An evaluation of the current methods used for assessing dietary intake in military-research settings: a scoping review

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ABSTRACT

Introduction: It is important to collate the literature that has assessed dietary intake within military settings to establish which methods are commonly used and which are valid so that accurate nutrition recommendations can be made. This scoping review aims to identify which methods are typically used to assess dietary intake in military settings and which of these have been validated. This review also aims to provide a recommendation as to which method(s) should be used in military-settings. Methods: This scoping review was conducted according to the PRISMA extension for scoping reviews. Searches were conducted in PubMed, web of science and SPORTDiscus with the most recent search executed on the 12th June 2020. Eligible studies had to report original data, assess and quantify dietary intake and have been published in peer-reviewed academic journals. The reporting bias was calculated for each study where possible. Results: Twenty-eight studies used a single method to assess dietary intake and seven studies used a combination of methods. The most commonly used methods were the gold-standard food intake/waste method, Food Frequency Questionnaire (FFQ) or a food diary (FD). The only method to date that has been validated in military settings is weighed food records (WFR). Conclusions: The food intake/waste method or WFR should be used where feasible. Where this is not practical the FFQ or FD should be considered with control measures applied.

There is currently not sufficient evidence to state that using multiple methods together improves validity.

Key words: dietary intake, diet assessment, military, nutrient intake

KEY MESSAGES

- The gold standard and most practical dietary assessment method is the food intake/waste method, and this should be used where feasible.
- In settings where the food intake/waste method is not feasible, researchers should use weighed food records.
- Where weighed food records are not feasible, researchers should consider methods such as the Food Frequency Questionnaire (FFQ) and self-reported food diary (FD).
- The limitations of the FFQ and FD should be recognised, and control measures should be considered.
- Future research should consider validating methods such as the FFQ and FD given these are practical and commonly used.

INTRODUCTION

Dietary assessment is usually undertaken to evaluate whether an individual is achieving specific dietary targets. Typical methods include: weighed food records (WFR), self-reported food diaries (FD), Food Frequency Questionnaires (FFQ) and dietary recalls (1,2). The recording of dietary intake is usually conducted over one to seven days with a three-day record considered the minimum requirement to indicate habitual energy and macronutrient intake (2).

The most practical method, and typically used as a gold-standard to assess dietary intake is the weighed food intake/waste collection method (3). This involves participants weighing their food pre-and-post consumption and the nutritional composition being known per a standard portion size (3). Despite this method having greater accuracy compared to other methods (FD, FFQ) it is more time-consuming and laborious for researchers and participants (3) and therefore may be less feasible to use in some military settings due to time constraints (4). Resultantly, military researchers typically utilise other prospective dietary assessment methods such as a FD or retrospective methods including a FFQ or dietary recall. It is acknowledged that existing reviews have assessed the validity of dietary assessment methods in populations such as athletes (1). However, the military are a unique population and one who may not be considered completely free-living with respect to energy expenditure (EE), and energy intake (EI) when in a training or deployment settings (5). Specific differences in relation to assessing dietary intake between a military and athletic cohort may include a greater number of participants, diverse working environments such as field exercises, time constraints and limited contact with participants (4–6). Consequently, the food intake/waste method may not always be practical or feasible. Therefore, the validity of other methods should be quantified so that future research studies can be informed. Some assessment methods, such as the FFQ have also been specifically designed for their use in military settings (7,8). Given this, it is important to collate the literature that has assessed dietary intake within military settings to establish which methods

65 are commonly used and which methods are most valid. This will inform future studies of the
66 most valid method(s) to use and highlight which methods need further validation.

67 The aims of this scoping review were three-fold; i) to establish which dietary assessment
68 methods are commonly used in military-settings; ii) to establish if the use of these dietary
69 assessment methods have been validated in military-settings; (iii) to provide a recommendation
70 as to which method(s) should be used in military-settings and which need further validation.

71

72 **METHODS**

73 This scoping review was conducted according to the PRISMA extension for scoping reviews
74 (PRISMA-ScR) (9).

75 Eligibility criteria

76 The eligibility criteria excluded: (1) non-military personnel studies; (2) studies not published
77 in English; (3) studies which were not full-text available; (4) studies which did not quantify
78 dietary intake; (5) PhD dissertations; (6) conference abstracts. To be included studies had to:
79 report original data, assess and quantify dietary intake and have been published in peer-
80 reviewed academic journals. Research reports were considered.

81 Database searches

82 Information searches were conducted in PubMed (the search engine for Medline), web of
83 science and SPORTDiscus with all years included up until the 12th June 2020. Search terms
84 that were entered into each database are presented in Table 1.

85 Study selection

To select the sources of evidence the titles and abstracts of identified papers were screened by one reviewer (SC) and those with titles not deemed relevant were removed. Remaining papers were then screened by two reviewers (SC and LS) against the inclusion and exclusion criteria and any differences were resolved by discussion. Reference lists of remaining papers after review were then searched to identify papers missed in electronic searches, and reference lists of those papers, and so on until no further papers could be identified.

Table 1 Search terms

PubMed	"dietary intake" [MeSH Terms] AND "military" [MeSH Terms] OR nutrient intake [All Fields] AND army [All Fields].
SPORTDiscus/web of science	Dietary intake and military or nutrient intake and army

Table 1. Search terms used for database search in PubMed, SPORTDiscus and web of science

Data extraction

The following data items were extracted from each paper: author, year of publication, study design, sample size, setting, dietary assessment method, key findings and method considerations highlighted by the original authors. Findings from the scoping literature were grouped and presented according to the dietary assessment method used. Once studies had been identified the method(s) which were utilised were recorded. If the study conducted a measure of validity of their dietary assessment method, this was also recorded. In studies which estimated daily EE (only using doubly labeled water (DLW)), the reporting bias was calculated as recorded EI – recorded EE / recorded EE (10). This was used as a method to indicate whether the specified dietary assessment method(s) potentially under or over-estimated energy intake. It was acknowledged that participants are required to be weight stable for the reporting bias to be effective.

RESULTS

Literature search

The search conducted in PubMed retrieved 209 papers, of which 28 were taken forwards to full-text review. SPORTDiscus and web of science searches resulted in 636 and 151 papers being identified. After excluding records due to an irrelevant title 41 duplicates were identified but an additional 14 previously unidentified papers were added to the full-text review. A total of 42 papers were fully reviewed, 8 of these were excluded. The reasons for these exclusions were that 1 paper was not undertaken during military training, 1 paper was not original data, 1 paper did not assess dietary intake and 5 were only available as abstracts. The reference lists of all remaining papers (34) were searched and 1 further paper was identified and included. A total of 35 papers were included (Figure 1).

Insert Figure 1 here.

Synthesis of results

The FFQ was used in the majority (11 studies) followed by the FD (five studies) and the food intake/waste collection method (four). The remaining studies used Visual estimation (VE) (three), ration discards (two) dietary recall (two) and WFRs (one). The results of these studies are summarised in supplementary Table 1.

It was found that in the studies which used more than one method of dietary assessment together the FFQ with dietary recall was used in two studies. While VE with ration discards, VE with a FD, FD with dietary recall, WFR with ration discards or WFR with a FD were each used together in one study. The results of these studies are summarised in supplementary Table 2.

DISCUSSION

It was most common to measure dietary intake via one method only and these were either the FFQ (11 studies), FD (five studies) or the food intake/waste collection method (four studies). These methods were used in a variety of settings including training establishments, field exercise and on deployment. Overall, there was a lack of reported validation for all methods in military settings with only the WFR method being validated against the food intake/waste method.

Summary of evidence: single methods only

Weighed food intake/waste collection

Of the 28 studies which used a single method, four of these used the gold standard weighed food intake/waste method (11–14). This method was used in a thermal chamber (11) and during field exercise (12–14). Given this method requires the precise nutritional content of foods to be known its use may be limited to ration foods or pre-prepared and packaged foods. In settings where this may not be possible an alternative method may need to be considered. Furthermore, given that this method is more time consuming and laborious compared to others (FD, FFQ) (3) it may be only feasible with smaller sample sizes, such as those identified in this review (11–13).

Weighed food records (WFR)

One study validated the WFR method wherein participants were provided food scales to weigh portion sizes (3). The Bland-Altman analysis demonstrated good agreement between the two methods with a mean bias of 108 $kcal \cdot day^{-1}$. As this is the only study to validate its method it suggests that researchers should use WFRs where feasible and where the food intake/waste method cannot be conducted. In scenarios where it is not possible to provide participants with

154 food scales, researchers should consider supervising the weighing of food (1), such as in
155 canteen settings. In settings where neither of these methods are feasible, other methods may
156 have to be considered.

157 Food Frequency Questionnaire (FFQ)

158 Eleven studies utilised the FFQ but none validated its use against the food intake/waste
159 collection method. Two studies observed EI in participants below that of the military dietary
160 reference intakes (MDRIs) with a simultaneous gain in body mass (8,15). In 70 female Israeli
161 recruits, daily EI was 74% of the MDRIs but participants gained body mass over a four-month
162 period, which suggests EI may have been underreported by >26 % due to participants being in
163 a positive energy balance (8) (supplementary Table 1). One study aimed to validate a FFQ
164 against a FD in military men and concluded that the FFQ had good reproducibility and validity
165 compared to the FD (7). However, a Pearson correlation was used to assess the validity of the
166 FFQ which may not be suitable, and instead, a Bland-Altman analysis should be used to assess
167 the agreement between two methods at measuring the same outcome (16). Also, the FD is not
168 a gold-standard method and therefore cannot be used to validate another (6,17).

169 The FFQ is a practical and feasible method which may be suitable to use when assessing dietary
170 intake over long periods of time (18) and particularly if validated in the specific population
171 being studied (7,8). Furthermore, control measures, including photos of food portion sizes (19)
172 and removing implausible intake data should be considered (20,21).

173 Self-report food diary (FD)

174 Five studies used a FD in a variety of settings (training establishments, garrisons, deployment)
175 (6,17,22–24) and over a range of durations ranging from three days (24) to twelve days (6) with
176 seven consecutive days being the most common (17,25). Increasing the recording period over
177 seven days may lead to reduced subject compliance (2). Adherence was not reported in the

178 studies evaluated here (6,17,22,24,25) but it was demonstrated that using a handheld personal
179 digital assistant instead of written records reduced participant burden whilst maintaining data
180 accuracy (25) whilst another found it may be valid in this population (3). Future studies should
181 consider validating methods which combine modern technology with the FD as this may be a
182 technique of enhancing dietary assessment validity, although it is acknowledged that this may
183 not always be feasible in some settings (field exercise). The reporting bias of the FD was
184 calculated in four out of the five studies and similarly to the FFQ it generally underestimated
185 EI although in one study EI was overestimated (25). The reporting bias for the remaining studies
186 ranged from -18 % -34 % which is smaller than the reporting bias for VE, dietary recall and
187 via collection of ration discards (supplementary Table 1). The use of the reporting bias method
188 may be limited due to participant weight loss across the study intervention (supplementary
189 Table 1). In this case the reporting bias may not reflect underreporting.

190 The lack of validation studies using the FD should be acknowledged. The number of recording
191 days should reflect the research question with three to seven days required to assess habitual
192 energy and macronutrient intake but more days or recording time-points required for assessing
193 micronutrient intake (1,26). Furthermore, when the analysis of FDs is undertaken by multiple
194 researchers the variability within the data may increase and therefore this should be done by
195 the same researcher (27) and who is experienced in FD analysis (24).

196 Future studies should aim to validate the FD further by comparing this method against the food
197 intake/waste method (3). Researchers may also want to consider control measures to improve
198 data accuracy. These may include a familiarisation process or pilot test being implemented with
199 potential participants prior to data collection, providing detail to participants on how to
200 complete the diary and estimate portion sizes (25) or assess the prevalence of reporting bias by
201 calculating the EI:EE ratio. A ratio between 0.76-1.24 indicates acceptable reporting of EI,
202 whereas <0.76 indicates underreporting of EI and >1.24 indicates an overreporting of EI (10).

203 Visual Estimation Method (VE)

204 Three studies used the VE method in canteen settings (23,28,29). In one study (29) where EE
205 was measured the VE method appeared to underestimate EI due to EI reported to be lower than
206 EE with no change in body mass. This method showed high variability between researchers
207 when estimating portion sizes with 43 % of food records requiring adjudication (23). In another
208 study (23), the mean daily EI of 487 male and 48 female U.S. Army soldiers in the on-site
209 dining facility (lunch time only) decreased over a six-month period but they did not lose body
210 mass (supplementary Table 1). It is unknown if this was due to an underestimation of EI or a
211 change in the physical demands of training. Together these studies provide evidence that VE
212 is feasible within a military canteen environment but its use in other settings may be limited.

213 Dietary Recall

214 The limitations of dietary recall are well documented such as requiring a trained interviewer
215 and relying on memory (2). This review found that dietary recall was used with smaller sample
216 sizes compared to those studies using the FFQ, FD and VE and that it was used in deployment
217 and field exercise settings. Both of these studies did not validate its use against the food
218 intake/waste method so its accuracy in this population remains unknown. In one study (30) the
219 reporting bias was greater than that for studies which have used a FD or VE but less than studies
220 which used only ration discards (supplementary Table 1). In another study in U.S. Special
221 Operation Forces (SOF) (30) the participants lost body mass (supplementary Table 1).
222 Therefore, the calculation of the reporting bias may not reflect underreporting. Future research
223 should aim to validate the dietary recall method in military populations as there is currently a
224 lack of data investigating this. Until then other methods should be considered due to this and
225 the known limitations of this method.

226

227 Ration Discards

228 Two studies used the ration discard method (31,32). Twenty-one male Norwegian soldiers had
229 EI and EE assessed during two phases (MTT and SKI). Participants were provided three rations
230 per day (3800 kcal·day^{-1}) during MTT and five rations per day (5100 kcal·day^{-1}) during SKI.
231 Dietary intake was determined from returned ration discards and ration food logs collected
232 daily (31). The reporting bias for these two phases were -43 % and -49 %, respectively. In the
233 SKI phase no weight was lost and thus the reporting bias calculated during this phase may
234 reflect underreporting. In the second study no validation method was used and due to no
235 measures of EE no reporting bias could be calculated (32). These data suggest that the
236 assessment of EI via the collection of ration discards alone should be avoided and other
237 methods should be considered (supplementary Table 1).

238 **Summary of evidence: combined methods**

239 Seven studies used a combination of methods together in garrison and field exercise settings,
240 but none validated their methods. The reporting bias was only calculated for three studies. The
241 VE method combined with a FD may have underreported (33). In another study the WFR
242 method combined with the collection of ration discards may have also both underreported EI
243 (34). The use of the VE method and collection of ration discards in weight stable participants
244 suggest the methods were accurate at estimating EI (35) (supplementary Table 2). Using a
245 combination of methods to assess dietary intake may increase the confidence in data reporting
246 accuracy. For example, WFRs, which are feasible in canteen but not field exercise settings due
247 to practical constraints could be used in combination with a FD or FFQ. Studies using a
248 combination of methods together and that validate this approach need to be conducted to
249 confirm this.

The reporting bias could not be calculated for the remaining four studies (19,36–38) and due to no validation method, it is difficult to establish whether the participants in these studies underreported EI.

LIMITATIONS

To our knowledge this is the first scoping review which evaluates methods for assessing dietary intake in military settings. The main limitation is that due to most studies not validating their method, we were unable to evaluate the validity of the methods identified. It was possible to calculate the reporting bias for studies that measured EE, but this was not possible for all studies. Furthermore, as acknowledged in our discussion, several studies used participants which were not weight stable, and therefore, the reporting bias may not reflect an underestimation of EI. Finally, as this was a scoping review, no ranking of study quality was conducted.

CONCLUSIONS

The most commonly used methods were the food intake/waste method, the FFQ and FD. Only WFRs method has been validated and therefore researchers should use this or the food intake/waste method where feasible. If using alternative methods such as the FFQ and FD due to feasibility constraints, then appropriate control measures such as a pilot/familiarisation for participants or reviewing reported data with participants should be considered. Future research should aim to validate other methods such as the FFQ and FD given their common use and feasibility. This will then allow nutrition research in this field to produce accurate assessments and nutritional recommendations relevant to individuals in this population.

ACKNOWLEDGEMENTS

There are no acknowledgments.

COMPETING INTERESTS

The authors have no competing interests.

FUNDING

There was no funding for this review.

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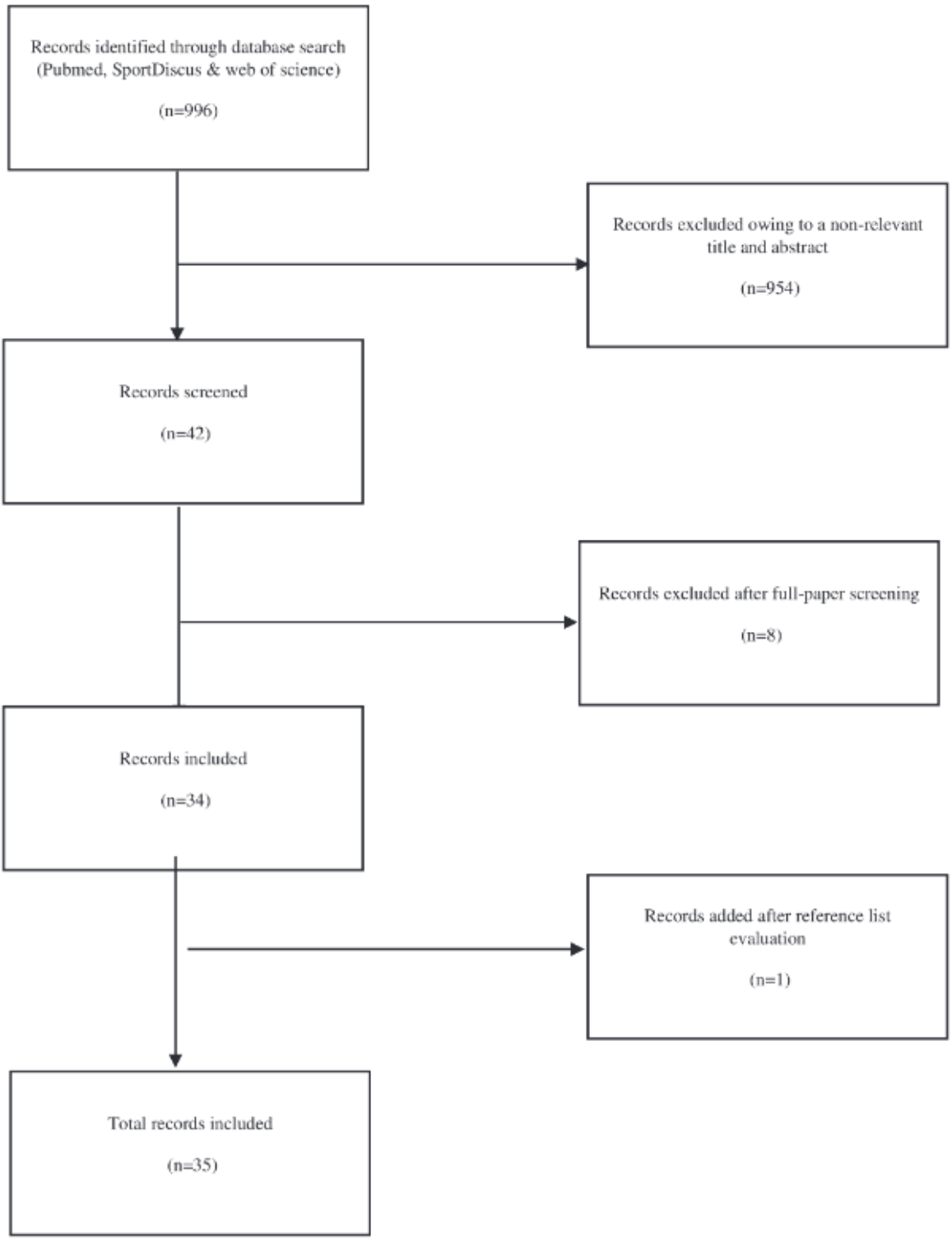
Figure 1

Preferred Reporting Items for Systematic Reviews and Meta- Analyses (PRISMA) extension flow chart of the screening process from initial search to records included



Supplementary Tables

Supplementary Table 2. Description of quantitative studies which have assessed dietary intake in military populations using two or more methods.

Study	Year	Design	Sample and setting	Method	Validation Method	Key Findings	Method considerations	~reporting bias
Chapman et al.	2019	Observational cross sectional	17 male and 28 female British Army recruits in basic training	WFR and 8-day FD	None	EI was 2846 ± 573 kcal·day^{-1} in men and 2207 ± 585 kcal·day^{-1} in women which was less than the recommended 3100 and 4100 kcal·day^{-1}	Participants should be briefed on how to complete FD and information should be checked by the researcher. Data processing should be completed by one researcher to reduce variability	N/A
Beals et al.	2015	Cross sectional	327 male & 67 female U.S. soldiers in garrison	FFQ & dietary recall	None	EI of 2574 ± 974 kcal·day^{-1} (males) and 1920 ± 956 kcal·day^{-1} (females), representing 88% of males and 83% of females estimated EE. Significantly more males vs. females (23% vs. 9%; p=0.035) reported EI that fell between 90% and 110% of their estimated energy requirements	None to report	N/A
Margolis et al.	2013	Cross sectional	36 SF soldiers. Cohort 1(airborne operations), cohort 2 (field exercise)	VE & Ration Discards	None	Energy and macronutrient intake were highest when eating in the dining facility. BM decreased by 4.2 kg. Soldiers were in NEB ~2390 kcal·day^{-1}. Cohort 1 were weight stable	None to report	Cohort 1 = 0 % Cohort 2 = -51 %

Supplementary Table 2. Continued.

Study	Year	Design	Sample and setting	Method	Validation Method	Key Findings	Method considerations	~reporting bias
Stark et al.	2008	Cross sectional	31 Israeli male pilots in garrison	FFQ & dietary recall	None	Daily EI (2657 ± 168 kcal·day^{-1}) was 82% of estimated EE (3250 kcal·day^{-1})	Photos of portion sizes and measuring cups and spoons may be used to improve data accuracy	N/A
Tharion et al.	2004	Cross sectional	45 U.S. soldiers in garrison	VE & FD	None	EI was 3024 kcal·day^{-1} which was less than the estimated energy requirement of 4200 kcal·day^{-1}	None to report	-11 %
Arsenault and Cline	1999	Cross sectional	50 female U.S. recruits in garrison	FD & dietary recall	None	EI of the RED and non-RED groups were 1961 ± 101 and 2097 ± 59 kcal·day^{-1}, respectively	None to report	N/A
Forbes-Ewan et al.	1989	Cross sectional	4 Australian soldiers in garrison	WFR & RD	None	EI was 4040 kcal·day^{-1}. Body fat loss was 1.2kg. EE was recorded to be 4750 ± 531 kcal·day^{-1}	None to report	-14 %

The data extracted included author, date of publication, study design, sample, method of dietary assessment, validation method, key findings and key recommendations. United States (U.S.), body mass (BM), energy intake (EI), military dietary reference intakes (MDRIs), food frequency questionnaire (FFQ), food diary (FD), visual estimation (VE), doubly labelled water (DLW), energy expenditure (EE), kilojoule (KJ), change in (Δ)., Negative energy balance (NEB), weighed food record (WFR), ration discard (RD), reduced energy foods (RED).