

Assessing injury risk in male and female Royal Navy recruits: does the Functional Movement Screen provide understanding to inform effective injury mitigation?

J. Gibbs,¹ C N T Power ,² D Böhning,³ M Warner,⁴ S Downie,⁵ A Allsopp,⁵ M Stokes,⁴ J L Fallowfield¹

¹Institute of Naval Medicine, Alverstoke, UK

²Department of Sport and Health, Solent University, Southampton, UK

³Southampton Statistical Sciences Research Institute, University of Southampton, Southampton, UK

⁴University of Southampton, Southampton, UK

⁵Institute of Naval Medicine, Gosport, UK

Correspondence to

Dr J L Fallowfield, Institute of Naval Medicine, Gosport PO12 2DL, UK; Joanne.Fallowfield258@mod.gov.uk

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ABSTRACT

Introduction Musculoskeletal injuries (MSKIs) are common during military and other occupational physical training programmes, and employers have a duty of care to mitigate this injury risk. MSKIs account for a high number of working days lost during initial military training, contribute to training attrition and impact training costs. Poorer movement quality may be associated with increased MSKI risk.

Methods The present study evaluated the relationship between the Functional Movement Screen (FMS) Score, as a measure of movement quality, and injury risk in Royal Navy (RN) recruits. A cohort of 957 recruits was assessed using the FMS prior to the 10-week phase I training programme. Injury occurrence, time, type and severity were recorded prospectively during the training period.

Results Total FMS Score was associated with injury risk ($p \leq 0.001$), where recruits scoring ≥ 13 were 2.6 times more likely to sustain an injury during training. However, FMS Score accounted for only 10% of the variance in injury risk ($R^2=0.1$). Sex was the only additional variable to significantly affect the regression model. Mean FMS Scores for men (14.6 ± 2.3) and women (14.4 ± 2.4) were similar, but injury occurrence in women was 1.7 times greater than in men. Examining the influence of individual FMS movement tests on injury prediction did not improve the model, where those movements that significantly contributed to injury prediction only accounted for a small amount of the variance ($R^2=0.01$).

Conclusion There was a weak relationship between FMS and injury risk in RN recruits. Evidence is provided that FMS score alone would not be appropriate to use as an injury prediction tool in military recruits.

INTRODUCTION

The UK military has a high incidence of musculoskeletal injuries (MSKIs) in young military trainees.¹ These injuries account for a high number of working days lost during initial training, and significantly contribute to training attrition.² Age, body mass, stature, physical fitness and previous levels of physical activity have been associated with injury risk,³ however, when used independently or combined, are not able to accurately predict injury rates in military cohorts. Female sex has also been identified as an important injury risk factor during initial military training.^{2,3} Gemmell² identified that women were 1.7 times more likely to sustain an

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Military training is arduous and those who undertake such training are likely to sustain injury.
- ⇒ The main injuries seen during initial military training are to the hip and lower limb.

WHAT THIS STUDY ADDS

- ⇒ This study demonstrates that the Functional Movement Screen (FMS) is unable to accurately identify severity, likelihood or location of injury.
- ⇒ The FMS Score is unable to distinguish between men's and women's movement quality, despite their difference in injury likelihood and outcome.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ This study does not recommend the use of the FMS for injury prediction and the Royal Navy has since ceased its use.

injury during military training. Being genetically female has been identified as an important variable in injury prediction within initial military training cohorts.⁴ However, Jones *et al*⁵ and Finestone *et al*⁶ have shown that women differ from men at the start of military training in two major ways. First, women present as smaller in mass and stature as well as having a lower level of physical fitness. Therefore, these two variables rather than sex per se may be the primary factor/s in increasing injury risk.

Previous studies investigating the mechanisms of injury in the military have highlighted movement quality as a potential factor for injury risk identification.⁷ Specifically, knowledge of the way individuals move and perform discrete tasks could identify those at greater risk of injury.⁸ Being able to effectively move within the limits of the structure and mobility of the joints could therefore reduce injury risk and would allow more efficient movements.

Movement screening refers to the assessment of a single movement or composite movement battery relative to physical performance and/or movement quality outcomes.⁹ Screening tools for MSKI risk are commonplace for athletic populations, contributing to injury risk management or as part of a performance enhancing strategy. These tools tend to take the form of functionally orientated tests, which can



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be highly specific to a sport movement or task.⁸ The Functional Movement Screen (FMS) is an evaluation tool involving seven exercise tests assessing the movement patterns of an individual. Each test is a specific movement, which requires appropriate function of the body's kinetic linking system for successful completion.¹⁰ The FMS has been shown to be a valid predictor of injury risk in American athletic populations,¹¹ in physically arduous occupational settings such as the Fire Service,¹² and in US Marine Recruits.¹³ US Marine recruits with an FMS Score of 14 or less were twice as likely to sustain an injury during military training. The FMS requires very little equipment, is not time intensive, and has both high intra-rater and inter-rater reliability.¹⁴ As such, the FMS was considered to be potentially useful for assessing movement in UK military personnel with small likelihood of local bias, where different raters work across different locations.

However, later research¹⁵ has reported that the FMS may not detect movement dysfunction,¹⁶ nor ultimately injury likelihood.¹⁷ Rusling and Edwards¹⁸ demonstrated that the only variables significantly improving an injury prediction model, which includes the FMS within a football player cohort, were deep squat and core press-up scores. An explanation for the predictive ability of these two movements was due to their associations with the kinetic chain, rather than the individual movements per se.¹⁸ Thus, it was argued that as core control and strength are components of both movements, this would influence the body's ability to effectively transfer movements from one body segment to another. If this is the case, some FMS movements may be statistically redundant and might, therefore, dilute the total FMS Score for certain populations, while increasing the resources required to undertake the test. Establishing the level of contribution each movement gives towards injury prediction would increase the specificity of the test battery.

While there is some potential for the FMS to be useful in understanding and mitigating injury risk in military populations, the potential limitations of the FMS warrant further investigation. Thus, the present study investigated the predictive validity of the FMS with respect to injury risk in Royal Navy (RN) recruits, and the contributions of the individual FMS movements to a population-specific model of injury risk.

Null hypothesis

1. H_0 —There will be no significant relationship between FMS Score and injury occurrence.
2. H_0 —There will be no significant difference in the contributions to the predictive model given by the individual movements within the FMS.

METHOD

Study participants

A cohort of 957 RN recruits (male, $n=862$ (90%); female, $n=95$ (10%)), mean age (SD) 22 (4) years from the training population, volunteered to participate in this study. Although the group sizes differ, these numbers represent the proportion of men and women recruited into the military at the training facility and is therefore representative of the population. All participants were informed of the requirements and details of the study 24 hours prior to participation and were given the opportunity to remove themselves from data recording or their data from analysis.

Patient and public involvement

The Principal Medical Officer and the RN Recruit Training Team were consulted to gain their views on issues associated with

MSKI in RN recruits. Tri-service regional rehabilitation units were consulted to determine the processes followed to mitigate these issues. These conversations highlighted that women in the military suffer a disproportionate number of injuries compared with men. The FMS had been used by some RN practitioners—but not all—to assess injury risk.

Study procedures

Participants completed the FMS prior to undertaking Initial Military training in which recruits learn survival and fieldcraft skills, first aid and rifle handling, alongside improving fitness levels. Five accredited FMS raters undertook the FMS assessments of the recruits. Each FMS assessment was undertaken in a confidential clinical examination area, with a volunteer wearing standard issue physical training clothing. The clinician rater used the standard FMS equipment (dowel rod, heel raise board and adjustable hurdle) to complete the assessment. The FMS comprises seven individual exercise tests including: deep squat with overhead handhold; in-line lunge; forward hurdle step-over; press-up; shoulder mobility; active straight leg raises while supine; and rotator stability while prone on all fours.¹⁹ Each movement was completed three times and scored on a scale from 0 representing 'pain during movement', to 3 representing 'perfect movement', depending on how well the participant performed the movement relative to the prescribed criteria. Hand and foot dominance were recorded on the FMS scoring sheet. Study participants completed a health history questionnaire, smoking and alcohol histories questionnaire,²⁰ as well as information describing general levels of physical activity undertaken during the previous year. Participants also completed a best effort 1.5-mile run test in week 1 of training as an assessment of aerobic fitness.²¹

MSKI occurrence was prospectively recorded during RN phase I training. Recruits participating in the study, who reported to the Medical Centre, had the 'Week of Training' (time) and the details of their injury coded onto the Defence Medical Information Capability Programme system by the reviewing doctor, nurse or medical assistant. Injury was defined as a musculoskeletal condition causing the recruit to lose 2 days of physical training; acute injuries were those conditions sustained from a traumatic event, and overuse injuries were those conditions with an insidious onset.

Data analysis

Data were initially assessed for normality of distribution by measuring skewness and kurtosis, and descriptive statistics were determined. Median split transformations were used on continuous variables (age, height, body mass, FMS Score, 1.5-mile run time) to create categorical variables. These categorical independent variables were cross-tabulated with injury occurrence and any association analysed (χ^2 tests).

Variables significantly correlated with injury occurrence were further analysed by logistic regression (forward stepwise, conditional method) to evaluate relationships. Injury occurrence was defined as either 'yes' or 'no'; therefore, a binary regression was completed with FMS Total Score as the independent variable and injury as the dependent variable. Analyses were also undertaken to establish if there was a relationship between injury occurrence and a specific FMS Score, or with those under/over a specific score. This was completed by setting the FMS Score as separate categories, and binary regression was repeated. Regression analyses of the relationships between injury type (ie, chronic or acute) and FMS Score were also completed.

Table 1 Independent variables subcategorised by injury outcome and sex

Sex	Injury (frequency)	Age (years)	Height (cm)	Body mass (kg)	BMI (kg/m ²)	FMS Score	VO ₂ (mL.kg.min)	
Female	No	59	21.6±3.4	166.5±6.6	63.3±8.1	22.8±2.6	15.1±1.7	43.7±6.9
	Yes	36	21.9±3.3	164.4±7.5	65.3±9.5	24.1±2.5	13.3±2.8	42.8±6.2
	Total	95	21.7±3.4	165.7±7.0	64.0±8.7	23.3±2.6	14.4±2.4	43.4±6.7
Male	No	633	22.2±3.5	178.7±6.7	74.5±10.6	23.3±2.9	15.1±2.1	50.5±6.2
	Yes	229	22.1±3.8	179.3±7.3	77.2±11.4	24.0±3.1	13.30±2.4	48.8±5.7
	Total	862	22.2±3.6	178.8±6.9	75.3±10.9	23.5±3.0	14.6±2.3	50.0±6.1

BMI, body mass index; FMS, Functional Movement Screen.

All FMS movements were assessed for their individual contribution by categorised stepwise regression analysis against the independent variable, FMS Total Score. Factors such as age, sex, fitness, smoking and alcohol consumption were assessed as covariates. Further investigation into injury rates included assessing the relationship between time and injury by assessing total injuries per week by FMS Score through regression analysis. Finally, five of the seven FMS movements were scored for both sides of the body to allow consideration of asymmetry as squat and press-up cannot be scored for each side separately. This was achieved by removing the non-dominant side score from the dominant score and categorising these now scores between -15 and +15. Additionally, a simpler 'difference' score was calculated by establishing a difference between left and right regardless of direction of difference. This generated only positive numbers. Using the FMS to establish asymmetrical movement differences, an examination between a calculated asymmetry score and injury likelihood was derived. Statistical significance was set *a priori* at $p < 0.05$.

RESULTS

A total of 265 injuries were recorded throughout the investigation, of which, 229 were sustained by men and 36 by women (Table 1). The majority of these injuries were classified as lower limb (201). Female sex, FMS Score, body mass, smoking status and aerobic fitness were associated with injury occurrence ($p < 0.05$). However, FMS Score and female sex were the only factors significantly influencing risk of injury occurrence (logistic regression analysis).

Relationship between total FMS Score and injury incidence during training

The binary regression showed a very weak predictive relationship between FMS Score and injury occurrence. FMS Score ≤ 13 was significantly correlated with injury occurrence (Coef (SD)=0.325 (0.033), $p \leq 0.0005$, CI -0.396 to -0.255). Injured recruits were most prevalent at an FMS Total Score of 12, whereas non-injured recruits were more prevalent at an FMS Total Score of 15 (Figure 1). Moreover, at least 50% of recruits scoring between 8 and 12 on the FMS were injured.

Relationship between FMS and injury onset

With an increase in FMS Score from 13 to 19, injury risk was reduced by a factor of 1.0 to 1.6 (Poisson regression; $p = 0.013$). Recruits with lower FMS Scores were at higher risk of chronic injuries and had a generally higher risk of injury ($p \leq 0.005$). An FMS Score of 10 would result in a 27% chance of passing phase I training without an injury, whereas an FMS Score of 18 would result in an 85% chance of finishing phase I training without an injury (Figure 1).

Relationship between individual FMS test scores and injury occurrence

Of the seven FMS exercise tests, only the shoulder mobility and trunk stability tests were significantly associated with injury occurrence (Table 1). For every unit increase in movement score, the likelihood of injury decreased by a factor of 1.3. However, although the relationship was significant, the regression only accounted for 10% of the variance in injury occurrence.

Relationship between Functional Movement Score and time in training

From the regression analysis between FMS Total Score and Week of Training, for every unit increase of time in training, the risk of injury decreased. However, only recruits with an FMS Total Score of between 13 (Coef±SE=-0.892±0.21) and 19 (Coef±SE=-2.054±0.372) had a significantly reduced risk. When examining the time of peak injury occurrence, the highest rate of injury occurrence was in week 4 (Figure 2).

Movement asymmetry and injury likelihood

There was a positive relationship between asymmetrical movements and injury likelihood, which accounted for a very small (2%) amount of variance in the data (Coef±SE=0.423±0.08, $p \leq 0.0005$, 95% Conf=0.259/0.586). The majority of recruits exhibited either none ($n=359$) or one asymmetrical ($n=403$) movement. The occurrence of injury, as expressed as a percentage of those in the category, increased with increases in asymmetrical movement differences (Figure 3).

Relationship between sex and injury

Logistic regression analysis of injury outcome, including those variables significantly associated with injury, demonstrated that only FMS Total Score and sex significantly contributed to the

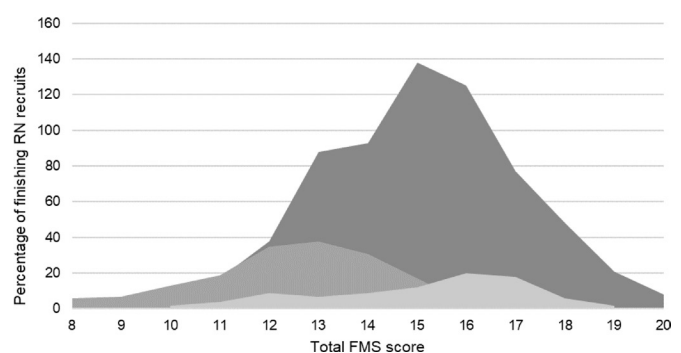


Figure 1 The percentage of chronic (light grey) and acute (medium grey) injuries and non-injured (dark grey) recruits who completed phase I training. FMS, Functional Movement Screen; RN, Royal Navy.

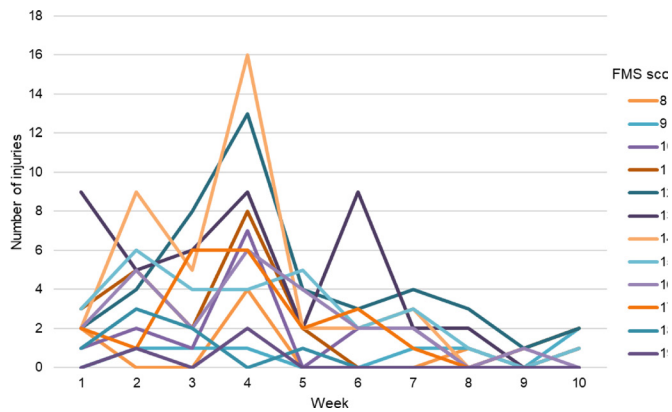


Figure 2 Injuries per week sorted by FMS Score, denoted by the individual lines. The legend illustrates the FMS Score associated with each line, with darker lines denoting a higher score. FMS, Functional Movement Screen.

prediction model (Equation 1). Shown below is a binary regression model based on the two variables that have been shown to significantly contribute to the model ($\chi^2(1) = 4.99$, $Pr=0.025$). The model explained 17% of the variance in injury outcome. The OR values for sex and FMS Score were 1.7 and 0.7, respectively. This indicated that the risk of injury increased by a factor of 1.7 for women, compared with a 0.7 decrease for men. This represents around a 12% increase in injury likelihood per unit increase in FMS Score.

$$\text{Probability of injury} = 1 / [1 + \exp(- (4.1 + 0.535 \text{ sex} - 0.359 \text{ FMS score}))]$$

(Equation 1: Logistic equation prediction output)

The model only correctly classified 23% of injured recruits and incorrectly identified 4% of non-injured participants as having an injury when applied to the study cohort (Table 2).

DISCUSSION

The present study investigated the predictive validity of the FMS with respect to injury risk in RN recruits, and further scrutinised the contributions of the individual FMS movements to evaluate the effectiveness of an injury prediction model. There was a very weak relationship between FMS and injury risk in RN recruits, where this relationship was unspecific and therefore would not further inform injury mitigation. As such, the FMS could not be used as an independent tool for predicting injury in these military recruits. Moreover, the contribution of the individual FMS movements to the injury prediction model did not inform an understanding of the relationship between movement quality and injury in this military population.

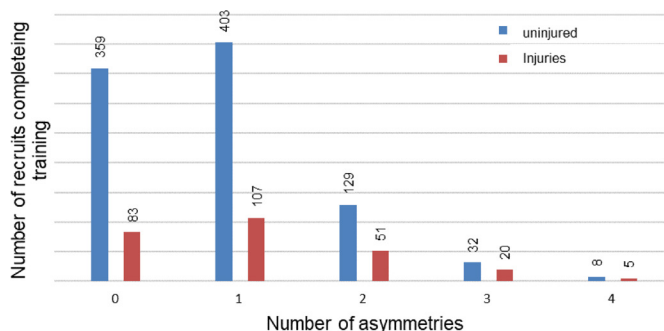


Figure 3 Injury occurrence categorised by total asymmetries scored.

Table 2 Classification of injured and uninjured Royal Navy (RN) recruit participants using the derived logistic regression model (n=938)

Observed	Predictive		Percentage correct
	Non-injured	Injured	
Non-injured	655	26	96
Injured	206	61	23
	Overall percentage		76

The present study identified that recruits with an FMS score of 13 or less were at an increased risk of injury. This is similar to the findings of Kiesel *et al.*,¹¹ O'Connor *et al.*²² and Lisman *et al.*,⁷ who reported a threshold score of 14 to be predictive of injury likelihood. However, this relationship was very weak ($r=0.033$) in the present study of an RN recruit population, with only 10% of the variance in injury risk being explained by the FMS Score. Thus, in this UK military cohort, the FMS poorly predicted injury occurrence.

The current study also confirmed previous reports²³ that sex significantly contributes to the risk of injury in military and athletic populations, where female recruits were 1.7-times more likely to sustain an injury compared with men. However, there was no significant difference between the mean FMS Score of the male and female recruits in this study cohort. As such, either, variables other than movement quality per se, as measured by the FMS, must be influencing injury risk in female RN recruits, or that the FMS is not sensitive or specific enough to detect movement quality in RN phase I cohorts.

Recruits with a lower FMS Score were more likely to sustain chronic injuries, whereas those with a higher FMS Score were more likely to sustain acute injuries. Nevertheless, recruits with a higher FMS Score were generally less likely to sustain any injury. This suggests two things: first, that acute injuries occur regardless of movement quality; and second, poor movement quality may be associated with increased risk of chronic injuries.

In the present study, greater time in training was associated with a lower likelihood of sustaining an injury, apart from the increase observed in week 4. This observation was regardless of a recruit's FMS Score, however only statistically relevant for those who scored between 13 and 19. This was in direct contrast to findings from comparably active cohorts, such as that shown by Chalmers *et al.*²⁴ The study was unable to rule out the influence of survivor bias, thus limiting the conclusion from this finding.

Movement asymmetry has also been suggested as a factor contributing to injury risk.⁷ The present study observed that asymmetry did make significant contributions to the injury prediction model. However, this only accounted for a small amount of the variance in the model (2%). Therefore, movement asymmetry, importantly as assessed by the FMS, was unlikely to be an important predicting factor in determining injury risk in RN recruits.

Shoulder mobility and trunk stability were the only movements from the FMS to make significant contributions to the injury prediction model. This was consistent with Rusling *et al.*,¹⁸ who demonstrated that core stability significantly contributed to injury prediction models. However, a link between lower limb injury and shoulder movement quality seems less clear. These movement assessments are aimed at the trunk and upper body, whereas the greatest number of injuries were sustained to the lower limbs (Table 3). Potentially, shoulder mobility could be representative of full body mobility and flexibility. However, a deep squat, which is also used within the

Table 3 Regression coefficients from all Functional Movement Screen (FMS) movements and scores with respect to prediction of injury

Movement	FMS Score	Coefficients (SD)	P value	95% CI
Shoulder mobility	1	-1.042 (0.64)	0.104	-2.297 to 0.214
	2	-1.334 (0.589)	0.024*	-2.49 to -0.179
	3	-1.963 (0.584)	0.001*	-3.107 to -0.82
Trunk stability	1	-0.828 (0.502)	0.099	-1.814 to 0.157
	2	-0.899 (0.47)	0.056	-1.823 to 0.024
	3	-1.424 (0.47)	0.002*	-2.334 to -0.504
Deep squat	1	0.003 (1.296)	0.998	-2.537 to 2.544
	2	-0.261 (1.294)	0.84	-2.798 to 2.276
	3	-0.142 (1.31)	0.913	-2.71 to 2.426
In-line lunge	1	-0.039 (1.309)	0.976	-2.604 to 2.525
	2	-0.303 (1.307)	0.817	-2.864 to 2.259
	3	-0.589 (1.321)	0.656	-3.179 to 2
Hurdle step-over	1	0.474 (0.329)	0.15	-0.171 to 1.119
	2	0.112 (0.292)	0.701	-0.459 to 0.684
	3		None	
Active straight-leg raise	1	0.376 (0.236)	0.112	-0.087 to 0.839
	2	-0.161 (0.222)	0.469	-0.595 to 0.274
	3		None	
Rotator stability	1	-1.02 (1.373)	0.458	-3.712 to 1.671
	2	-1.861 (1.354)	0.169	-4.516 to 0.793
	3	-2.001 (1.511)	0.185	-4.963 to 0.959

*Significance.

FMS, may perhaps prove a more complete movement²⁵ due to the movement involving a greater number of joints than the shoulder mobility test. Coupled with the small contribution (10.5% of the variance) towards the predictive model, this indicated that individual movements comprising the FMS informed injury prediction but remained unclear as to the direct link in this military cohort.

Future research

The findings of this study suggest that the FMS would offer little insight into informing injury mitigation interventions in this RN population. Furthermore, the FMS was unable to differentiate between male and female RN recruit injury likelihood. Therefore, future research may yield greater results by better understanding the mechanisms that are associated with these injuries and seek to develop more specific and impactful screening tools and interventions.

Limitations

This study assessed the ability of the FMS to identify those most likely to sustain injury. However, injuries were classified as a singular outcome measure. It is still unclear whether injuries to specific areas of the body can be identified with the whole of a subset of the movements within the FMS. There is a chance that injuries were under-reported due to participants having to self-report. However, outside of the issues raised in week 4, there is little advantage a recruit would have in not making it known that they are injured. Due to this, if any injuries were to have been undeclared, they were likely not severe enough as to stop the recruit from successfully completing their training.

CONCLUSIONS

The current study assessed the ability of the FMS to predict injury occurrence in military phase I recruits. Preliminary analyses of the association between the total FMS Score and injury occurrence indicated a weak predictive ability. However, the predictive model accounted for a very small amount of variance within the data. Moreover, the individual movements that specifically contributed to the prediction model did not appear to relate directly to the most common injuries sustained by RN recruits. The relationship between the FMS and injury was found to be very weak and unspecific, offering little benefit in informing injury mitigation interventions in this population. Moreover, the FMS was insensitive to the difference in injury rates between male and female RN recruits. Therefore, the findings from the current study challenge the use of the FMS alone in RN cohorts as a tool for assessing and understanding injury risk.

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Contributors JG and JLF were responsible for the conception and design of the original study. JG managed and supported the primary data collection, while JLF is held as guarantor of the study. MW, MS, CNTP and JLF were responsible for the conception and design of the retrospective data analysis study. CNTP was responsible for extraction and collation of data for the retrospective analyses. CNTP and DB were responsible for the data analysis. CNTP, MW, MS and JLF were responsible for the data interpretation. The first draft was produced by CNTP, and the coauthors contributed to the iterations of the paper, with all approving the final version.

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Competing interests This was a collaboration between the Institute of Naval Medicine – Ministry of Defence (MOD) and the University of Southampton, to conduct research for the MOD, funded by the MOD, with 'in kind' funding by the University. There are internal University numbers to identify the study, but a number was not assigned by the funder (MOD).

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval This study involves human participants and was approved by the MOD research ethics committee (217/GEN/11). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

ORCID iD

C N T Power <http://orcid.org/0000-0002-7417-2839>

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