball, P., Hornsby, H., von Witt, R.J., Dwyer, T. (1997). The Hobart salt study 1995: few meet national sodium intake data. *Medical Journal of Australia* 166: 404–407.

Better Health Commission (1986). *Looking Forward to Better Health Volume 2*. Better Health Commission. AGPS, Canberra.

Booth C.K., Clark T., Fenn A. (1998). Folic acid, riboflavin, thiamin, and vitamin B-6 status of a group of first-time blood donors. *American Journal of Clinical Nutrition* 68 (5): 1075–1080.

Booth, C., Carins, J. (2006). Nutritional determinants of bone health: Implications for the Australian Defence Force. *Australian Military Medicine* 15(1): 9–14.

Booth, C.K., Coad, R.A. (2002). The 1998 Army recruit health and diet survey. *Australian Military Medicine* 11(2): 63–70.

Booth, C.K., Coad, R.A., Forbes-Ewan, C.H., Thomson, G.F., Niro, P.J. (2003). The physiological and psychological effects of combat ration feeding during a 12-day training exercise in the tropics. *Military Medicine* 168: 63–70.

Booth, C., Coad, R., Roberts, W. (2003) Evaluation of an Australian combat ration pack as a sole nutrition source during a 23-day military exercise in the tropics. *Nutrition and Dietetics* 60(4): 239–247.

Brotherhood, J.R. (1973). Studies on energy expenditure in the Antarctic. In Edholm, O.G., Gunderson, E.K.E. (eds): *Polar Human Biology*. London, Heinemann Medical, pp. 182–192.

Burke, L.M., Claassen, A., Hawley, J.A., Noakes, T.D. (1998). No effect of glycemic index of pre-exercise meals with carbohydrate intake during exercise. *Medicine and Science in Sports and Exercise* 30: S82 (Abstract 471).

Burke, L. M. (2001). Nutritional needs for exercise in the heat. *Comparative Biochemistry, Physiology and Molecular Integrative Physiology* 128: 735–748.

Burke, L., Deakin, V. (2006). *Clinical Sports Nutrition*, Third Edition. McGraw-Hill Australia Pty Ltd.

Burke, L., Bell, L., Cort, M., Cox, G., Farthing, L., Greenaway, B., Minehan, M., Petrunoff, N., Wood, C. (2008). *Current Concepts in Sports Nutrition*. Australian Institute of Sport. Australian Sports Commission. Public access URL: http://www.ausport.gov.au/ais/nutrition/publications/current_concepts. (Site accessed 27 May, 2008)

Burstein, R., Coward, A.W., Askew, E.W., Carmel, K., Irving, C., Shpilberg, O., Moran, D., Pikarsky, A., Ginot, G., Sawyer, M., Golan, R., Epstein, Y. (1996). Energy expenditure variations in soldiers performing military activities under cold and hot climate conditions. *Military Medicine* 161 (12): 750–754.

Carins, J., Booth, C., Coad, R. (2005). *Low Dose Ferrous Gluconate Supplement Fails to Alter the Iron Status of Female Officers-in-Training*. DSTO-RR-0297. CBRN Defence Centre, Defence Science and Technology Organisation

Carins, J.E., Forbes-Ewan, C.H., Kullen, C.J. (2007). *Nutrition for military personnel operating in hot environments*. DSTO-CR-2007-0314. Defence Science and Technology Organisation.

Chen, Y.J., Heung-Sang Wong, S., Wong, C.K., Lam, C.W., Huang, Y.J., Ming-Fai Siu, P. (2008). The effect of a pre-exercise carbohydrate meal on immune responses to an endurance performance run. *British Journal of Nutrition* 9: 1–9.

Coad, R.A. (2001). *Potential High Carbohydrate Food Items for Combat Ration Packs.* Internal Report. Defence Nutrition Research Centre, Combatant Protection and Nutrition Branch, Aeronautical and Maritime Research Laboratory.

Consolazio, C. F., Johnson, H. L., Nelson, R. A., Dowdy, R., Krzywicki, H. J., Daws, T. A., Lowry, L. K., Waring, P. P., Calhoun, W. K., Schwenneker, B. W., Canham, J. E (1979). *The relationship of diet to the performance of the combat soldier. Minimal calorie intake during combat patrols in a hot humid environment.* LAIR Report 76. Presidio of San Francisco, CA, Letterman Army Institute of Research.

Coyle, E.F. (1995). Substrate utilization during exercise in active people. *American Journal of Clinical Nutrition* 61(suppl.): 968S-979S.

Crowdy, J.P. (1969). Low Calorie Diets and Military Efficiency. *Proceedings of the Commonwealth Defence Science Organisation Food Study Group Meeting, Australia*, CDSO-FSG, Paper No. FSG/P(69): 1.

Demzcuk, V. (2001). Unpublished results, Land Operations Division, DSTO-Elizabeth, Defence Science and Technology Organisation. Department of Defence.

Denton, D. (1982). *The Hunger for Salt*. Springer-Verlag, Berlin, Heidelberg, New York.

Department of Defence (undated a). *SAFETYMAN, Chapter 25 of Volume 2, Part 3, Table 25C–1.* URL (Defence Intranet): http://defweb.cbr.defence.gov.au/home/documents/data/DEFPUBS/DEPTMAN/SAFETYMANV2/V2P3/25C.pdf. (Site accessed 3 June, 2008.)

Department of Defence (undated b). *Australian Defence Force Ration Scales and Scales of Issue (SUPMAN 4), Edition 5*. Army Material Management Agency, Support Command Australia (Army). Published by: Directorate of Publishing, Defence Centre, Canberra.

Department of Defence (1994). DI(G) PERS 32-1 *Employment of Women in the Australian Defence Force.* Amendment No 2. URL (Defence Intranet): http://intranet.defence.gov.au/home/documents/DATA/ADFPUBS/DIG/DIP32_1.PDF. (Site accessed 27 May, 2008.)

Department of Defence (2000a). *Defence Review 2000 – Our Future Defence Force*. A public discussion paper. Canberra: Defence Publishing Service DPS 38459/2000, June 2000).

Department of Defence (2000b). *The Australian Defence Force Health Status Report*. Defence Publications, Department of Defence, Canberra ACT 2600

Department of Defence (2002). *Defence Health Policy Directive No. 206, Amendment No. 4*, Director General Defence Health Service. URL (Defence Intranet: http://defweb.cbr.defence.gov.au/home/documents/DATA/ADFPUBS/HPD/HD206.PDF. (Site accessed 27 May, 2008.)

Department of Defence (2007). *Health Directive No. 242.* URL (Defence Intranet): http://defweb.cbr.defence.gov.au/home/documents/data/ADFPUBS/HPD/HD242.PDF. (Site accessed 20 May, 2008.)

Department of Defence (2009). *Defence White Paper. Defending Australia in the Asia-Pacific Century: Force 2030*. Department of Defence. URL (Defence Intranet): http://intranet.defence.gov.au/oscdfweb/sites/WhitePaper/docs/defence_white_paper_2009.pdf

Dlugos, D.J., Perrotta, P.L., Horn, W.G. (1995). Effects of the submarine environment on renal-stone risk factors and vitamin D metabolism. *Undersea Hyperbaric Medicine* 22: 145–152.

Durnin, J.V.G.A., McKay, F.C. and Webster, C.I. (1985). *A New Method of Assessing Fatness and Desirable Weight, for use in the Armed Forces*. Ministry of Defence, Whitehall, London, SW1A 2HB.

Earnest, C.P., Lancaster, S.L., Rasmussen, C.J., Kerksick, C.M., Lucia, A., Greenwood, M.C., Almada, A.L., Cowan, P.A., Kreider, R.B. (2004). Low vs. high glycemic index carbohydrate gel ingestion during simulated 64-km cycling time trial performance. *Journal of Strength and Conditioning Research* 18(3): 466-472.

Edwards, J.S.A., Roberts, D.E., Mutter, S.H. (1992). Rations for Use in a Cold Environment. *Journal of Wilderness Medicine* 3: 27–47.

Engell, D.B., Roberts, D.E., Askew, E.W., Rose, M.S., Buchbinder, J., Sharp, M.A. (1987). *Evaluation of the Ration, Cold Weather during a 10-day Cold Weather Field Training Exercise.* Technical Report Natick/TR-87/030. United States Army Natick Research, Development and Engineering Center, Natick, Massachusetts.

Erith, S., Williams, C., Stevenson, E., Chamberlain, S., Crews, P., Rushbury, I. (2006). The effect of high carbohydrate meals with different glycemic indices on recovery of performance during prolonged intermittent high-intensity shuttle running. *International Journal of Sport Nutrition and Exercise Metabolism* 16(4): 393–404.

FAO:WHO:UNU (2004). Food and Agricultural Organization: World Health Organization: United Nations University Expert consultation. *Report on human energy requirements.* FAO, Rome.

Febbraio, M.A., Keenan. J., Angus, D.J., Campbell, S.E., Garnham, A.P. (2000). Preexercise carbohydrate ingestion, glucose kinetics, and muscle glycogen use: effect of the glycemic index. *Journal of Applied Physiology* 89(5): 845-51.

Feeney, R.E. (1989). Food Technology and Polar Exploration. *Food Technology* 43: 70–82.

Flakoll, P.J., Judy, T., Flinn, K., Carr, C., Flinn, S. (2004). Postexercise protein supplementation improves health and muscle soreness during basic military training in Marine recruits. *Journal of Applied Physiology* 96: 951–956.

Fogelholm G.M., Koskinen, R., Laakso, J., Rankinen, T., Ruokenen, I. (1993). Gradual and rapid weight loss: effects on nutrition and performance in male athletes. *Medicine and Science in Sports and Exercise* 25: 371–377.

Forbes-Ewan, C.H. (1986). *Salt in Defence Feeding; a Literature Review.* Internal Report. Armed Forces Food Science Establishment, Defence Science and Technology Organisation.

Forbes-Ewan, C.H. (1988). *Interim Report on Food Intake and Energy Expenditure of Navy Recruits*. Annex A to a letter to Director General Supply-Navy, dated 15 Sep 88, MRL-Tasmania file reference 432/24/7. Defence Science and Technology Organisation.

Forbes-Ewan, C.H., Morrissey, B.L.L., Gregg, G.C., Waters, D.R. (1988). *Food Intake and Energy Expenditure of Soldiers Undergoing Jungle Warfare Training*. MRL-R-1130. Materials Research Laboratory, Defence Science and Technology Organisation.

Forbes-Ewan, C.H., Morrissey, B.L.L. (1989). *Interim Report on Food Intake and Energy Expenditure of Submariners*. Annex A to a Letter to DGSUP-N, dated 11 Aug 89, MRL-Tasmania file reference 432/24/7, Materials Research Laboratory, Defence Science and Technology Organisation.

Forbes-Ewan, C.H. (1990). *Interim Report on Energy Expenditure of Sailors in a Patrol Boat*. Annex A to a Letter sent to DLS-N, dated 15 May 90, MRL-Tasmania file reference 432/24/7. Materials Research Laboratory, Defence Science and Technology Organisation.

Forbes-Ewan, C.H., Morrissey, B.L.L., Waters, D.R., Gregg, G.C. (1990)*Food Intake and Energy Expenditure of Sailors at a Large Naval Base.* MRL-TR-90-11, Defence Science and Technology Organisation, Materials Research Laboratory, Defence Science and Technology Organisation.

Forbes-Ewan, C.H. (1991). Development of a nutritional basis for naval feeding. *Proceedings of the Nutrition Society of Australia* 16: 21.

Forbes-Ewan, C.H., Waters, D.R. (1991). *Food Intake and Energy Expenditure of Sedentary Soldiers*. Internal Report. Materials Research Laboratory, Defence Science and Technology Organisation.

Forbes-Ewan, C.H. (1993). *ADF Nutrient Requirements. A report on the nutrient requirements of ADF members engaged in base, operational and training activities*. Internal Report. Materials Research Laboratory, Defence Science and Technology Organisation.

Forbes-Ewan, C.H. (2001). *Acceptability and Service Suitability of the Combat Ration One Man during Operation Warden*. Internal Report. Defence Nutrition Research Centre, Defence Science and Technology Organisation.

Forbes-Ewan, C.H., Waters, D.R., Coad, R.A., Sawyer, M.B., Coward, W.A. (1995). Energy Expenditure of Special Forces Soldiers. *Proceedings of the Nutrition Society of Australia*, 19: 112.

Forbes-Ewan, C.H. (2000). *Revision of Combat Ration Packs*. Internal Report. Defence Nutrition Research Centre, Defence Science and Technology Organisation.

Forbes-Ewan, C.H. and Waters, D.R. (2000). *Final Report of TTCP-HUM-AG16.* Subtitle: *A review of the effects of long-term ration pack feeding*. Defence Nutrition Research Centre, Defence Science and Technology Organisation.

Forbes-Ewan, C.H. (2002a). *ADF Nutrient Requirements in the 21st Century.* Internal Report. DSTO-Scottsdale, CBRN Defence Centre Platform Sciences Laboratory, Defence Science and Technology Organisation.

Forbes-Ewan, C.H. (2002b). *Commanders Guide on Nutrition in Hot Environments*. Internal Report. Defence Nutrition Research Centre, Defence Science and Technology Organisation.

Forbes-Ewan, C.H. (2002c). *Commanders Guide on Nutrition in Cold Environments and at Altitude*. Internal Report. Defence Nutrition Research Centre, Defence Science and Technology Organisation.

Forbes-Ewan, C.H. (2005). *Carbohydrate combined with protein as an aid to physical performance: a short review*. DSTO-CR-2005-0155. Defence Science and Technology Organisation.

Forbes-Ewan, C., Probert, B., Coad, R. (2007). *Assessment of Adequacy of Rationing during Infantry Initial Employment Training*. DSTO-CR-2007-0237. Defence Science and Technology Organisation.

Friedl, K.E., Marchitelli, L.J., Sherman, D.E., Tulley, R. (1990). *Nutritional Assessment of Cadets at the US Military Academy: Part 1. Anthropometric and Biochemical Measures*. USARIEM Technical Report T4-91. United States Army Research Institute of Environmental Medicine, Natick, MA.

Gisolfi, C.V., Ryan, A.J. (1995). Gastrointestinal physiology during exercise. In: Sutton, J.R., Thompson, M.W., Torade, M.E. (1995). *Exercise and Thermoregulation: Proceedings of the 10th Biennial Conference*, Faculty of Health Science, The University of Sydney, Australia, pp. 143–174.

Guezennec, C.Y., Satabin, P., Legrand, H., Bigard, A.X. (1994). Physical performance and metabolic changes induced by prolonged exercise and difference energy intakes in humans. *European Journal of Applied Physiology* 68: 525–530.

Hawley, J.A., Burke, L.M. (1998). *Peak Performance: Training and Nutritional Strategies for Sport*. Sydney: Allen and Unwin.

Helge, J.W., Richter, E.A., Kiens, B. (1996). Interaction of training and diet on metabolism and endurance during exercise in man. *Journal of Physiology* 492: 293–306.

Hickson, J.F., Wolinsky, I. (1989). *Nutrition in Exercise and Sport*. CRC Press, Boca Raton.

Hoyt, R.W., Honig, A. (1996). Energy and macronutrient requirements for work at high altitudes. In: *Nutritional Needs in Cold Climates and High-Altitude Environments.* Pp. 379–391. National Academy Press. Washington DC.

Huntford, R. (1979). *Scott and Amundsen*. Published by Hodder and Stoughton: Sydney, pp. 522–523.

IOM (2006). *Nutrient Composition of Rations for Short-Term, High-Intensity Combat Operations. Committee on Military Nutrition Research. Food and Nutrition Board*. Institute of Medicine. The National Academies Press. Washington DC.

James, K.W., Thomson, G.F., Hancock, A.T., Walker, G.J., Coad, R.A., Lichon, M.J. (1993). *Laboratory Evaluation of Australian Ration Packs*. MRL Technical Report MRL-TR-92-30. Materials Research Laboratory, Defence Science and Technology Organisation.

Kiens, B, Helge, J.W. (2000). Adaptations to a high fat diet. In: *Nutrition in Sport*, edited by Maughan R.J. Oxford, UK: Blackwell Science, p. 192–202.

Klesges, R.C., Ward, K.D., Shelton, M.L., Applegate, W.B., Cantler, E.D., Palmieri, G.M., Harmon, K., Davis, J. (1996). Changes in bone mineral content in male athletes. Mechanisms of action and intervention effects. *Journal of the American Medical Association* 276: 226–230.

Kramer, T.R., Moore, R.J., Shippee, R.L., Friedl, K.E., Martinez-Lopez, L. Chan, M.M., Askew, E.W. (1997). Effects of food restriction in military training on T-lymphocyte responses. *International Journal of Sports Medicine* 18 (Supplement 1): S84–S90.

Kreider, R.B., Almada, A.L., Antonio, J., Broeder, C., Earnest, C., Greenwood, L., Greenwood, M., Incledon, T., Kalman, D.S., Kerksick, C., Kleiner, S.M., Leutholtz, B., Lowery, L.M., Mendel, R., Rasmussen, J., Stout, J.R., Weir, J.P., Willoughby, D.S., Ziegenfuss, T.N. (2003). Exercise and sport nutrition: A balanced perspective for exercise physiologists. *Professionalization of Exercise Physiology-online* 6(8). URL: http://faculty.css.edu/tboone2/asep/balancedPerspective.pdf

Kullen, C.J. (2009). *Food and Fluid in the Heat: Military Implications and Future Research Needs.* DSTO General Document (in publication). Defence Science and Technology Organisation.

Lambert, E.V., Goedecke, J.H., Van Zyl, C.G., Murphy, K., Hawley, J.A., Dennis, S.C., Noakes, T.D. (2001). High-fat versus habitual diet prior to carbohydrate loading: effects on exercise metabolism and cycling performance. *International Journal of Sport Nutrition and Exercise Metabolism* 11: 209–225.

Lauder, T.D., Williams, M.V., Campbell, C.S., Davis, G.D. and Sherman, R.A. (1999). Abnormal eating behaviours in military women. *Medicine and Science in Sports and Exercise* 31 (9): 1265–1271.

Lemon, P.W. (1996). Is increased dietary protein necessary or beneficial for individuals with a physically active lifestyle? *Nutrition Reviews* 54: S169–S175.

Lichon, M.J., James, K.W. (1991). *Exploding the myths about dietary fibre in operational ration packs*. Proceedings of the Commonwealth Defence Science Organisation Food Studies Group meeting, Auckland, New Zealand, 18–22 February, 1991.

Lieberman, H.R., Falco, C.M., Slade, S.S. (2002). Carbohydrate administration during a day of sustained aerobic activity improves vigilance, as assessed by a novel ambulatory monitoring device, and mood. *American Journal of Clinical Nutrition* 76: 120–127.

Lukaski, H.C. (2000) Magnesium, zinc, and chromium nutriture and physical activity. *American Journal of Clinical Nutrition* 72: 585S–593S.

Maresh, C.M., Gabaree-Boulant, C.L., Armstrong, L.E., Judelson, D.A., Hoffman, J.R., Castellani, J.W., Keneflick, R.W., Bergeron, M.F., Casa, D.J. (2004). Effect of hydration status on thirst, drinking, and related hormonal responses during low-intensity exercise in the heat. *Journal of Applied Physiology* 97: 39-44.

Manz, F. (2007). Hydration and disease. *Journal of the American College of Nutrition* 26(5 Suppl): 535S–541S.

McArdle, W.D., Katch, F.I., Katch, V.L. (2005). *Sports and Exercise Nutrition, 2nd Edition*. ISBN 0-7817-4993-X. Lippincott, Williams and Wilkins: Philadelphia.

McClung, J.P., Marchitelli, L.J., Friedl, K.E., Young, A.J. (2006). Prevalence of Iron Deficiency and Iron Deficiency Anemia among Three Populations of Female Military Personnel in the US Army. *Journal of the American College of Nutrition* 25(1): 64–69.

Mahan, L.K., Escott-Stump, S. (1996). *Krause's Food, Nutrition & Diet Therapy: 9th Edition*. W.B Saunders Company. ISBN 0-7216-5835-0.

Millwood, D.J. (1998). Optimal intakes of protein in the human diet. *Proceedings of the Nutrition Society* 58: 403-413.

Montain, S.J., Young, A.J. (2003). Diet and physical performance. *Appetite* 40: 255–267

Moore, R.J., Friedl, K.E., Kramer, T.R., Martinez-Lopez, L.E., Hoyt, R.W., Tulley, R.E., DeLany, J.P., Askew, E.W. and Vogel, J.A. (1992). *Changes in soldier nutritional status & immune function during the Ranger Training Course.* Report No. T13-92. US Army Research Institute of Environmental Medicine, Natick, Massachusetts.

Morrissey, B.L.L. (1988). *Interim Report on Food Intake and Energy Expenditure of Army Recruits*. Annex A to MRL-Tasmania 432/24/5 to DLD-A, dated 22 Aug 88, Materials Research Laboratory, Defence Science and Technology Organisation..

Morrissey, B.L.L. (1989). *Interim Reports on Task ARM 87/159 'Food Needs of Adolescent and Active Soldiers'*. Annex A and Annex B to MRL-Tasmania 432/24/5 to DLD-A, dated 23 May 89, Materials Research Laboratory, Defence Science and Technology Organisation..

Morrissey, B.L.L., Forbes-Ewan, C.H., Waters, D.R. and Gregg, G.C. (1989). Energy Expenditure and Food Intake of Soldiers Undergoing Arduous Training. *Proceedings of the Nutrition Society*. 14: 151.

Morrissey, B.L.L., Cavanough, P.J., Forbes-Ewan, C.H. and Waters, D.R. (1990). Energy Expenditure and Food Intake of Soldiers in Three Operational Environments. *Proceedings of the Nutrition Society* 15: 241.

Newman, S. J. (2000). *Calcium Intake by Female Cadets at the Australian Defence Force Academy – Implications for Future Bone Health.* Master of Applied Science Thesis. University of Canberra, March 2000.

Nindl, B.C., Barnes, B.R., Alemany, J.A., Frykman, P.N., Shippee, R.L., Friedl, K.E. (2007). Physiological consequences of US Army Ranger training. *Medicine and Science in Sports and Exercise* 8: 1380-1387.

NHMRC (1984). *Report of the Working Party on Sodium in the Australian Diet*. National Health and Medical Research Council. AGPS, Canberra.

NHMRC (1991). *Recommended Dietary Intakes for Use in Australia*. National Health and Medical Research Council. AGPS, Canberra.

NHMRC (2003). *Clinical Practice Guidelines for the Management of Overweight and Obesity in Adults.* National Health and Medical Research Council. Commonwealth of Australia. Print ISBN 1 864961 90 2.

NHMRC (2006). *Nutrient Reference Values for Australia and New Zealand Including Recommended Dietary Intakes.* National Health and Medical Research Council. Department of Health and Ageing. Commonwealth of Australia. Print ISBN 1 864962 43 7. URL: http://www.nhmrc.gov.au/publications/synopses/n35syn.htm (Site accessed 27 May, 2008)

Nicholson, J. (1994). *The Cruellest Place on Earth: Stories from Antarctica*. Allen and Unwin, ISBN 1 86373 766 9.

Norton, K., Olds, T. (1996). *Anthropometrica. A textbook of body measurement for sports and health courses.* ISBN 0 86840 2230. UNSW Press, Sydney.

Pandolf, K.B., Givoni, B., Goldman, R.F. (1977). Predicting energy expenditure with loads while standing or walking very slowly. *Journal of Applied Physiology* 43 (4): 577–581.

Passmore, R., Eastwood, M.A. (1986). *Human Nutrition and Dietetics* (Eighth Edition), Churchill Livingstone, Melbourne.

Pennefather, J., Badcock, W.E., Lichtenstein, D.J. (1980). The Energy Expenditure and Food Intake of Trainee Naval Clearance Divers. *Proceedings of the Nutrition Society* 5: 168.

Roberts, D.E., Askew, E.W., Rose, M.S., Sharp, M.A., Bruttig, S., Buchbinder, J.C., Engell, D.B. (1987). *Nutritional and hydration status of special forces soldiers consuming the Ration, Cold Weather, or the Meal, Ready-to-Eat ration during a ten day cold weather field training exercise.* Report No. T8-87. US Army Research Institute of Environmental Medicine. Natick, Massachussets. US Army Medical Research & Development Command.

Rognum, T.O., Vartdal, F., Rodahl, K., Opstad, P.K., Knudsen-Baas, O., Kindt, E., Withey, W.R. (1986). Physical and mental performance of soldiers on high- and low-energy diets during prolonged heavy exercise combined with sleep deprivation. *Ergonomics* 29 (7): 859–867.

Schmidt, W.D., O'Connor, P.J., Cochrane, J.B., Cantwell, M. (1996). Resting metabolic rate is influenced by anxiety in college men. *Journal of Applied Physiology* 80(2): 638–642.

Schofield, W.N. (1985). Predicting basal metabolic weight, new standards and review of previous work. *Human Nutrition: Clinical Nutrition* 39C; Suppl. 1: 5-41.

Shirreffs, S.M., and Ronald J. Maughan, R.J. Volume repletion after exercise-induced volume depletion in humans: replacement of water and sodium losses. *American Journal of Physiology* 274 (*Renal Physiology* 43): F868–F875, 1998.

Simopoulos, A.P., Pavlou (Editors) (1993). Nutrition and Fitness for Athletes. *World Review of Nutrition and Dietetics* Vol. 71. Karger, Sydney.

Siu, P.M., Wong, S.H. (2004). Use of the glycemic index: effects on feeding patterns and exercise performance. *Journal of Physiological Anthropology and Applied Human Science* 23(1): 1–6.

Skiller, B., Booth, C., Coad, R., Forbes-Ewan (2005). *Assessment of nutritional status and fatigue among Army recruits during the Army Common Recruit Training Course. Part A: Catering Services & Diet*. DSTO-TR-1736. Defence Science and Technology Organisation.

Smith, A.P., Miles, C. (1986). Effects of lunch on selective and sustained attention. *Neuropsychobiology* 16: 117–20.

Smith, J.S., Morrissey, B.L.L., Waters, D.R., Forbes-Ewan, C.H., McNaughton, L. (1989). The Energy Cost of Walking with Military Equipment. *Proceedings of the 25th Annual Scientific Conference of the Australian Sports Medicine Federation*, Melbourne.

Steele, S.R., Mullenix, P.S., Martin, M.J., Place, R.J. (2005). The effect of combat rations on bowel habits in a combat environment. *The American Journal of Surgery* 189: 518–21.

Stepto, N.K., Carey, A.L., Staudacher, H.M., Cummings, N.K., Burke, L.M., Hawley, J.A. (2002). Effect of short-term fat adaptation on high-intensity training. Medicine and Science in Sports and Exercise 34(3):449–55.

Stevenson, E., Williams, C., Nute, M. (2005). The influence of glycaemic index of breakfast and lunch on substrate utilisation during the postprandial periods and subsequent exercise. *British Journal of Nutrition* 93: 885–893.

Stroud, M. (1998). The nutritional demands of very prolonged exercise in man. *Proceedings of the Nutrition Society* 57: 55-61.

Sundgot-Borgen, J. (1993). Prevalence of eating disorders in elite female athletes. *International Journal of Sports Medicine* 3: 29-41.

Tharion, W.J., Baker-Fulco, C.J., Bovill, M.E., Montain, S.M., DeLany, J.P., Champagne, C.M., Hoyt, R.W., Lieberman, H.R. (2004). Adequacy of garrison feeding for Special Forces Soldiers during training. *Military Medicine* 169 (6): 483-490.

Tharion, W.J., Lieberman, H.R., Montain, S.J., Young, A.J., Baker-Fulco, C.J., DeLany, J.P., Hoyt, R.W. (2005). Energy requirements of military personnel. *Appetite* 44: 47–65.

Thomas, C.D., Friedl, K.E., Mays, *et al.* (1995). *Nutrient Intakes and Nutritional Status of Soldiers Consuming the Meal, Ready-to-Eat (MRE XII) During a 30-Day Field Training Exercise*. USARIEM Tech. Rep. T95-6, US Army Research Institute of Environmental Medicine, Natick, MA.

Thomas, D.E., Brotherhood, J.R., Brand, J.C. (1991). Carbohydrate feeding before exercise: effect of glycemic index. *International Journal of Sports Medicine* 12: 180–186.

Topping, D.L., Bajka B., Bird, A., Clarke, J., Keogh, J., Li, Z, Morell, M., Regina A., Rahman S., (2007). *Complex Carbohydrates and Gut Health.* In: Defence Nutrition Workshop, April 2006, Proceedings pp. 20–22. DSTO-GD-0507. Defence Science and Technology Organisation.

Truswell, A.S. (1992). *Report of the NHMRC Working Party*. National Health and Medical Research Council, AGPS: Canberra.

US Army (2001). Army Regulation 40–25, BUMEDINST 10110.6 AFI 44-141, Medical Services. *Nutrition Standards and Education.* Headquarters Departments of the Army, Navy, and Air Force, Washington, DC, 15 June 2001.

US AMRMC (1999). Health and Performance Research for Militarv Women: The 1994 Defense Women's Health Research Program. Fort Detrick, MD. U.S. Army Medical Research and Materiel Command.

US CMNR (1993). *Nutritional needs in hot environments: Applications for military personal in field operations.* Committee on Military Nutrition Research. Food and Nutrition Board. Institute of Medicine. National Academy Press, Washington, D.C.

US CMNR (1995). *Not eating enough: overcoming underconsumption of military operational rations.* National Academy Press, Washington, D.C.

US CMNR (2006). *Mineral requirements for military personnel: Levels needed for cognitive and physical performance during Garrison training*. Committee on Military Nutrition Research. Food and Nutrition Board. Institute of Medicine. National Academy Press, Washington, D.C.

Waters, D.R., Coad, R.A., Forbes-Ewan, C.H. (1992). *Energy Expenditure of Sailors on Board a large Naval Vessel*. Interim report to Director Logistic Services – Navy, MRL-Tasmania file reference 432/24/12. Materials Research Laboratory, Defence Science and Technology Organisation.

Westerterp, K.R., Donkers, J.H.H.L.M., Fredrix, E.W.H.M., Boekhoudt, P. (1995). Energy intake, physical activity and body weight: a simulation model. *British Journal of Nutrition* 73: 331–341.

WHO (1997). *Preventing and Managing the Global Epidemic of Obesity*. Report of the World Health Organisation Consultation of Obesity. WHO, Geneva, June 1997.

Wu, C.L., Williams, C. (2006). A low glycemic index meal before exercise improves endurance running capacity in men. *International Journal of Sport Nutrition and Exercise Metabolism* 16(5): 510–27.

Wood, P. (2007). *The Prevalence of UK Service Personnel at Risk of Obesity-Related Ill-Health.* Dstl\TR27252. Human Systems Group, Dstl Farnborough, Farnborough Hants GU14 0LX, UK.

12. Tables

Table 1: Energy Expenditures (EE) of Male ADF Members

Category Of Expenditure & Situation Studied	Mean Daily EE (MJ)
Category 1 **(11–13 MJ)**	
HMAS Albatross (sedentary subjects)	11.3
Submariners	11.5
RAAOC Centre (sedentary course)	12.5
Category 2 **(13–15 MJ)**	
Frigate	13.2
Naval Recruits	14.0
Parachute Training (Ground Phase)	14.0
Army College of TAFE	14.6
Category 3 **(15–17 MJ)**	
Field Activity in the Desert (Vital Asset Protection)	15.1
Airfield Defence Guards (field exercise in hot-wet)	15.5
Field Exercise in Tropical Rainforest	15.8
SASR (Base Activities)	16.0
HMAS Albatross (Active Subjects)	16.0
Parachute Training (Descent Phase)	16.7
Army Recruits	16.7
Soldiers undergoing Infantry IET	17.0
Category 4 **(17–20 MJ)**	
Patrol Boat	18.0
Jungle Warfare Training (LCBS)	19.0
Naval Clearance Divers	19.0
Alpine Field Exercise (Ski Patrol)	20.3
Category 5	
SASR Selection Course	≥ 25
Recovery feeding following sustained and vigorous activity when feeding was exclusively by combat ration packs*	~25

*The suggested range for recovery feeding is based on theoretical and literature results—see section 7.5 for discussion on this.

Table 2: Categorisation of Military Situations

Situation	**Activity Category**				
	1	2	3	4	5
ADF					
Re-feeding following sustained CRP rationing					
NAVY					
Submarine Voyage		■			
Large Surface Vessel		■			
Naval Recruits		■			
Patrol Boat				■	
Naval Clearance Divers				■	
AIR FORCE					
Airfield Defence Guards (hot-wet environment)			■		
ARMY					
Field Exercises					
Desert - Vital Asset Protection			■		
- Jungle			■		
Alpine (ski patrol)				■	
Training					
Army College of TAFE			■		
Army Recruits			■		
Parachute Training (Ground)		■			
Parachute Training (Descents)			■		
Jungle Warfare Training (LCBS)				■	
SASR Base Squadron				■	
SASR Selection Course					■
TRI-SERVICE					
Base (Sedentary occupation)	■				
Base (Active training or occupation)			■		
Infantry Initial Employment Training			■		
Approximate Physical Activity Level (PAL)*	1.6	1.8	2.0	2.4	3.2

*The six PAL levels for the NHMRC EERs are 1.2, 1.4, 1.6, 1.8, 2.0 and 2.2 (see section 4.1.1 for explanation)

Table 3: Protein Intakes Recommended by the Australian Institute of Sport

TRAINING SITUATION	*INTAKE (g/kg body weight)*
Sendentary	0.8
General Training	1.0
Endurance (heavy training)	1.2–1.6
Endurance (extreme training or race)	2.0
Strength Athlete (heavy training)	1.2–1.7
Adolescent Athlete	2.0

Source: Burke *et al.* (2008)

Table 4: Recommended Percentage Contributions to Total Energy (EE) by Protein, Fat And Carbohydrate (P:F:C)

CATEGORY	*MEAN EE (MJ)#*	*P:F:C* (%)*
1	12	15–20:25–35:50–55
2	14	14–19:24–34:52–57
3	16	13–18:23–33:54–59
4	18	12–17:22–32:56–61
5	≥ 25	11–16:21–31:58–63

#Mean total daily energy expenditure for adult males
***Note**—*P:F:C above 3000 m altitude is recommended as 15:20:65*

Table 5: Military Recommended Dietary Intakes for Adult Males (19–30 years)

Nutrient	**Activity Category**				
	1	2	3	4	5
Energy (MJ)	**12**	**14**	**16**	**19**	**25**
Protein* (g)	**106–141**	**115–156**	**122–169**	**134–190**	**162–235**
CHO** (g)	**375–413**	**455–499**	**540–590**	**665–724**	**906–984**
Dietary Fibre (g)	30	30	30	30	30
Vitamin A (µg)	900	900	900	900	900
Vitamin C (mg)	45	45	45	45	45
Vitamin E (mg)	10	10	10	10	10
Thiamin (mg	**1.2**	**1.4**	**1.6**	**1.9**	**2.5**
Riboflavin (mg)	**1.8**	**2.1**	**2.4**	**2.9**	**3.8**
Niacin (mg)	**19**	**22**	**26**	**30**	**40**
VitaminB6# (mg)	**2.1**	**2.3**	**2.4**	**2.7**	**3.2**
Vitamin B12 (µg)	2.4	2.4	2.4	2.4	2.4
Folate (µg)	400	400	400	400	400
Pantothenic Acid (mg)	6	6	6	6	6
Biotin (mg)	30	30	30	30	30
Choline (mg)	550	550	550	550	550
Vitamin D (µg)	5	5	5	5	5
Vitamin K (µg)	70	70	70	70	70
Calcium (mg)	1000	1000	1000	1000	1000
Chromium (µg)	35	35	35	35	35
Copper (µg)	1.7	1.7	1.7	1.7	1.7
Iodine (µg)	150	150	150	150	150
Iron (mg)	8	8	8	8	8
Magnesium (mg)	400	400	400	400	400
Manganese (µg)	5.5	5.5	5.5	5.5	5.5
Molybdenum (µg)	45	45	45	45	45
Phosphorus (mg)	1000	1000	1000	1000	1000
Potassium (mg)	3800	3800	3800	3800	3800
Selenium (µg)	70	70	70	70	70
Sodium (mg)	**920–2300**	**920–2500**	**920–2750**	**920–3000**	**920–3200**
Zinc (mg)	14	14	14	14	14

**Based on a decreasing percentage of energy being derived from protein as ADF work level categories increase from 1 to 5 (see section 4.1.2.1) and on the recommended ranges for protein (see Table 4).*
***Based on an increasing percentage of energy being derived from carbohydrate as ADF work level categories increase from 1 to 5 (see section 4.1.2.2) and on the recommended ranges for carbohydrate (see Table 4).*
#Based on 0.02 mg of vitamin B6 per gram of the MRDI for protein.
Note 1: *Those figures in bold type differ from the corresponding recommended nutrient intakes in the other work level categories.*
Note 2: *This table does not include an allowance for unavoidable food discards. An appropriate allowance for this is considered to be 15% (see section 6.2.1). Therefore, the above values should all be multiplied by 1.15 when using these tables to set entitlements to fresh feeding.*

Table 6: Military Recommended Dietary Intakes for Adult Females (19–30 years)

Nutrient	Activity Level			
	1	2	3	4
Energy (MJ)	**8.5**	**10**	**11.5**	**13**
Protein* (g)	**75–100**	**82–112**	**88–122**	**92–130**
CHO** (g)	**266–292**	**325–356**	**388–424**	**455–496**
Dietary Fibre	25	25	25	25
Vitamin A (µg)	700	700	700	700
Vitamin C (mg)	45	45	45	45
Vitamin E (mg)	8	8	8	8
Thiamin (mg)	**0.9**	**1.0**	**1.2**	**1.3**
Riboflavin (mg)	**1.3**	**1.5**	**1.7**	**2.0**
Niacin (mg)	**14**	**16**	**18**	**21**
Vitamin B6# (mg)	**1.5**	**1.6**	**1.8**	**1.8**
Vitamin B12 (µg)	2.4	2.4	2.4	2.4
Folate (µg)	400	400	400	400
Pantothenic Acid (mg)	4	4	4	4
Biotin (µg)	25	25	25	25
Choline (mg)	425	425	425	425
Vitamin D (µg)	5	5	5	5
Vitamin K (µg)	60	60	60	60
Calcium (mg)	1000	1000	1000	1000
Chromium (µg)	25	25	25	25
Copper (µg)	1.2	1.2	1.2	1.2
Iodine (µg)	150	150	150	150
Iron (mg)	18	18	18	18
Magnesium (mg)	310	310	310	310
Manganese (µg)	5.0	5.0	5.0	5.0
Molybdenum (µg)	45	45	45	45
Phosphorus (mg)	1000	1000	1000	1000
Potassium (mg)	2800	2800	2800	2800
Selenium (µg)	60	60	60	60
Sodium (mg)	**920–2300**	**920–2500**	**920–2750**	**920–3000**
Zinc (mg)	8	8	8	8

**Based on a decreasing percentage of energy being derived from protein as ADF work level categories increase from 1 to 5 (see section 4.1.2.1) and on the recommended ranges for protein (see Table 4).*
***Based on an increasing percentage of energy being derived from carbohydrate as ADF work level categories increase from 1 to 5 (see section 4.1.2.2) and on the recommended ranges for carbohydrate (see Table 4).*
#Based on 0.02 mg of vitamin B6 per gram of the MRDI for protein.
Note 1: *Those figures in bold type differ from the corresponding recommended nutrient intakes in the other work level categories.*
Note 2: *This table does not include an allowance for unavoidable food discards. An appropriate allowance for this is considered to be 15% (see section 6.2.1). Therefore, the above values should all be multiplied by 1.15 when using these tables to set entitlements to fresh feeding.*

Table 7: Military Recommended Dietary Intakes for Adolescent Males (17–18 years)

Nutrient	Activity Category			
	1	2	3	4
Energy (MJ)	**12.5**	**14.5**	**16.5**	**19.5**
Protein* (g)	**110–147**	**119–162**	**126–175**	**138–195**
CHO** (g)	**391–430**	**471–517**	**557–608**	**683–743**
Dietary Fibre (g)	30	30	30	30
Vitamin A (µg)	900	900	900	900
Vitamin C (mg)	40	40	40	40
Vitamin E (mg)	10	10	10	10
Thiamin (mg)	**1.3**	**1.5**	**1.7**	**2.0**
Riboflavin (mg)	**1.9**	**2.2**	**2.5**	**2.9**
Niacin (mg)	**20**	**23**	**26**	**31**
Vitamin B6# (mg)	**2.2**	**2.4**	**2.5**	**2.8**
Vitamin B12 (µg)	2.4	2.4	2.4	2.4
Folate (µg)	400	400	400	400
Pantothenic Acid (mg)	6	6	6	6
Biotin (µg)	30	30	30	30
Choline (mg)	550	550	550	550
Vitamin D (µg)	5	5	5	5
Vitamin K (µg)	55	55	55	55
Calcium (mg)	1300	1300	1300	1300
Chromium (µg)	35	35	35	35
Copper (µg)	1.5	1.5	1.5	1.5
Iodine (µg)	150	150	150	150
Iron (mg)	11	11	11	11
Magnesium (mg)	410	410	410	410
Manganese (µg)	3.5	3.5	3.5	3.5
Molybdenum (µg)	43	43	43	43
Phosphorus (mg)	1250	1250	1250	1250
Potassium (mg)	3600	3600	3600	3600
Selenium (µg)	70	70	70	70
Sodium (mg)	**920–2300**	**920–2500**	**920–2750**	**920–3000**
Zinc (mg)	13	13	13	13

**Based on a decreasing percentage of energy being derived from protein as ADF work level categories increase from 1 to 5 (see section 4.1.2.1) and on the recommended ranges for protein (see Table 4).*

***Based on an increasing percentage of energy being derived from carbohydrate as ADF work level categories increase from 1 to 5 (see section 4.1.2.2) and on the recommended ranges for carbohydrate (see Table 4).*

#Based on 0.02 mg of vitamin B6 per gram of the MRDI for protein.

Note 1: *Those figures in bold type differ from the corresponding recommended nutrient intakes in the other work level categories.*

Note 2: *This table does not include an allowance for unavoidable food discards. An appropriate allowance for this is considered to be 15% (see section 6.2.1). Therefore, the above values should all be multiplied by 1.15 when using these tables to set entitlements to fresh feeding.*

Table 8: Military Recommended Dietary Intakes for Adolescent Females (17–18 years)

Nutrient	Activity Level			
	1	2	3	4
Energy (MJ)	**9**	**10.5**	**12**	**13.5**
Protein* (g)	**79–106**	**86–117**	**92–127**	**95–135**
CHO (g)	**281–309**	**341–374**	**405–443**	**473–515**
Dietary Fibre (g)	25	25	25	25
Vitamin A (µg)	700	700	700	700
Vitamin C (mg)	30	30	30	30
Vitamin E (mg)	8	8	8	8
Thiamin (mg)	**0.9**	**1.1**	**1.2**	**1.4**
Riboflavin (mg)	**1.4**	**1.6**	**1.8**	**2.0**
Niacin (mg)	**14**	**17**	**19**	**22**
Vitamin B6# (mg)	**1.6**	**1.7**	**1.8**	**1.9**
Vitamin B12 (µg)	2.4	2.4	2.4	2.4
Folate (µg)	400	400	400	400
Pantothenic Acid (mg)	4	4	4	4
Biotin (µg)	25	25	25	25
Choline (mg)	400	400	400	400
Vitamin D (µg)	5	5	5	5
Vitamin K (µg)	55	55	55	55
Calcium (mg)	1300	1300	1300	1300
Chromium (µg)	25	25	25	25
Copper (µg)	1.1	1.1	1.1	1.1
Iodine (µg)	150	150	150	150
Iron (mg)	15	15	15	15
Magnesium (mg)	360	360	360	360
Manganese (µg)	3.0	3.0	3.0	3.0
Molybdenum (µg)	43	43	43	43
Phosphorus (mg)	1250	1250	1250	1250
Potassium (mg)	2600	2600	2600	2600
Selenium (µg)	60	60	60	60
Sodium (mg)	**920–2300**	**920–2500**	**920–2750**	**920–3000**
Zinc (mg)	7	7	7	7

**Based on a decreasing percentage of energy being derived from protein as ADF work level categories increase from 1 to 5 (see section 4.1.2.1) and on the recommended ranges for protein (see Table 4).*
***Based on an increasing percentage of energy being derived from carbohydrate as ADF work level categories increase from 1 to 5 (see section 4.1.2.2) and on the recommended ranges for carbohydrate (see Table 4).*
#Based on 0.02 mg of vitamin B6 per gram of the MRDI for protein.
Note 1: *Those figures in bold type differ from the corresponding recommended nutrient intakes in the other work level categories.*
Note 2: *This table does not include an allowance for unavoidable food discards. An appropriate allowance for this is considered to be 15% (see section 6.2.1). Therefore, the above values should all be multiplied by 1.15 when using these tables to set entitlements to fresh feeding.*

Table 9: Recommended Nutritional Criteria for General Purpose Combat Ration Packs

Energy (MJ)	16
Protein (g)	122–150
Fat (g)	108–143
Saturated + *trans* fat (g)	≤ 43
CHO (g)	565–590
Dietary Fibre (g)	24
Vitamin A (µg)	900
#Vitamin C (mg)	135
Vitamin E (mg)	10
#Thiamin (mg	5.1
#Riboflavin (mg)	7.5
#Niacin (mg)	78
#VitaminB6 (mg)	7.5
Vitamin B12 (µg)	2.4
Folate (µg)	400
Pantothenic Acid (mg)	6
Biotin (mg)	30
Choline (mg)	550
Vitamin D (µg)	5
Vitamin K (µg)	70
Calcium (mg)	1300
Chromium (µg)	35
Copper (µg)	1.7
Iodine (µg)	150
Iron (mg)	18
Magnesium (mg)	410
Manganese (µg)	5.5
Molybdenum (µg)	45
Phosphorus (mg)	1250
Potassium (mg)	3800
Selenium (µg)	70
Sodium (mg)	2300–4600
Zinc (mg)	14

**Based on the experimental result that typical field exercises involve energy expenditures of 15–16 MJ per day for male ADF members (*Category 3*). All other values are based on the 'worst case' situation – i.e. the MRDI (or an appropriate percentage of the MRDI) for the population group with the greatest estimated requirement for that nutrient. These criteria are recommended to apply at the time of* packing, *not necessarily at the time of* consumption. *They do not necessarily apply to mission-specific ration packs.*

#The recommended levels of these vitamins are three times the MRDI for adult males at Category 3 *physical workload, to allow for likely loss during storage and also for discarding of ration items.*

Table 10a: Recommended Nutritional Criteria for Fresh Food Availability – Mixed ADF Populations (based on MRDI)

	Activity Category				
	1	2	3	4	5
Energy (MJ)	**12.5**	**14.5**	**16.5**	**19.5**	**25**
Protein (g)	**110–147**	**119–162**	**126–174**	**138–195**	**162–235**
Saturated + *trans* fat (g)	**≤ 34**	**≤ 39**	**≤ 45**	**≤ 53**	**≤ 68**
CHO (g)	**391–430**	**471–517**	**557–608**	**683–743**	**906–984**
Dietary Fibre (g)	30	30	30	30	30
Vitamin A (µg)	900	900	900	900	900
Vitamin C (mg)	45	45	45	45	45
Vitamin E (mg)	10	10	10	10	10
Thiamin (mg	**1.3**	**1.5**	**1.7**	**2.0**	**2.5**
Riboflavin (mg)	**1.9**	**2.2**	**2.5**	**2.9**	**3.8**
Niacin (mg)	**20**	**23**	**26**	**31**	**40**
VitaminB6 (mg)	**2.2**	**2.4**	**2.5**	**2.8**	**3.2**
Vitamin B12 (µg)	2.4	2.4	2.4	2.4	2.4
Folate (µg)	400	400	400	400	400
Pantothenic Acid (mg)	6.0	6.0	6.0	6.0	6.0
Biotin (mg)	30	30	30	30	30
Choline (mg)	550	550	550	550	550
Vitamin D (µg)	5	5	5	5	5
Vitamin K (µg)	70	70	70	70	70
Calcium (mg)	1300	1300	1300	1300	1300
Chromium (µg)	35	35	35	35	35
Copper (µg)	1.7	1.7	1.7	1.7	1.7
Iodine (µg)	150	150	150	150	150
Iron (mg)	18	18	18	18	18
Magnesium (mg)	410	410	410	410	410
Manganese (µg)	5.5	5.5	5.5	5.5	5.5
Molybdenum (µg)	45	45	45	45	45
Phosphorus (mg)	1250	1250	1250	1250	1250
Potassium (mg)	3800	3800	3800	3800	3800
Selenium (µg)	70	70	70	70	70
Sodium (mg)	**920–2300**	**920–2500**	**920–2750**	**920–3000**	**920–3200**
Zinc (mg)	14	14	14	14	14

Note 1: *Those figures in bold type differ from the corresponding recommended nutrient intakes in the other work level categories*
Note 2: *This table does not include an allowance for unavoidable food discards. An appropriate allowance for this is considered to be 15% when the efficiency of the mess is not known (see section 6.2.1). Therefore, when using these tables to set entitlements to fresh feeding, the above nutrient values should all be multiplied by the appropriate factor (if the approximate efficiency of the mess is known), or by 1.15 if the efficiency is unknown.*

Table 10b: Recommended Nutritional Criteria for Assessing Adequacy of ADF Fresh Feeding – Mixed ADF Populations (based on MEARs)

	Activity Category				
	1	2	3	4	5
Energy (MJ)	**12.5**	**14.5**	**16.5**	**19.5**	**25**
Protein (g)	**110–147**	**119–162**	**126–174**	**138–195**	**162–235**
Saturated + *trans* fat* (g)	**≤ 34**	**≤ 39**	**≤ 45**	**≤ 53**	**≤ 68**
CHO (g)	**391–430**	**471–517**	**557–608**	**683–743**	**906–984**
Dietary Fibre (g)	30	30	30	30	30
Vitamin A (µg)	630	630	630	630	630
Vitamin C (mg)	30	30	30	30	30
Vitamin E (mg)	10	10	10	10	10
Thiamin (mg	**0.9**	**1.1**	**1.2**	**1.4**	**1.8**
Riboflavin (mg)	**1.3**	**1.5**	**1.8**	**2.0**	**2.7**
Niacin (mg)	**14**	**16**	**18**	**22**	**28**
VitaminB6 (mg)	**1.5**	**1.7**	**1.8**	**2.0**	**2.2**
Vitamin B12 (µg)	2	2	2	2	2
Folate (µg)	330	330	330	330	330
Pantothenic Acid (mg)	6	6	6	6	6
Biotin (mg)	30	30	30	30	30
Choline (mg)	550	550	550	550	550
Vitamin D (µg)	5	5	5	5	5
Vitamin K (µg)	70	70	70	70	70
Calcium (mg)	1050	1050	1050	1050	1050
Chromium (µg)	35	35	35	35	35
Copper (µg)	1.7	1.7	1.7	1.7	1.7
Iodine (µg)	100	100	100	100	100
Iron (mg)	8	8	8	8	8
Magnesium (mg)	340	340	340	340	340
Manganese (µg)	5.5	5.5	5.5	5.5	5.5
Molybdenum (µg)	34	34	34	34	34
Phosphorus (mg)	1055	1055	1055	1055	1055
Potassium (mg)	3800	3800	3800	3800	3800
Selenium (µg)	60	60	60	60	60
Sodium (mg)	**920–2300**	**920–2500**	**920–2750**	**920–3000**	**920–3200**
Zinc (mg)	12	12	12	12	12

**For Saturated + trans fat the criterion is <10% of total energy.*

Note: *Those figures in bold type differ from the corresponding recommended nutrient intakes in the other work level categories*

Table 10c: Nutritional Criteria for Developing a Basic ADF Fresh Feeding Ration Scale – Mixed ADF Population at Category 1 Energy Expenditure (Based on MRDIs)

Energy (MJ)	12.5
Protein (g)	110–147
Saturated + *trans* fat (g)	≤ 34
CHO (g)	391–430
Dietary Fibre (g)	30
Vitamin A (µg)	900
Vitamin C (mg)	45
Vitamin E (mg)	10
Thiamin (mg	2.0
Riboflavin (mg)	2.9
Niacin (mg)	31
VitaminB6 (mg)	2.8
Vitamin B12 (µg)	2.4
Folate (µg)	400
Pantothenic Acid (mg)	6
Biotin (mg)	30
Choline (mg)	550
Vitamin D (µg)	5
Vitamin K (µg)	70
Calcium (mg)	1300
Chromium (µg)	35
Copper (µg)	1.7
Iodine (µg)	150
Iron (mg)	18
Magnesium (mg)	410
Manganese (µg)	5.5
Molybdenum (µg)	45
Phosphorus (mg)	1250
Potassium (mg)	3800
Selenium (µg)	70
Sodium (mg)	2300–3000
Zinc (mg)	14

The values shown as the MRDIs for energy and the macronutrients are those that apply to adolescent males. The MRDIs for micronutrients are the 'worst case' situations at Level 4 Category of energy expenditure (see Table 10a). As examples, the criterion for calcium is the MRDI for adolescent males, the criterion for iron is the MRDI for adult females, and for vitamin K it is the MRDI for adult males. Generally the MRDI for micronutrients is identical to the NHMRC (2006) RDI (or AI if there is no RDI), with the exceptions of thiamin, riboflavin, niacin, vitamin B6 and sodium, for which military specific MRDIs apply.

Note*: This table does not include an allowance for unavoidable food discards. An appropriate allowance for this is considered to be 15% when the efficiency of the mess is not known (see section 6.2.1). Therefore, when using these tables to set entitlements to fresh feeding, the above nutrient values should all be multiplied by the appropriate factor (if the approximate efficiency of the mess is known), or by 1.15 if the efficiency is unknown.*

Table 10d: Nutritional Criteria for Assessing the Adequacy of Nutritional Intakes of a Mixed ADF Population at Level 1 Energy Expenditure (Based on MEARs)

Energy (MJ)	12.5
Protein (g)	110–147
Saturated + *trans* fat (g)	≤ 34
CHO (g)	391–430
Dietary Fibre (g)	30
Vitamin A (µg)	630
Vitamin C (mg)	30
Vitamin E (mg)	10
Thiamin (mg	1.4
Riboflavin (mg)	2.0
Niacin (mg)	22
VitaminB6 (mg)	2.0
Vitamin B12 (µg)	2
Folate (µg)	330
Pantothenic Acid (mg)	6
Biotin (mg)	30
Choline (mg)	550
Vitamin D (µg)	5
Vitamin K (µg)	70
Calcium (mg)	1050
Chromium (µg)	35
Copper (µg)	1.7
Iodine (µg)	100
Iron (mg)	8
Magnesium (mg)	340
Manganese (µg)	5.5
Molybdenum (µg)	34
Phosphorus (mg)	1055
Potassium (mg)	3800
Selenium (µg)	60
Sodium (mg)	920–3000
Zinc (mg)	12

The values for energy and the macronutrients are the MRDIs for adolescent males. For micronutrients, the values shown are the 'worst case' MEAR at Level 4 Category of energy expenditure (see Table 10b). As examples, the criterion for calcium is the MEAR that applies to adolescent males, the criterion for iron is the MEAR for adult females, and for vitamin K it is the MEAR for adult males. Generally, the MEARs for micronutrients are identical to the NHMRC (2006) EARs (or AI if there is no EAR), with the exceptions of thiamin, riboflavin, niacin, vitamin B6 and sodium, for which military specific MEARs apply.

Table 11: Recommended Nutritional Criteria for Assessing the Adequacy of Nutritional Intakes within a Group of Adult Male ADF Members (aged 19–30 Years)

Nutrient	**Activity Category**				
	1	2	3	4	5
Energy (MJ)	**12**	**14**	**16**	**19**	**25**
Protein (g)	**106–141**	**115–156**	**122–169**	**134–190**	**162–235**
Saturated + *trans* fat (g)	**≤ 32**	**≤ 38**	**≤ 43**	**≤ 51**	**≤ 67**
CHO (g)	**375–413**	**455–499**	**540–590**	**665–724**	**906–984**
Dietary Fibre (g)	30 (21)	30 (21)	30 (21)	30 (21)	30 (21)
Vitamin A (µg)	625	625	625	625	625
Vitamin C (mg)	30	30	30	30	30
Vitamin E (mg)	10	10	10	10	10
Thiamin (mg	**0.9**	**1.0**	**1.1**	**1.3**	**1.8**
Riboflavin (mg)	**1.3**	**1.5**	**1.7**	**2.0**	**2.7**
Niacin (mg)	**13**	**15**	**18**	**21**	**28**
VitaminB6 (mg)	**1.5**	**1.6**	**1.7**	**1.9**	**2.2**
Vitamin B12 (µg)	2.0	2.0	2.0	2.0	2.0
Folate (µg)	320	320	320	320	320
Pantothenic Acid (mg)	6	6	6	6	6
Biotin (mg)	30	30	30	30	30
Choline (mg)	550	550	550	550	550
Vitamin D (µg)	5	5	5	5	5
Vitamin K (µg)	70	70	70	70	70
Calcium (mg)	840	840	840	840	840
Chromium (µg)	35	35	35	35	35
Copper (µg)	1.7	1.7	1.7	1.7	1.7
Iodine (µg)	100	100	100	100	100
Iron (mg)	6	6	6	6	6
Magnesium (mg)	330	330	330	330	330
Manganese (µg)	5.5	5.5	5.5	5.5	5.5
Molybdenum (µg)	34	34	34	34	34
Phosphorus (mg)	580	580	580	580	580
Potassium (mg)	3800	3800	3800	3800	3800
Selenium (µg)	60	60	60	60	60
Sodium (mg)	**920–2300**	**920–2500**	**920–2750**	**920–3000**	**920–3200**
Zinc (mg)	12	12	12	12	12

The estimated requirement for energy is the MRDI. For macronutrients the estimated requirements (also MRDIs) are expressed as acceptable ranges (see Table 4). For each micronutrient the MEAR applies. The MEAR is identical to the NHMRC (2006) EAR with the exceptions of thiamin, riboflavin, niacin, vitamin B6 and sodium, for which military-specific MEAR are recommended.

Note: *Those figures in bold type differ from the corresponding recommended nutrient intakes in the other work level categories.*

Table 12: Recommended Nutritional Criteria for Assessing the Adequacy of Nutritional Intakes within a Group of Adult Female ADF Members (Aged 19–30 Years)

Nutrient	**Activity Category**			
	1	2	3	4
Energy (MJ)	**8.5**	**10**	**11.5**	**13**
Protein (g)	**75–100**	**82–112**	**88–122**	**92–130**
Saturated + *trans* fat (g)	**≤ 23**	**≤ 27**	**≤ 31**	**≤ 35**
CHO (g)	**266–292**	**325–356**	**388–424**	**455–496**
Dietary Fibre	25 (18)	25 (18)	25 (18)	25 (18)
Vitamin A (µg)	500	500	500	500
Vitamin C (mg)	30	30	30	30
Vitamin E (mg)	7	7	7	7
Thiamin (mg)	**0.6**	**0.7**	**0.8**	**0.9**
Riboflavin (mg)	**0.9**	**1.1**	**1.2**	**1.4**
Niacin (mg)	**9.5**	**11**	**13**	**15**
Vitamin B6 (mg)	**1.1**	**1.1**	**1.3**	**1.3**
Vitamin B12 (µg)	2.0	2.0	2.0	2.0
Folate (µg)	320	320	320	320
Pantothenic Acid (mg)	4.0	4.0	4.0	4.0
Biotin (µg)	25	25	25	25
Choline (mg)	425	425	425	425
Vitamin D (µg)	5	5	5	5
Vitamin K (µg)	60	60	60	60
Calcium (mg)	840	840	840	840
Chromium (µg)	25	25	25	25
Copper (µg)	1.2	1.2	1.2	1.2
Iodine (µg)	100	100	100	100
Iron (mg)	8	8	8	8
Magnesium (mg)	255	255	255	255
Manganese (µg)	5	5	5	5
Molybdenum (µg)	34	34	34	34
Phosphorus (mg)	580	580	580	580
Potassium (mg)	2800	2800	2800	2800
Selenium (µg)	50	50	50	50
Sodium (mg)	**920–2300**	**920–2500**	**920–2750**	**920–3000**
Zinc (mg)	6.5	6.5	6.5	6.5

The estimated requirement for energy is the MRDI. For macronutrients the estimated requirements (also MRDIs) are expressed as acceptable ranges (see Table 4). For each micronutrient the MEAR applies. The MEAR is identical to the NHMRC (2006) EAR with the exceptions of thiamin, riboflavin, niacin, vitamin B6 and sodium, for which military-specific MEAR are recommended.
Note: *Those figures in bold type differ from the corresponding recommended nutrient intakes in the other work level categories.*

Table 13: Recommended Nutritional Criteria for Assessing the Adequacy of Nutritional Intakes of Adolescent Male ADF Members (Aged 17–18 Years)

Nutrient	**Activity Category**			
	1	2	3	4
Energy (MJ)	**12.5**	**14.5**	**16.5**	**19.5**
Protein (g)	**110–147**	**119–162**	**126–175**	**138–195**
Saturated + *trans* fat (g)	**≤ 34**	**≤ 39**	**≤ 45**	**≤ 53**
CHO (g)	**391–430**	**471–517**	**557–608**	**683–743**
Dietary Fibre (g)	30	30	30	30
Vitamin A (µg)	630	630	630	630
Vitamin C (mg)	28	28	28	28
Vitamin E (mg)	10	10	10	10
Thiamin (mg	**0.9**	**1.1**	**1.2**	**1.4**
Riboflavin (mg)	**1.3**	**1.5**	**1.8**	**2.1**
Niacin (mg)	**14**	**16**	**18**	**22**
VitaminB6 (mg)	**1.5**	**1.7**	**1.8**	**2.0**
Vitamin B12 (µg)	2.0	2.0	2.0	2.0
Folate (µg)	330	330	330	330
Pantothenic Acid (mg)	6	6	6	6
Biotin (mg)	30	30	30	30
Choline (mg)	550	550	550	550
Vitamin D (µg)	5	5	5	5
Vitamin K (µg)	55	55	55	55
Calcium (mg)	1050	1050	1050	1050
Chromium (µg)	35	35	35	35
Copper (µg)	1.5	1.5	1.5	1.5
Iodine (µg)	95	95	95	95
Iron (mg)	8	8	8	8
Magnesium (mg)	340	340	340	340
Manganese (µg)	3.5	3.5	3.5	3.5
Molybdenum (µg)	33	33	33	33
Phosphorus (mg)	1055	1055	1055	1055
Potassium (mg)	3600	3600	3600	3600
Selenium (µg)	60	60	60	60
Sodium (mg)	**920–2300**	**920–2500**	**920–2750**	**920–3000**
Zinc (mg)	11	11	11	11

The estimated requirement for energy is the MRDI. For macronutrients the estimated requirements (also MRDIs) are expressed as acceptable ranges (see Table 4). For each micronutrient the MEAR applies. The MEAR is identical to the NHMRC (2006) EAR with the exceptions of thiamin, riboflavin, niacin, vitamin B6 and sodium, for which military-specific MEAR are recommended.
Note: *Those figures in bold type differ from the corresponding recommended nutrient intakes in the other work level categories.*

Table 14: Recommended Nutritional Criteria for Assessing the Adequacy of Nutritional Intakes within a Group of Adolescent Female ADF Members (Aged 17–18 Years)

Nutrient	**Activity Level**			
	1	2	3	4
Energy (MJ)	**9**	**10.5**	**12**	**13.5**
Protein (g)	**79–106**	**86–117**	**92–127**	**95–135**
Saturated + *trans* fat (g)	**≤ 24**	**≤ 28**	**≤ 32**	**≤ 36**
CHO (g)	**281–309**	**341–374**	**405–443**	**473–515**
Dietary Fibre (g)	25	25	25	25
Vitamin A (µg)	485	485	485	485
Vitamin C (mg)	25	25	25	25
Vitamin E (mg)	8	8	8	8
Thiamin (mg)	**0.6**	**0.8**	**0.8**	**1.0**
Riboflavin (mg)	**1.0**	**1.1**	**1.3**	**1.4**
Niacin (mg)	**10**	**12**	**13**	**15**
Vitamin B6 (mg)	**1.1**	**1.2**	**1.3**	**1.4**
Vitamin B12 (µg)	2.0	2.0	2.0	2.0
Folate (µg)	330	330	330	330
Pantothenic Acid (mg)	4	4	4	4
Biotin (µg)	25	25	25	25
Choline (mg)	400	400	400	400
Vitamin D (µg)	5	5	5	5
Vitamin K (µg)	55	55	55	55
Calcium (mg)	1050	1050	1050	1050
Chromium (µg)	24	24	24	24
Copper (µg)	1.1	1.1	1.1	1.1
Iodine (µg)	95	95	95	95
Iron (mg)	8	8	8	8
Magnesium (mg)	300	300	300	300
Manganese (µg)	3.0	3.0	3.0	3.0
Molybdenum (µg)	33	33	33	33
Phosphorus (mg)	1055	1055	1055	1055
Potassium (mg)	2600	2600	2600	2600
Selenium (µg)	50	50	50	50
Sodium (mg)	**920–2300**	**920–2500**	**920–2750**	**920–3000**
Zinc (mg)	6	6	6	6

The estimated requirement for energy is the MRDI. For macronutrients the estimated requirements (also MRDIs) are expressed as acceptable ranges (see Table 4). For each micronutrient the MEAR applies. The MEAR is identical to the NHMRC (2006) EAR with the exceptions of thiamin, riboflavin, niacin, vitamin B6 and sodium, for which military-specific MEAR are recommended.
Note: *Those figures in bold type differ from the corresponding recommended nutrient intakes in the other work level categories.*

*Table 15: Suggested Dietary Targets (SDT) to Reduce Chronic Disease Risk – Micronutrients, Dietary Fibre and Long Chain N-3 Fats**

Nutrient	Suggested Dietary Target (intake per day on average)	Comments
Vitamin A	*Vitamin A:* Men 1,500 µg Women 1,220 µg *Carotenes:* Men 5,800 µg Women 5,000 µg	The suggested dietary target is equivalent to the 90th centile of intake in the Australian and New Zealand populations, to be attained by replacing nutrient-poor, energy dense foods and drinks with plenty of red-yellow vegetables and fruits, moderate amounts of reduced-fat dairy foods and small amounts of vegetable oils.
Vitamin C	Men 220 mg Women 190 mg	Equivalent to the 90th centile of intake in the Australian and New Zealand populations, to be attained by replacing nutrient poor, energy-dense foods and drinks with plenty of vegetables, legumes and fruit.
Vitamin E	Men 19 mg Women 14 mg	Equivalent to the 90th centile of intake in the Australian and New Zealand populations, to be attained by including some poly- or monounsaturated fats and oils and replacing nutrient poor, energy-dense foods and drinks with plenty of vegetables and moderate amounts of lean meat, poultry, fish, reduced-fat dairy foods and wholegrain cereals.
Selenium	No specific figure can be set. There is some evidence of potential benefit for certain cancers but adverse effects for others.	There are no available population intake data for Australia. New Zealand is a known low selenium area, thus recommendations based on centiles of population intakes are inappropriate. Selenium-rich foods include seafood, poultry and eggs and to a lesser extent, other muscle meats. The content in plant foods depends on the soil in which they were grown.
Folate	An additional 100–400 µg DFE over current intakes (ie a total of about 300–600 µg DFE) may be required to optimise homocysteine levels and reduce overall chronic disease risk and DNA damage.	Current population intakes are well below the new recommended intakes. Increased consumption through replacement of nutrient-poor, energy-dense foods and drinks with folate-rich foods such as vegetables and fruits and wholegrain cereals is recommended as the primary strategy. Dairy foods can also help with folate absorption but reduced fat varieties should be chosen. It should be noted that fortified foods contain folic acid which has almost twice the potency of naturally occurring food folates.
	Potassium: Men 4,700 mg 120 mmol Women 4,700mg 120 mmol	As potassium can blunt the effect of sodium on blood pressure, intakes at the 90th centile of current population intake may help to mitigate the effects of sodium on blood pressure until intakes of sodium can be lowered. At the level of 4,700 mg/day for potassium there is also evidence of protection against renal stones. Increased potassium intake should be through greater consumption of fruits and vegetables
Dietary Fibre	Men 38 g Women 28 g	Upper level at 90th centile of intake for reduction in CHD risk. Increased intakes should be through replacement of nutrient-poor, energy-dense foods and drinks (with) plenty of vegetables, fruits and wholegrain cereals.
LC n-3 fats (DHA:EPA: DPA)	Men 610 mg Women 430 mg	The suggested dietary target is equivalent to the 90^{th} centile of intake in the Australian/New Zealand population to be attained by replacing energy-dense, low nutrient foods and drinks with LC n-3-rich foods such as fish such as tuna, salmon and mackerel, lean beef or low energy density, LC n-3-enriched foods.

**Reproduced from Table 1 of NHMRC (2006) with the exception of the SDT for sodium (see sections 5.1 and 5.2.4)*

*Table 16: Recommended Upper Levels (UL) of Intake of Nutrients for ADF Rationing**

Nutrient	**Upper Level**			
	Adult Male	Adult Female	Adolescent M	Adolescent F
Vitamin A (µg)	3000	3000	2800	2800
Vitamin E (mg)	300	300	250	250
Niacin (mg)	35	35	30	30
Vitamin B6 (mg)	50	50	40	40
Folate (µg)	1000	1000	800	800
Choline (mg)	3500	3500	3000	3000
Vitamin D (µg)	80	80	80	80
Calcium (mg)	2500	2500	2500	2500
Copper (µg)	10	10	8	8
Iodine (µg)	1100	1100	900	900
Iron (mg)	45	45	45	45
Molybdenum (µg)	2000	2000	1700	1700
Phosphorus (mg)	4000	4000	4000	4000
Selenium (µg)	400	400	400	400
Sodium (mg)*	4600	4600	4600	4600
Zinc (mg)	40	40	35	35

**The ULs shown here are those recommended by the NHMRC (2006) other than that for sodium (see section 5.2.4 for the rationale for this.*

Note that only those nutrients for which a UL exists are shown.

Appendix A: Nutritional specifications and menu exchar for a 24-hr Combat Ration

Food Group	No of items	Items list –examples of suitable exchanges	Weight (g)	Nutritional Specification for Foo… Energy (kJ)	Carbohydrate (g)	F…
Main meal - hot	1	Sausages & vegetables, BBQ chicken, BBQ beef	250	1200	20	
Main meal - cold	2	Jerky bars (2), Tinned/pouched tuna, Ham & potato, Chicken & vegetables	240	1200	15	
High starch	2	Tortilla bread, Instant beef noodles	100	1500	60	
Bf Cereal	1	Fruit muesli mix (with milk powder)	70	1000	40	
Dairy	2	Cheddar cheese, Sustagen. Condensed milk	225	1500	40	
Fruit	2	Dried apricots, Sultanas, Tinned fruit, Fruit grains	150	1000	60	
High sugar confectionary	2	Mentos (fruit, mint), Sport beans, Fruitip pastilles, Skittles, Sports gel	70	1200	70	
Biscuits	2	Tiny Teddy biscuits (2), Jam sandwich, Shortbread, Krispie, Shapes (Pizza, BBQ, Cheddar), Cracked pepper vita wheat	90	1500	60	
Cake/muesli slice	2	Cereal bar, Ski D'lite muesli bar, Almond & sesame muesli bar, Original muesli bar, Uncle Toby's (forest fruits, tropical, Apricot)	80	1100	40	
High energy bars/mixes	1	Protein bar (Cookie, chocolate), M&Ms, Ration chocolate (original, new varieties), Honey-roasted nuts, Trail mix	70	1200	30	
Beverages - cold	2	Sports pouch (lemon/lime, berry, pineapple)-2, Sports beverage (orange, ,mixed berry, grape, lemon/lime)	140	1800	100	
Other items	15	Packet sugar (7g), Cappuccino beverage, Chewing gum, Chilli sauce, Vegemite, Tomato sauce, Pepper, Tea bag, Matches, Plastic spoon, Rubber band, Toilet paper, Scouring pad, Plastic bag	100	650	20	
MENU AVERAGE			1580	14900	560	
MILITARY RECOMMENDED DIETARY INTAKE				15000	560	

** The specifications are for the average nutrient composition of all ration menus (e.g. menus A to H). Weight is the maximum for a 24 hour pack.*
 # These items will need to be fortified with calcium in order to meet the nutritional specification

NOTE: Nutritional specs are presented as the total requirement for each food grouping. For example "Biscuits": 2 pkts of Tiny Teddy biscuits plus 1 pkt jam sand… carbohydrate etc and less than 90 g weight. "High energy bars/mixes": 1 ration Chocolate would provide 1200 kJ, 30 g carbohydrate etc and ≤ 70 g weight.

Appendix B: Calculating the Required Energy Availability at a Mess with a Mixed ADF Population

An example is shown how the food entitlements can be determined for an ADF mess with the hypothetical population mix shown in the table, based on activity category.

Population Data

Work Level Category	Number
2	154
3	97
4	30

Assumptions underpinning the Calculation

From section 6.2 the entitlement to each nutrient for fresh feeding is based on the nutritional requirement of the ADF population sub-group with the greatest need for that nutrient. These entitlements are shown in Table 10. *Note that the calculation does not take into account age or gender, only the number of troops in each work level category, and it does not take into account the need to allow an additional 15% for inevitable food discarding.*

From Table 10a:

For 154 ADF members at Category 2, energy availability should be (154 x 14.5) = 2233 MJ;

For 97 ADF members at Category 3, energy availability should be (98 x 16.5) = 1617 MJ

For 30 ADF members at Category 4, energy availability should be (30 x 19) = 570 MJ.

Therefore, total food available at the mess for that day should provide for an energy intake of:

(2233 + 1617 + 570) = 4420 MJ.

If 15% is added to take into account inevitable food discarding, the total food energy availability should be:

4420 x 1.15 = 5083 MJ

To the nearest 100 MJ, this equates to **5100 MJ**.

Appendix C: Energy Costs of Selected Military and Sporting Activities (applies to adult males)

Level	Activity	(MJ/hour)
1 (Basal)	Asleep/lying awake	0.3
2 (Sedentary)	Seated/standing at ease	0.4
3 (Slightly active)	Rifle shooting, housework (e.g. making bed, cleaning equipment), throwing hand grenades, ablutions, slow walking (no pack)	0.7
4 (Moderately active)	Drill, slow patrolling, (patrol order or low marching order), low level sports (e.g. volleyball), digging (50% rest) light callisthenics	1.2
5 (Very active)	Digging (no rest), rope climbing (50% rest), high level callisthenics, level marching (marching order), physical fitness training, Naval clearance diving, medium level sports (e.g. basketball, soccer, rugby, Australian football)	2.0
6 (Extremely active)	Fast uphill marching (full marching order), Army Basic Fitness Assessment, Army Combat Fitness Assessment, high level sports (e.g. squash, cross country running)	3.0

Appendix D: Using a Record of Activities to Estimate Energy Expenditure of an ADF Group

Activity	**Time (hours) (from Table 11)**	**MJ/h**
Asleep	6.0	0.3
Lying awake (night ambush)	3.3	0.3
Seated in truck	4.0	0.4
Sitting, standing inactive	4.5	0.4
Ablutions	0.2	0.7
Cleaning equipment	0.5	0.7
Slow patrolling, marching order	3.0	1.2
Digging (50% rest)	1.5	1.2
Crawling, marching order	0.5	2.0
Digging (no rest)	0.5	2.0
Total	24	NA

Energy expenditure for an adult male conducting these activities over the 24-hour period can be calculated from Appendix C as shown below:

Time spent on Level 1 activities is 9.3 hours @ 0.3 MJ per hour = 2.8 MJ

Time spent on Level 2 activities is 8.5 hours @ 0.4 MJ per hour = 3.4 MJ

Time spent on Level 3 activities is 0.7 hours @ 0.7 MJ per hour = 0.5 MJ

Time spent on Level 4 activities is 4.5 hours @ 1.2 MJ per hour = 5.4 MJ

Time spent on Level 5 activities is 1.0 hour @ 2.0 MJ per hour = 2.0 MJ

Total energy expenditure per 24 hours **= 14.1 MJ.**

From Table 4, a male soldier expending 14.1 MJ per day is working at Category 2 energy expenditure.

For other ADF groups (adult females, adolescent males and adolescent females), reference would then be made to the appropriate table (Table 6, 7 or 8 respectively) to determine the actual energy and nutrient requirements that apply to Category 2 for the group of interest.

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Combat rations, Nutrients, Nutritional requirements, Military rations, Food

19. ABSTRACT
This report addresses the determinants of military nutritional requirements-that is, the relevant variables that determine the types and quantities of foods necessary to support ADF training and operations-and the current state of knowledge about nutritional requirements. It also includes recommendations on nutritional standards for ADF rationing systems, and suggests areas of research that will help fill the gaps in our knowledge. Nutritional standards are recommended for fresh (i.e. in-barracks or garrison) feeding and for combat ration packs. These standards are based largely on the Nutrient Reference Values recommended by the National Health and Medical Research Council for Australia and New Zealand, but include specific Military Nutrient Reference Values for certain key nutrients.