A structured review of literature on body composition profiles in Navy personnel: current practices and considerations for the future

K Havenetidis, A Bissas

Abstract

Introduction
There is need of a better understanding of body composition profiles in multi-national Navy personnel and their relationship with health and fitness. The aim of this review was to produce a critical assessment of original research addressing body composition in this military branch.

Methods
Electronic databases PubMed and SPORTDiscus were searched to identify surveys and randomised clinical trials from journal articles and technical reports investigating body composition profiles on Navy populations.

Results
Twenty-two studies were selected on the basis of stated inclusion criteria for military surveys and randomised clinical trials. Excepting Navy personnel in special operation force units, data indicated that body composition profiles, as determined by Body Mass Index (BMI) and body fat percentage for Navy personnel, were lower compared to respective Army profiles. BMI values increase from shore to ship deployment, with body composition profiles showing less healthy trends for personnel serving on vessels with limited space, whilst special operation forces do not conform to this pattern, constituting a mission-oriented body composition profile.

Conclusions
Body composition profiles in multi-national Navy personnel vary in relation to other military branches, geographical locations, specialty and deployment status. There is a need to validate new body composition techniques so recruitment is based on more representative profiles. Finally, the development of fitness interventions for personnel serving on vessels is deemed absolutely necessary in order to counterbalance health and fitness negative adaptations.

Introduction
Military resilience and preparedness require high levels of physical conditioning. Body composition amongst other factors (muscular endurance, aerobic fitness, muscular strength, flexibility) is considered one of the essential components determining health in all combat-oriented branches of the military. Despite its importance for military performance the prevalence of obesity (Body Mass Index (BMI) greater than 30) in the military increased by 17% per year between 2005 and 2012. Although some data exist on body composition of Army personnel, fewer data are available for Navy recruits ashore or afloat, making it difficult to implement targeted interventions and education programmes among at-risk recruits. In addition, Army recruits may engage in different occupational tasks compared to their Navy counterparts. These mission differences may require varying fitness levels which might prove crucial to the appraisal of obesity prevalence and risk to obesity-related diseases in the Navy. Of particular interest are the deployment conditions under which Navy personnel are assigned to perform, primarily afloat, based in a range of vessels characterised by differences in the available space (e.g. aircraft carriers versus submarines). For example, a recent study has shown that significant differences existed in body composition between personnel assigned to three different United States (US) Navy operational workplaces.

These issues necessitate the need for research utilising Navy populations to quantify body composition and set the limits for overweight and obesity thresholds in Navy personnel. The aim of this article is to provide a review of the current literature regarding the body composition profiles in Navy personnel. This article will examine early and recent studies conducted using Navy personnel and compare body composition data with those obtained in other military branches in order to describe the spectrum of body composition profiles in the Navy, and to
achieve a better understanding of the environmental factors contributing to these profiles.

**Data from early studies (1984-1999)**

These studies\(^5\)\(^6\) were driven by the axiom that anthropometric predictive equations such as those derived by an earlier related study\(^7\) tend to be population-specific; therefore, it was firstly necessary to cross-validate those equations and statistics with Navy populations. For this reason, emphasis was given to body composition estimation equations and how accurately body fat for Navy personnel can be predicted via non-specific equations using circumferences, skinfolds and height measurements. The data showed that for Navy populations ashore, with ages ranging from 31 to 33 years, body fat values ranged from 21.6% to 27.7% (calculations were based on circumferences and skinfolds measurements).

However, the above values should be treated with caution, as the key message of these studies was that the dated circumference equations used for predicting body composition in Navy personnel classified incorrectly 6.8% and 18% of the recruits sampled as overweight and obese respectively. Further data were communicated by Conway and Cronan in a later study which primarily assessed the efficacy of conditioning and obesity programmes in various Navy groups (enlisted and officers) characterized by an average age of 28 years.\(^8\)

Body composition values (body fat percentages measured via circumferences), obtained as part of physical fitness testing, presented significantly lower percentage body fat (mean value 15.8%) compared to the earlier studies.

Lineger et al.\(^9\) in their study approached the effect of environment on physical fitness and subsequent body composition in a more holistic manner by assessing a range of contributing factors, including lifestyle and family circumstances. By utilising the same method for body fat determination, they reported identical body fat values (15.8%) to the study of Conway & Cronan in Navy recruits of similar age (average age 29 years).

Similar findings were also presented by Trent and Hurtado,\(^10\) but the most interesting aspect of that study was that body fat values significantly increased for the two cohorts studied longitudinally. In particular, the first cohort of Navy personnel which was followed for 8 years showed an increase in their body fat from 15% to 17.4% whilst the second cohort, followed for 11 years, showed an increase from 16.4% to 17.3%. The same picture emerged for BMI values where an increase from 25.1 to 26.5 and from 24.4 to 26.1 was evident for the 8 and 11-year time frames accordingly. This study was the first to provide longitudinal data concerning a variety of health behaviours and fitness measures for Navy personnel. It also highlighted the growing effect of obesity on military populations and specifically on Navy recruits.

Finally, a study by King-Lewis and Allsopp\(^11\) investigated the effect of 16-week ship deployment on health and fitness status utilizing Navy personnel with an average age of 28.0 years, BMI 25.5 and body fat of 20.3%. Data showed that BMI values remained unaffected following deployment whereas body fat values were elevated by an average of 5.4% (3.8-7.0%).

**Data from recent studies (2000-2018)**

Recent studies have been characterised by a large range of independent variables such as nationality, type of enlisted personnel, age category, and vessel type, as presented in Table 1.

Data obtained by Vantarakis et al.\(^12\) as part of a training study investigating the effects of a resistance training regimen on two similar groups of Navy cadets in Greece located within the residential setting of the Naval Academy, showed average body fat and BMI values of 9.1% and 23.5 respectively. These data acquire more meaning when compared with results reported in the same year for infantry recruits of the Greek (Hellenic) Army Academy of similar age who possessed higher values for both body fat (14.7%) and BMI (25.0).\(^13\)

A similar variance between Navy and Army cadets is observed when data from studies conducted in the USA with Navy cadets from the US Naval Academy and students from the Uniformed Services University,\(^14\)\(^15\) are contrasted against Army data for similar populations\(^16\) with the Navy personnel having lower BMI values (24.6 versus 26.1). These body composition profiles for the Navy cadets remained unchanged during a subsequent three-year period as data drawn from their bi-annual physical fitness readiness tests showed.

In Asia, studies from Malaysia show that BMI values for Navy personnel were lower (21.6 versus 23.0) but body fat values were higher (16.8% versus 10.2%) in relation to the respective groups of the Army branch.\(^17\)\(^18\)

In Europe, Malavoti et al.\(^19\) assessed body composition using various methods [air displacement plethysmography (ADP), ultrasound, dual-energy x-ray absorptiometry (DXA), skinfolds, waist to hip ratio, BMI] in a group of deployed Italian Navy officers. The authors concluded that body fat percentage measured via skinfolds showed significantly higher values compared to other methods used in that study, but in each case all body composition indices were higher than those reported ashore by another research group from a different European nation as described above.\(^12\)

Another large scale study\(^20\) (n=18,537) utilising US Navy troops deployed in Iraq and Kuwait showed higher BMI values (26.3) in comparison to US Navy personnel ashore (25.3).\(^21\) The same trend was observed in a study conducted in Greece\(^22\) (n=274) where BMI values of Navy officers deployed to a warship were elevated by 5.5% compared to those reported for other Greek Navy staff on land (23.5 versus 24.8). Comparisons made by various research groups\(^4\)\(^23\)\(^24\) using specialised employment groups, such as submariners and crew in aircraft carriers have highlighted the effect of limited space and exercise availability on body composition and obesity levels. Examination of the data from these studies indicates
Table 1: Recent studies (2000–2018) across the world containing body composition data from various Navy groups (values presented as means).

<table>
<thead>
<tr>
<th>Study No</th>
<th>Subjects</th>
<th>Sample size</th>
<th>Age</th>
<th>Body composition index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Category</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BMI 26.7 SS; 26.5 LS; 26.3 AC</td>
</tr>
<tr>
<td>USA</td>
<td>US crew in SS, LS &amp; AC</td>
<td>5439 SS; 3707 LS; 17195 AC</td>
<td>26.6 SS; 26.4 LS; 26.5 AC</td>
<td>BMI 24.7</td>
</tr>
<tr>
<td></td>
<td>US Navy cadets</td>
<td>1397</td>
<td>18</td>
<td>BMI 24.6</td>
</tr>
<tr>
<td></td>
<td>US Navy students</td>
<td>51</td>
<td>18-21</td>
<td>BMI 26.3</td>
</tr>
<tr>
<td></td>
<td>US Navy crew</td>
<td>18537</td>
<td>28.8</td>
<td>BMI 24.9</td>
</tr>
<tr>
<td></td>
<td>US Navy personnel</td>
<td>50</td>
<td>18-24</td>
<td>BMI 28.0; BFP via DXA 27.3%</td>
</tr>
<tr>
<td></td>
<td>SEAL trainees</td>
<td>1046</td>
<td>23</td>
<td>BMI 24.9</td>
</tr>
<tr>
<td></td>
<td>US Navy SOF teams</td>
<td>18</td>
<td>36.8</td>
<td>BMI 27.1</td>
</tr>
<tr>
<td></td>
<td>SEAL teams</td>
<td>85</td>
<td>29.2</td>
<td>BFP via ADP 16.5%</td>
</tr>
<tr>
<td></td>
<td>SEAL teams</td>
<td>18</td>
<td>31</td>
<td>BFP via ADP 17.5%</td>
</tr>
<tr>
<td>EUROPE</td>
<td>Greek Navy cadets</td>
<td>31</td>
<td>20.5</td>
<td>BMI 23.4; BFP via SF 9.1%</td>
</tr>
<tr>
<td></td>
<td>Italian Navy crew</td>
<td>27</td>
<td>24.9</td>
<td>BMI 25.4; W/H 0.83; BFP via DXA 13%; via ADP 14%; via SF 16%</td>
</tr>
<tr>
<td></td>
<td>Greek Navy crew W</td>
<td>274</td>
<td>24.4</td>
<td>BMI 24.8</td>
</tr>
<tr>
<td></td>
<td>Norwegian SOF teams</td>
<td>28</td>
<td>28.0</td>
<td>BFP via BIA 11.5%</td>
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<tr>
<td>ASIA</td>
<td>Malaysian Navy personnel</td>
<td>1818</td>
<td>28.3</td>
<td>BMI 23.9; BFP via BIA 22.5%</td>
</tr>
<tr>
<td></td>
<td>Indian crew W &amp; SB</td>
<td>35 W; 20 SB</td>
<td>24.8 W; 26.5 SB</td>
<td>BFP via BIA 11.9% W; 14.4% SB; W/H 0.85 W; 0.88 SB; BMI 20.4 W; BMI 21.8 SB</td>
</tr>
</tbody>
</table>

SS=small submarines, LS=large submarines, AC=aircraft carriers, BMI=body mass index, BFP=body fat percentage, DXA=dual-energy x-ray absorptiometry, SEALs=Sea, Air and Land teams, SOF=Special Operations Forces, ADP=air displacement plethysmography, W/H=waist to hip ratio, SF=skinfolds, W=warship, BIA=bioelectrical impedance analysis, SB=submarine

an average 5% (range 1.5-6.9%) increase in BMI values in Navy recruits, of similar age, deployed in small submarines compared to larger vessels. It seems that BMI values follow a pattern depending on the Navy group’s residential setting.

Finally, interesting data have been recorded by studies utilising Navy units of Special Operations Forces (SOF) of varying ages. In particular, BMI values collected by Trone et al.²⁵ for US Navy SEALs (n=1,046) were found to be just below the overweight limit (25.0) set by the World Health Organisation (WHO) but lower in relation to an Army SOF group²⁶ (SEALS 23.9 versus Rangers 26.0).

However, Jensen et al.²⁷ employed a Navy SOF group, and reported an average BMI value of 27.1, which was above the overweight cut-off point but represented a higher mean age sample group (23.3 years versus 37.0 years) compared to the Trone study. Abt et al.²⁸ and Oliver et al.²⁹ presented body fat values for SEAL teams which were higher (16.5% and 17.5% versus 13.1% respectively) in comparison to a younger age cohort in the US Army³⁰ (29 years and 31 years versus 21 years respectively). In contrast, data on Navy SOF from a study conducted in Norway³¹ showed that body fat values (11.5%) were lower (15.7%) than those reported for the respective Norwegian Army SOF (Rangers) units.³² It is worth mentioning that in the aforementioned studies Navy personnel²⁸-²⁹,³¹ were still within the acceptable range of body fat for US SOF units (below 18%).³³

Discussion

This review provides an appraisal of body composition profiles in multi-national Navy personnel. When comparing BMI and body fat values in relation to the respective Army data, in almost all studies conducted ashore²²,²⁴,²⁵ (except for the study of Razalle et al.²⁷), a lower body composition profile was evident for Navy personnel. This is an important observation, as all comparative data were collected via similar methods of body fat measurement and from analogous age groups.
However, BMI values during ship deployment have been reported to be higher than those obtained for personnel ashore; this is a universal trend as it is apparent in US (26.4), European (25.1), and Asian crews (21.1) despite the fact that the latter crews are traditionally characterised by lower BMI values. This trend was further magnified when Navy personnel were assigned to vessels with limited space. It is well known that deployment is considered stressful, so it is reasonable to assume that deployment to a vessel, with limited space having an added effect, has the potential to intensify the expected levels of stress due to particular conditions not existing ashore. Apart from the psychological impact of considerable time away from familiar settings, many potential health risk factors such as inactivity, limited nutritious meal opportunities, alongside the demand for consistent optimal performance for extended periods of time, may operate cumulatively towards an impaired total force fitness.

Even though this trend within Navy personnel is observed similarly in different countries, some main differences in body composition exist between Navy groups in different continents. For instance, average BMI values in seven out of ten US Navy studies were 26.6 (above the 25.0 overweight limit) whilst, in almost all European and in all Asian studies, Navy recruits were on average below the overweight limit (23.4-25.4 and 21.8-23.9 respectively). Figure 1 depicts these differences and shows that the spread of BMI values increases when results are combined from different continents, whereas the variance lowers when considering only the US Navy studies, which display higher BMI values in both categories (ashore-based and ship-deployed) than the other countries.

However, when body fat rather than the BMI becomes the variable of interest, the picture alters significantly. The same US Navy recruits from the same studies are now considered non-overweight given an average body fat value of 19.0% (which is below the 22.0% threshold set for Navy recruits from 17 to 39 years of age). When the US body fat threshold (22%) is applied to Navy troops from Europe and Asia for the sake of cross-continent comparison, these troops also remain below this overweight limit (11.6% and 17.8% respectively). As BMI is influenced by various factors, commitment to the same overweight limit (e.g. BMI=25.0) in people of different ethnicities and backgrounds may be problematic, as those ethnicities and backgrounds are bound by specific fat distributions.

The diagnostic challenges associated with BMI in obesity classification are also evidenced by the results of Gasier et al. who reported that 38% of submariners in their study were misclassified as not obese by BMI measurements when using the 25.0 cut-off point. This study was one of the few in which body fat measurement in Navy personnel was evaluated via DXA. Early investigators exclusively used circumference equation methods for body fat determination. They suggested that body composition measurements should be assessed with care, so that candidates with potential to offer good service in the Navy remain eligible for recruitment despite the limitations of calculating body composition profiles from surrogate measurements.

Another study conducted almost 20 years later highlights that this problem still exists. By examining the use of different parameters (circumference or skinfold-based) for body fat prediction the authors suggested that the circumference-based equations used in the US military might be unsuitable for assessing individual body composition. A 42% difference between circumference (309 noncompliant recruits) and skinfold-based (438 noncompliant recruits) measurements was shown in the number of recruits classified as non-compliant with US Navy standards. Additionally, body fat percentages calculated by circumference skinfold equations differed by more than 3.0%, 2.2% and 2.3% for the age groups of 21-29 years, 30-39 years and 40-49 years respectively. In spite of their aptness and usability, it seems that the current practices in the Navy cannot correctly identify those recruits who do not meet the military standards, nor do they accurately predict body fat percentages. A further challenge has been highlighted by Schuna et al. who reported that the prediction equations and methodology used by the US Department of Defense (common for all branches of service) were not adequate to detect body composition differences following small body changes.

![Figure 1: Body mass index profiles under ashore-based and ship-deployed conditions in various military (Navy) groups, apart from Special Forces, across the world and in the US (mean ± standard deviation values).](image_url)
A related point to consider is that the early studies utilised US Navy personnel of an average age of 30 years and with a very narrow standard deviation in evaluating recruits’ capability to pass fitness limits or to fulfil their specific military occupational tasks. However, it was shown that large differences existed in body fat percentages between subsequent age groups on either side of the sample age of 30 years. This critical observation was not taken into consideration when setting the limits for the Navy according to the maximal allowable body fat percentages by branch of service.38 Greater age stratification for the US Army exists (four age categories: 17-20 years, 21-27 years, 28-39 years, 40+ years) whilst the Navy includes only two age categories (17-39 years and 40+ years). This limited stratification for Navy age categories may provide a more rounded estimate of body composition of the enlisted Navy personnel, but it may also be considered an unfair procedure for those recruits who are in the upper age limit.

A further parameter influencing military body composition profiles is the broader trend in the whole population. Since military personnel reflect the civilian population from which recruits are drawn, any pre-recruitment dietary or lifestyle habits and genetic predispositions leading to the occurrence of obesity at an earlier age stage have to be taken into account when attempting to understand military body composition profiles. For instance, obesity trends for ages 12-19 years in the US show a substantial increase from 6.1% in the period 1971-74 to 20.6% in the period 2013-14.37 Likewise, for 18-year olds applying to enter the US Army between 1993 and 2006, the prevalence of being overweight (BMI >25.0) increased from 25.6% to 33.9%.38 Thus, a more frequent body composition examination in military populations from the enlistment age, and with greater frequency afterwards, could be informative for assessing the magnitude and progression of obesity. However, even with a more regular BMI measurement throughout a military career, serious doubts exist as to whether BMI can ensure a reliable classification to overweight or obese categories for Navy personnel. This is compounded by the observation that when deployed, Navy personnel are potentially exposed to fewer physical fitness opportunities and appropriate dietary choices than their Army counterparts.

Taking into account the results and arguments presented so far, it becomes clear that there is a need to increase the accuracy, reliability and specificity of body composition measures in the Navy by basing them on primary data collected on Navy units through contemporary measurement techniques. Some of these include computerized axial tomography, air displacement plethysmography (ADP), magnetic resonance imaging, ultrasound, DXA, and bioelectrical impedance analysis (BIA). Contrary to previous body composition methods (circumferences and skinfolds) based on the two-compartment model (fat and fat-free mass) these new techniques provide information on various parameters such as fat, lean soft tissue, bone mineral, body cell mass and total body water. This information might prove critical in the Navy, where operational stressors related to the environment, such as vibration, noise and radiation, or to metabolism, such as sleep deprivation, malnutrition, and inactivity, can be further aggravated by a prolonged stay on small vessels. These stressful conditions may alter the hormonal (cortisol, growth hormone, insulin) fluid distribution and physiological status. This can only be detected by specific body composition parameters such as body cell mass and water content.39

Despite being characterised by high accuracy, the necessary equipment is expensive and requires a high level of technical skill to use.40 These factors may make access to these technologies challenging so, when such measurements are not available, credible alternatives should be sought. BIA may provide the most useful alternative when measuring the aforementioned body composition parameters in Navy personnel. It is affordable, transportable and requires minimal operator training.41 As standardisation of dietary intake and physical exercise already applies ashore and especially afloat in most Navy units, variation in body composition parameters via BIA may be related only to the validity of the reference method.42

Where SOF Navy units are concerned it seems that BMI values are not aligned with other Navy groups. Young US SOF trainees would be expected to present lower BMI values compared to general Navy populations, as selection for such units is based on criteria requiring taller recruits with low body fat. A reasonable explanation for this finding would be the higher muscle mass characterising SOF personnel, which inevitably influences BMI readings given the weakness in discriminating between lean and fat mass.43 Consistent with this reasoning, and by extrapolating data from Solberg et al.31 and Singh et al.,44 who used the same measurement method on populations of similar age, it is observed that the Norwegian Navy SOF units, whilst sharing similar low body fat values (<12%) with non-SOF Indian Navy personnel, in contrast exhibited higher average BMI values (25.1) compared to those of the Indian crews (21-22). This variance between SOF and non-SOF units is partly supported by the fact that, although all service groups promote general physical readiness and good health, BMI calculations for SOF units may exhibit higher than expected masses for heights.45 As BMI is related to health promotion and not to military task performance,46 present data indicate that SOF Navy units possess a unique body composition profile which enables successful fulfilment of military-relevant tasks according to specific operational roles and needs.

Considering the absence of previous literature presenting and contrasting Navy body composition profiles from around the world, this synoptic review provides an initial platform for exploring and explaining such profiles. It is acknowledged that the number of studies included in this review is small and influenced strongly by the US literature, but this has been
dictated by the exclusion criteria, which ensured that only Navy studies following rigorous methodological standards were included. Therefore, the strength of this review is the collection of all well-designed studies globally which comprise, exclusively, body composition data for Navy personnel.

Finally, several within- and between-country comparisons were made in order to provide the reader with some comparative summaries. It is appreciated that such comparisons between unrelated studies could be over-ambitious, due to the lack of reproducibility and measurement error data, but it was felt that a level of synthesis was also required in order that initial and useful conclusions could be drawn from this review.

Conclusions

In this review, body composition data are described from various Navy groups characterised by different ethnicity, age, deployment status, specialty and vessel type. Although the use of body composition standards, mainly based on BMI guidelines as a normal practice, is not the ideal methodology for assessing and monitoring adiposity in Navy recruits, this body composition index alongside body fat percentage appears to be lower than those reported for respective Army groups.

Furthermore, BMI values increase from shore to ship deployment, with body composition profiles showing less healthy trends for personnel serving on vessels with limited space. Contrary to this, SOFs do not conform to this pattern as they constitute a mission-oriented body composition profile. Future studies should focus on validating new body composition techniques on specific Navy groups such as submariners, and assess the effects of deployment period on weight loss and gain interventions. This will facilitate recruitment based on more accurate scores, so that candidates are not excluded from service, and the development of fitness interventions for personnel afloat in order to counterbalance negative health and fitness adaptations that may arise from spending significant time in spaces with limited capacity for physical activity.

References

is not associated with performance on military relevant tasks in US Army Soldiers.


