IN-DEPTH REVIEW

Armed Forces occupational health—a review

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Background
The Armed Forces operate in a particularly arduous physical and psychological environment. The occupational health (OH) of all personnel is of paramount importance to sustain the service’s fighting ability.

Aims
Firstly, to bring readers up to date with the current organization and delivery of OH to uniformed personnel in the Armed Forces. Secondly, to review the research that has led to an improvement in OH services and the ways in which the Armed Forces are responding to the various challenges.

Methods
A description of the type and delivery of OH to the Armed Forces is followed by a review of the relevant contemporaneous literature from both open publications and research dissertations.

Results
Although there are some similarities with civilian OH, the principal requirement to prepare and sustain service personnel for operations on land, sea and air adds considerable complexity to the task. Research undertaken by Armed Forces OH professionals has added to the evidence base and enabled attrition in all aspects of the Armed Forces to be reduced.

Conclusions
To meet the challenges of the 21st century, Armed Forces OH practitioners must continue to provide the best evidence-based advice to enhance force preparation and sustainment. All consultations in the Armed Forces involve an OH consideration from the simplest consultations through to the input from specialist OH practitioners. While the assessment of fitness to work in home bases and on deployed operations remains the primary output of OH, the provision of support to command policy, procurement and research are also key to the ability to operate worldwide.

Key words
Armed Forces; British Army; occupational health; Royal Air Force; Royal Marines; Royal Navy.

Introduction
Occupational medicine (OM) and its wider discipline of occupational health (OH) are firmly embedded in the Armed Forces. The Armed Forces Health policy is to

- reduce the impact of ill-health on the fighting strength of the Armed Forces and

- ensure that the maximum number of personnel are fit to carry out their operational duties.

These statements emphasize the fact that all medical support provided by the Defence Medical Services is established not only to save life and treat illness but also to restore Armed Forces personnel to a level of function to meet the operational commitments. Although there are minor differences between the three services, Figure 1 illustrates the myriad of medical processes that contribute to Force Health Protection [1].

The aim of this review is 2-fold. Firstly, to bring readers who have not served in a branch of the regular or reserve forces up to date with the current organization and delivery of OH to the c. 178 000 uniformed personnel in the Armed Forces who undertake a wide variety of occupations/trades. Secondly, to review the research that has led to an improvement in OH services and the ways in which the Armed Forces are responding to the various challenges. It is assumed that the reader has a basic understanding of the function of the Armed Forces, which are described in detail at the Ministry of Defence (MoD) and individual service Websites [2–5].
Organization and delivery of OH

As well as the general health and job components common to all OH practice, the additional human requirements for the serviceman or servicewoman are for them to be able to handle a weapon and serve worldwide under potentially physically and psychologically demanding conditions. This may well be at short notice for deployment, at a distance from medical support (especially early in the deployment) and for sustained periods. It is clear that preparation for the operational deployment and its sustainment requires an OH team with very specialist expertise. Consequently, although supported by civilian practitioners, the main effort of OH is delivered by uniformed staff.

Communication with the employer

The PULHHEEMS system of medical classification [6] is common to all services and is designed to provide a functional assessment of the individual’s capacity for work and assist the Executive in assigning service personnel to appropriate employment and deploy them on operations. The categorization is presented in Box 1.

The standards for each type of work are set by the appropriate service employer [7–9]. Tri-service guidelines to assist medical staff to interpret conditions against the standards are well established and frequently reviewed [6]. A medical employment standard appears as a suffix to the ‘P’ grade and differs between services primarily because of the different predominant environments of sea, land and air in which the Royal Navy (RN), Army and Royal Air Force (RAF), respectively, operate. There is, however, a move towards a harmonized system, the Joint Medical Employment Standard, which is due to be introduced at the end of 2009.

![Diagram of Force Health Protection and the force generation pathway](https://academic.oup.com/occmed/article-abstract/59/8/528/1370567)

**Box 1. The PULHHEEMS system of medical classification**

The letters stand for:

- **P**: Overall physical capacity
- **U**: Upper limbs
- **L**: Locomotion
- **HH**: Hearing acuity (right then left)
- **EE**: Visual acuity (right then left)
- **M**: Mental capacity
- **S**: Stability (emotional)

The most important quality is the P’ grade summarized as follows:

- **P2**: Medically fit for unrestricted service worldwide
- **P3**: Medically fit for duty with minor employment limitations
- **P4**: Medically fit for duty within the limitations of pregnancy
- **P7**: Medically fit for duty with major employment limitations
- **P8**: Medically unfit for service
Integrated OH and primary care

OH support starts with the primary health care team. Although a broad range of medical personnel who have a basic understanding of the requirements to assess the fitness for work are involved, the general practitioner (GP), in particular, has the responsibility to provide an immediate assessment of fitness for work at almost every consultation. This has therefore pre-empted the statement in ‘Working for a healthier tomorrow’ [10] that ‘developing an integrated approach to working age health requires OH to be brought into the mainstream of healthcare provision’.

This integrated approach has distinct advantages. Armed Forces GP and their patients usually enjoy a clearly defined immediate ‘employer’ who is normally their unit commander, e.g. an RN ship’s captain, an Army Regimental commanding officer or RAF station commander both in peacetime and on operations. As an officer of the unit, the Armed Forces GP knows the workplace and workforce intimately. He or she will undertake a similar degree of physical training and be exposed to the same hazards and environmental conditions as their patients on many occasions. Consequently, with a holistic knowledge of the individual, when they have to make a recommendation on return to work, or at least an opinion upon functional capability, they are able to do so with the full knowledge that their patients know that their doctor is well aware of the level of function they must achieve.

The medical fitness of their units is of such importance that daily personal contact between commander and GP is a common occurrence and the GP is often regarded by the commander as a confidante in an otherwise hierarchical structure. Far from being intrusive to medical practice, it is the epitome of an effective employer–medical interaction to ensure operational effectiveness and the delivery of responsible care.

Specialist OH services

Armed Forces primary care organizations (including community mental health teams) and secondary care consultants have ready access to specialist OH advice as do unit commanders. Although there are subtle differences in the organization between the services, each provides a regional network to which referral can be made. These generally comprise a multidisciplinary team of medical, nursing and administrative personnel who also have access to environmental health staff for specific assessments. The regional OH team’s main effort is to provide an evidence-based recommendation on an individual’s fitness for service in both the peacetime and operational context. The latter is further described later in this review. The process for recommendations upon permanent ‘downgrading’ and eligibility for discharge from the service on medical grounds differs slightly between the services. Although all use the same principles, the RN and RAF provide a centralized medical board at which all cases of permanent restriction of duties are seen while the Army devolves this responsibility to its regional teams although decisions are confirmed centrally. With the reduced number of uniformed secondary care consultants and the demise of the service hospitals, the regional OH teams are increasingly required to assess and interpret the abilities and limitations of patients treated by National Health Service (NHS) consultants where no long-term employability guidance is given in the clinic or discharge letters.

OH policy advisors (usually doctors but occasionally nurses) are established both in the central MoD and the headquarters of each service to assist in the planning and delivery of OH throughout the Armed Forces.

OH on deployed operations

Although an environmental health team is invariably an integral part of each operation and has an important monitoring and control role, the deployment of an occupational physician or nurse is dependent upon the specific requirement of the operation at the time. For example, specialists were deployed in the early phases of operations in Iraq and Afghanistan to assist in the determination of health support for deployed forces. An OH review of operational theatres is conducted annually and a specific visit is arranged if necessary.

However, both the primary care team and the specialist OH practitioner have a vital role in preparing the force to be deployed on operations. All three services conduct a similar risk assessment process, but for simplicity, the Army process is described.

A commander ordered to prepare for operations usually wishes to take the maximum number of men and women with him who are fully fit for task. Although there may be a myriad of other reasons why personnel may not be deployed on operations, it is the medical reasons that are most prevalent and the OH team must clearly be involved.

Provided they are categorized correctly, the deployment of personnel who are fully fit need not be considered further as they are fit to be deployed anywhere at any time. Similarly, those who are graded as non-deployable are likely to be employed in the rear party when the unit deploys. Because of the increasing frequency of recent deployments, considerable effort has been made to ensure that all personnel are correctly graded so that the main OH effort when deployment is ordered can be applied individually to those who have a limited employability standard.

Commanders must determine whether these personnel are fit to deploy. This is done before each intended deployment to meet the requirements that the service person must be physically suitable for the deployed role, that
their condition should not deteriorate during deployment and that the deployment should not interrupt any planned medical treatment. Each individual is subjected to a medical risk assessment of these requirements against information about the available situation in the theatre of operations, including factors such as location, climatic stressors, local disease prevalence, living conditions, physical demands, logistical support and medical facilities and the ease of medical re-supply. Other considerations may include whether the individual has worked in a similar role before, has previously deployed successfully/unsuccessfully to this or a similar operational theatre and the mitigation measures that have been put in place for this deployment to ensure that medical restrictions can be met.

For the Army, the minimum physical requirement for deployment is the ability to operate a personal weapon, wear appropriate personal protective equipment (especially body armour) and to be able to rapidly take defensive cover (the minimum requirement is to sprint 40 m and throw oneself to the ground).

Appropriate recommendations are made by the unit medical officer (in conjunction with the regional OH team if necessary). In turn, the regional OH team may consult with in-theatre medical staff to ensure that the risk is acceptable to the current level of medical support on operations. These recommendations will then be communicated in functional terms (‘can do’ and ‘can’t do’) to the commander who will make the final decision on deployment.

These types of procedures have enabled appropriate management of the individual while maximizing the numbers of personnel that can be deployed for a particular operation. The decision-making process must, however, be dynamic as the operational situation changes frequently. For example, the environmental conditions may change with season, e.g. creating a greater risk to those with respiratory or dermatological conditions when dust concentrations increase in hot weather, or the medical operational tempo dictates that ‘at risk’ personnel should not be deployed as their potential care may jeopardize the primary role of deployed medical support of caring for combat casualties.

The deploying unit should ensure that the operational medical staff has a list of personnel who are deployed in medical grades that are less than fully fit, and audit of the operational outcome of these ‘at risk’ personnel is conducted periodically. Although data are limited, to date there appears to be little difference in the disease and non-battle injury medical evacuation rates of Army personnel between those deployed fully fit and those who have undergone a medical risk assessment with a limited deployability grade.

**Sub-specialized OM**

Although almost the whole gamut of OH issues are encountered in practice, various subspecialties are formally established in Armed Forces OM and are worthy of mention.

**Aviation medicine**

Although the RAF is nominated as the lead service, aviation medicine is practised by all three services in which occupational physicians address the specific aviation needs of their own service environment. Specialists from all three services are now included in the staff of the RAF Centre for Aviation Medicine at RAF Henlow. There are many potential hazards for aircrew, including pressure change with altitude, hypoxia, decompression sickness, gravitational stress, noise, vibration, extremes of temperature, spatial disorientation and air sickness [11]. The medical standards required of military aircrew from all services are documented in Air Publication 1269A [9]. With the aim of ensuring as far as possible that they are based on the best available evidence, the standards are regularly reviewed by the Standing Committee on Aircrew Medical Standards. Recent topics considered have been medical standards for unmanned aerial vehicle operators, cardiovascular screening in aircrew over 60 years, aircrew neck conditioning programmes, aircrew with asthma and the use of metformin and anticholinesterase inhibitors by aircrew. Although aircrew in all aircraft are supported, the main aviation medicine effort is directed towards new and future types. In the RN, the joint strike fighter will be the first fast jet to fly from aircraft carriers since 1974; in the Army, the human factors aspects of operating the Apache attack helicopter require considerable attention, and in the RAF, the Eurofighter Typhoon is one of the most agile fighter aircraft in the world.

**Submarine and radiation medicine**

The RN provides the MoD lead on policy from the Institute of Naval Medicine (INM) at Gosport. Submarines and radiation go hand in hand as the RN now only operates nuclear-powered submarines. Although support to all aspects of submarine operations are provided, recent work has concentrated upon the submarine atmosphere with a view to maintaining as normal an atmosphere as possible within the boats for patrols lasting up to 90 days. In case of a submarine accident, the INM would provide a core of specialist submarine and diving doctors to respond and assist those escaping or being rescued from the disabled submarine. Although ionizing radiation has higher visibility with submarine reactors and weapons and the chemical, biological, radiation and nuclear risk, there are many sources of non-ionizing radiation in ships, aircraft and land equipments ranging from radar and radios to lasers and power generation systems. The INM provides a 24-h advice service able to respond to MoD radiation incidents and has been used in the past to support civilian responses.
Diving and hyperbaric medicine

Again the RN provides the MoD lead on policy. Diving as an occupation is practised within the RN and the Army who employ ~450 and 250 occupational divers, respectively. This is greatly outnumbered by nearly 5000 service recreational sports divers who, when undertaking organized sports, are considered to be diving at work in the same way as the occupational divers. The standards for diver fitness run very close to those laid out by the Health & Safety Executive (HSE) in the MA1 [12] although as the military is not subject to the Disability Discrimination Act some HSE-accepted conditions are excluded. Those who do not meet the standards for any form of pressure exposure are referred to the INM for final arbitration of fitness. This may include attendance for pulmonary function testing if their history indicates previous asthma or other lung diseases. One of the diving and hyperbaric medicine team’s key tasks is to teach medical staff and divers how to deal with diving emergencies in remote locations without easy access to hospital facilities and how to manage patients in a remote, small recompression chamber. To support this, a 24-h emergency call line is maintained so that military personnel can seek support of a diving medical officer. This line also provides support for civilian emergencies and can help link divers in difficulty with an appropriate recompression facility.

OM training

On completion of foundation year 2, doctors entering their respective services undertake a 3- to 4-month course designed to prepare them for their additional responsibilities. These courses include OH training as a specific educational objective and OH issues are also addressed when studying other medical disciplines (e.g. tropical medicine). This training goes a long way to overcome the current deficiencies in undergraduate medical education. Unlike their civilian counterparts, those progressing to GP vocational training also receive additional service-specific OH training. The Royal College of General Practitioners having recognized the influence of the workplace on a patient, its curriculum statement now emphasizes this as an ‘essential feature of the discipline of general practice’ and has stated this as a learning outcome for GP training [13]. Once qualified as an Armed Forces GP, attendance on a Diploma in Occupational Medicine course and subsequent examination is strongly encouraged.

Only serving doctors may apply for specialist OM training. The majority (though not all) of applicants are vocationally trained as GPs and the Diploma in Occupational Medicine is encouraged as a pre-application qualification. Potential specialty registrars (StRs) have therefore already had a considerable exposure to OH and specialty training is seen by many as a natural professional progression as a military medical officer. There are 32 PMETB-approved training posts in the Armed Forces (RN 11, Army 13, RAF 8).

The Armed Forces OH professional must achieve and maintain the competences set by his or her professional body with which the reader will be familiar. Additionally, because of the nature of the employment, they must gain expertise to enable them to provide advice in the specific requirements of the population that they serve. In order to gain required competences and a range of experience, StRs rotate through a number of different posts (normally 2 or 3) usually commencing in a post with a broad OH content and then undertaking more specialized training. In addition, many registrars complete a university MSc course. They are encouraged to gain exposure to ‘civilian’ OM, and with the assistance of many OM colleagues, periodic placements are arranged in a variety of environments. Once trained and approved as a new consultant, the OM specialist who wishes to follow the clinical professional pathway can expect to occupy a range of posts normally for 2–3 years at a time.

Rehabilitation and return to work

Rehabilitation has long been recognized as an essential part of the clinical treatment pathway for service personnel and it is in this area that many consider the Armed Forces provide the ‘gold standard’.

Army data in 1999 showed that 68% of medical discharges and 55% of medical downgradings were due to injuries and musculoskeletal disorders [14]. Recognizing the impact of the problem on the fighting strength of the Armed Forces, the Health Strategy [15] identified the requirement for an Injuries Steering Group that would draw the military chain of command into ownership of the challenge of preventing and treating the large number of training and operational injuries. Following resource allocation, the Defence Medical Rehabilitation Programme (DMRP) was established in April 2004 and has developed incrementally into a three-tier service as described below. Additionally, medical rehabilitation teams are deployed on operations to provide early assessment and treatment of musculoskeletal injuries (MSIs) in theatre, or advise on the appropriate care for patients being evacuated. This concept of operation complies with Audit Commission direction [16] to design new care pathways that are quicker, more cost effective and less dependent on secondary care facilities.

Primary care rehabilitation facility

At unit level, all military patients have access to a primary care rehabilitation facility (PCRF). Staffed by military and civilian physiotherapists and uniformed remedial instructors (RIs), the principal role of the PCRF is to provide the immediate care for personnel with musculoskeletal conditions referred by the primary healthcare team.
The target from referral to first appointment for routine cases is 10 working days, but this is shortened considerably for personnel undertaking initial military training. PCRFs generally deal with cases that have a definitive diagnosis, can be dealt with on an outpatient basis and can be returned to fitness within 1 month.

Regional rehabilitation units

Regional rehabilitation units (RRUs) are established in 15 of the larger service bases at which patients of all three services will be seen from regionally based catchment areas. Patients may be referred from a PCRF or directly by a medical officer, though in the latter case it is expected that there will have been physiotherapy involvement in the decision. The RRU has two main functions: a Multidisciplinary Injury Assessment Clinic (MIAC) and a treatment role. The MIAC is staffed by a doctor trained in the management of MSIs, an experienced physiotherapist and an RI. The team’s aim is to establish a firm diagnosis so that an optimum treatment pathway can be devised. The RRU has rapid access to magnetic resonance imaging and other investigation services and can ‘fast track’ patients to orthopaedic surgery with a target time to operation of 6 weeks. Where possible, patients will be referred back to the PCRF for treatment, but for more complex cases, particularly those that require structured group work on a daily basis, the RRU runs its own courses. Typically, these are for 1–3 weeks for up to 30 patients. RRUs also have an important role in accepting urgent referrals direct from an operational theatre for patients who cannot be managed by the deployed rehabilitation teams. Where resources permit, the regional occupational physician takes part in joint discharge clinics at the end of a course of treatment to ensure that the patient is in the correct medical category for their stage of recovery.

There has been little published on the efficacy of RRUs. An internal study of outcomes examined the employment status 12 weeks after discharge for patients admitted over a 6-month period. Eighty per cent showed improvement in function and 63% showed reduction in pain. Less than 50% of patients had been reviewed by a military GP during the 12-week period following admission, but of those reviewed, 35% were fit for full military duties and 55% were considered operationally deployable with some medical restrictions [17]. A more recent study confirmed that RRUs are effective in returning soldiers to operational duty with 77% of a sample of 143 patients achieving operational fitness after admission compared with 64% who were deployable at the start of treatment. Crucially, this improvement was confirmed after 1 year of followup [18].

Defence medical rehabilitation centre Headley Court

The third tier of rehabilitation is the defence medical rehabilitation centre (DMRC), which provides accommodation and rehabilitation facilities for up to 175 patients with complex injuries, including amputees and brain-injured patients. It has no direct NHS equivalent. Polytrauma, neurological and rheumatology patients who require nursing support are accommodated in two 35-bedded wards. An amputee centre was opened in June 2006 and to date (July 2009) ~100 patients have been assessed and treated since the unit became fully operational. Clinical oversight of the DMRC is by the consultant in charge of complex trauma rehabilitation, while day-to-day clinical management is provided by specialist physiotherapists and two full-time contracted prosthetists.

Complex group-based rehabilitation is delivered to over 100 accommodated patients who are admitted to a specific group according to their clinical problem and stage of rehabilitation. Patients often undergo a series of admissions as they progress from early to late stage rehabilitation. The process is fully supported by a consultant-led multidisciplinary team. In the future, the MoD is considering the development of a national centre of excellence for military and civilian rehabilitation in the Midlands.

The DMRP, with its tiered approach, has produced considerable improvements in effective diagnosis and treatment of musculoskeletal disorders. Since its inception, the number of patients seen has been substantial. For example, Table 1 shows the number of patients assessed by RRU MIAC clinics over a 30-month period.

Before establishment of the DMRP, the vast majority of the 21 000 patients would have been referred to orthopaedic outpatients or directly to the DMRC, with significantly longer waiting times. Moreover, injuries would have become more chronic in nature and therefore taken longer to treat once the patients had been assessed. The effectiveness of the introduction of the RRUs is demonstrated by the result that 80% of patients are managed with physiotherapy and group rehabilitation at the RRU or the referring PCRF and have no requirement for onward referral once a definitive diagnosis has been made. Only ~20% require onward referral, 10% into the orthopaedic fast-track programme where conversion rate to surgery is extremely high and 10% for appropriate orthopaedic or DMRC consultant opinion due to the complexity of the particular condition.

Table 1. RRU outcomes (1 April 2004–1 October 2007)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients assessed</td>
<td>21 368</td>
</tr>
<tr>
<td>Patients requiring physiotherapy or rehabilitation only</td>
<td>17 712</td>
</tr>
<tr>
<td>Referral to fast-track orthopaedic surgery</td>
<td>2100</td>
</tr>
<tr>
<td>Routine orthopaedic referral</td>
<td>1207</td>
</tr>
<tr>
<td>Patients discharged from rehabilitation</td>
<td>11 250</td>
</tr>
</tbody>
</table>
The precise measurement of benefits in terms of outcomes is difficult, but the assessment of ‘deployable man days’ gained has been accepted as best evidence. This is based on a comparison between the time taken for an individual to be assessed and treated within the DMRP and the time taken for a similar process from an NHS referral. For example, the conservative estimate for the period 1 April 2007–30 September 2007 is a potential gain of 652 363 deployable man days, or the equivalent of some 3670 personnel available for deployment who would otherwise be unfit.

The demand for rehabilitation services continues to increase, and there is no doubt that service personnel are being returned to full operational fitness quicker than in the past by ensuring that the patient is assessed and treated in the right environment at the right time. There are also broader beneficial effects including improved morale and encouraging earlier presentation of musculoskeletal problems. The Healthcare Commission carried out an independent review of the Defence Medical Services in 2008 and its rehabilitation service was one of the areas it classed as an ‘example of exemplary practice’, praising the motivation of its staff [19]. The benefits of a rehabilitation programme that is fully integrated with primary care and specialist OH services can best be summarized by quoting the description used by the National Director for Health and Work, Dame Carol Black:

Primary healthcare in the Defence Medical Services provides day-to-day healthcare and occupational health, both meeting the individual’s immediate healthcare needs and assessing the effect of any reduction in functional capacity on fitness to work. The aim is to convey to the employer an assessment of the employability of all service men and women, whilst maintaining the individual’s medical confidentiality, protecting and promoting their health and facilitating their most appropriate employment within the organisation. Rehabilitation is immediately accessible and available on site at all major primary care centres, with more extensive in-patient rehabilitation at the MoD’s dedicated centre as required [10].

Research review

Armed Forces OH professionals make regular contributions to the open literature in national and international publications and also to the ‘in-house’ journals: The Journal of the Royal Army Medical Corps [20] and Journal of the Royal Naval Medical Service [21]. However, there is also a wealth of ‘grey literature’ mainly in the form of academic dissertations (e.g. MSc and Membership of the Faculty of Occupational Medicine) that has helped the way the Armed Forces do their business, and this review provides an opportunity to mark these and other valuable contributions that have made an impact in preparing and sustaining the Armed Forces.

Organization of research

Royal Navy

The INM, in Gosport, is the Navy’s centre of occupational and environmental medicine and sciences and provides its principal research base. From its beginnings just after the Second World War, the unit has expanded to take on work particularly relating to the submarine programme. The INM conducted the original physiological studies on the effects of prolonged exposure to higher levels of CO₂ likely to be experienced on nuclear submarine patrols. Other topics of active research include injury prevention; the effects of nutrition on training injury and operational fitness and the effects of both hot and cold climates.

Army

Since the incorporation of the function of the Army Personnel Research Establishment into the Defence Evaluation and Research Agency and thence to QinetiQ (a public private partnership defence technology company), the main effort of in-house Army OH research has been led by the Army Recruiting and Training Division (ARTD). Applied research is driven by the business case to reduce the attrition of training and related injuries (mainly musculoskeletal) on the organization’s output.

Royal Air Force

As well as being a world-class aviation medicine training organization, the RAF Centre for Aviation Medicine at RAF Henlow provides a range of research and specialist support services particularly in the area of aircrew personal protective and survival equipment.

Assessment of fitness for work

Adams [22] assessed the prevalence of unfit regular soldiers and officers incorrectly listed as fully fit in order to assess the training knowledge and use of the PULHHEEMS system among individual medical officers. He concluded that 6.5% were outside the limits for such classification and that 33% of medical officers did not feel that they had an adequate working knowledge of the classification system. He recommended that training be improved. Mutalik [23] audited the effect that formal training of medical staff had upon their knowledge of PULHHEEMS at medical boards and showed that the disparity in knowledge and/or compliance with the medical board procedure between civilian and military GPs was bridged by such training. Rooms [24] examined the process of medical screening of the Regular Army and Territorial Army (TA) to determine the relationship between operational medical grade allocation and medical evacuation rates from theatre. In comparison with
Regular Army and TA, an odds ratio of 1.34 was found in the evacuees but there were no statistically significant differences between Regular and TA soldiers in proportions of pre-existing morbidity. He concluded that pre-deployment screening remains a variable activity in regular military medical centres.

Both Jenkins [25] and Roberts [26] assessed the quality, benefits and predictive value of routine screening medical examinations in RAF personnel and RN aircrew, respectively. The former was a cross-sectional study while the latter employed a prospective self-completed questionnaire by aircrew compared with the physician’s prediction of the examination outcome. In Jenkins’ study, 85% of assessments contained screening abnormalities, yet only 23% of the abnormalities were judged to have been appropriately managed by the medical officer. Although there was a possibility of selection bias in the study population, the results supported the view that untargeted physical examination is of little value. Roberts reported that the results of the study supported the point of view that examining physicians undertaking the aircrew medical assessment can reliably predict ‘fitness to fly’ prior to the physical examination.

In Army aircrew, Curry [27] ascertained what, if anything, had been discovered in the 15 years that the British Army has been conducting routine annual blood screening. In all, 8491 tests were analysed for degree of abnormality, subsequent action, resulting diagnoses and therapeutic interventions. The overall percentages of tests that resulted in a diagnosis were between 0.08% and 3.5%, and therapeutic intervention between 0.08% and 3.4%. No evidence for the continuation of routine blood testing was found other than in the case of periodic cholesterol and lipid estimation. As a result of this work, the aircrew blood screening programme in all three services was amended.

**Ill-health retirement**

The centralization of medical retirement boards in both the RN and RAF facilitate the assessment of outcomes and provide useful information to inform fitness for task.

Aitken [28] reviewed ill-health retirement rates in the RAF, and found that the rate had increased from 1.5 per 1000 in 1988 to 3 per 1000 in 1999. More recently, Talabi examined the ill-health retirement trends between 2000 and 2004 [29]. He found that the ill-health retirement rate had increased further from 3.6 per 1000 in 2000 to 4.5 per 1000 by 2004. These increases are probably due to the higher operational tempo bringing a greater proportion of personnel to the attention of the medical services. The rate is above Her Majesty's Treasury’s recommended target of 3.6 per 1000 employees [30], but below the rate of 5.5 per 1000 NHS employees reported by Pattani et al. [31]. Injuries, musculoskeletal disorders and mental ill-health were the major reasons for ill-health retirement.

Turnbull [32] compared the risk of and causes of medical retirement from the RN submarine service (125 cases) with those in the surface flotilla (737 cases). Based on previous evidence of the morbidity and mortality of submariners, it was expected that they would have a lower risk of medical retirement. The relative risk of medical retirement for submariners was 0.93 (95% CI: 0.77–1.12). In all, 55% of discharges were attributable to musculoskeletal disorders, and the next most common causes being mental and behavioural problems (8%) and injuries (8%). He concluded that the incidence of medical retirement in submariners was lower than in non-submariners, but the difference was not statistically significant. The high incidence of medical retirements attributed to musculoskeletal problems was not an unexpected finding in a military population.

Leonard [33] who was responsible for advising on the OH of the Royal Fleet Auxiliary (RFA) Service compared the experience of the rates and causes of retirement upon medical grounds in the RFA with those in the RN, the study being prompted by concern about the apparent wastage rate of older RFA personnel. He concluded that the prime causes of medical retirement are essentially common to the RFA and RN groups, with most cases being attributable to one of four major diagnostic categories: injuries, musculoskeletal conditions, cardiovascular disease and mental illness. These causes predominate in surveys of medical retirement elsewhere in British industry. However, the log linear model that he used demonstrated a significant difference in the age-adjusted medical retirement rates attributable to a number of these causes between the RFA and RN groups. There was evidence that certain particular features of the structure and operational processes of the RFA contribute to this finding.

**Noise-induced hearing loss**

Noise-induced hearing loss (NIHL) is a perennial issue for the Armed Forces and this topic continues to be challenging. Folkes [34] conducted an audiometric survey of recruits at the start and end of basic training. She found that although there was a downward shift in the hearing grading after training, none of the recruits fell below the retention standards. However, the need was emphasized for further improvement in initial medical examinations and education in the hazards of noise and the correct use of hearing protection to reduce exposure to potentially harmful noise levels at all stages of a military career. Cain [35] compared the prevalence and cause of hearing impairment in employment sub-groups in the British Army, ISO 7029 and other published studies to determine the effectiveness of the Army hearing conservation programme. He concluded that the programme does not protect all workers from NIHL and the main cause is...
Aviation medicine
- Positive pressure breathing: McLoughlin [47] reviewed the effects of ambient temperature on the responses to positive pressure breathing and found that positive pressure breathing at 40 mmHg for 5 min at 40°C imposed a large, but tolerated cardiovascular stress.
- Spatial disorientation: Spatial disorientation (SD) is the failure to correctly sense the position, motion and attitude of the aircraft or oneself with respect to the fixed coordinates of the gravitational vertical and the horizon. It is one of the most insidious hazards in aviation and has warranted comprehensive investigation by several Armed Forces occupational physicians.
  - SD in US Army rotary-wing operations [48]: Surveys of accident records and aircrew experiences. The accident survey showed that 30% of class A–C (serious) accidents involved SD as a significant factor, while the aircrew survey showed that 78% of aircrews had been disoriented (8% to the extent that flight safety was threatened).
  - Survey of SD in military pilots and navigators [50]: The most frequently experienced SD episodes were ‘the leans’ (by 92% of respondents), loss of horizon due to atmospheric conditions (82%), misleading altitude cues (79%), sloping horizon (75%) and SD arising from distraction (66%).
  - Factors affecting the incidence of SD in military aircrew—a survey of US Air Force pilots [51]. Data from 2582 completed surveys were analysed, covering 2.17 million flying hours in 33 aircraft types. Overall, 8% of surveyed pilots had experienced an episode of SD severe enough to adversely affect flight safety.

Submarine research
- The role of the chest X-ray in assessing the risk of pulmonary barotrauma in trainees undertaking submarine escape training in the Royal Navy [53]: The use of the chest X-ray as a tool in the assessment of fitness for submarine training should be continued, pending a full risk-benefit analysis. Further research to look at the clinical outcomes of trainees excluded from training should be conducted to produce clinical guidance for the requirement for chest X-rays for future trainees.
- Changes in plasma vitamin D and matrix metalloproteinase 9 (MMP9) in submariners during a submerged patrol [54]: Circulating vitamin D concentrations were insufficient to prevent a rise in MMP9 (associated with vitamin D deficiency) in submariners. Intervention studies are required into the effectiveness of full spectrum lighting and increased dietary supplementation as countermeasures against hypovitaminosis D.
- An assessment of the influence of SD upon military aircraft accidents from 1983 to 2002 [52]. Inattention to orientation cues was found to be the most common basis for SD and the most common countermeasures suggested were a ground proximity warning system for fast jets and additional training for rotary wing pilots.

An assessment of nickel ingestion by Royal Navy submariners [55]: Although the concentration of nickel in the submarine’s fresh water was elevated above the UK statutory limit and this led to a significant increase in nickel ingestion by submariners at sea compared with ashore, it was not associated with increased absorption of nickel. This suggests that submariners may not be at increased risk of adverse health effects even though they are exposed to a high dietary intake of nickel.

thought to be weapon firing. Research should be aimed at compliance and effectiveness of personal hearing protection in the workplace. In a specific population, Owen [36] studied 121 aircrew, who had more than 10 years flying experience and concluded that there was a threshold shift in excess of that expected from the ISO levels for otologically normal males. Consequently, aircrew should continue to be monitored annually and the non-flying sources of occupational noise exposure should be evaluated.

Greenish [37] studied hearing loss in RAF aircrew. His review of the audiometric data for 263 individuals showed that the hearing loss between initial and final audiometry was less than predicted by comparison with ISO 7029. He postulated that this was due to the relatively small proportion of time that military aircrew fly and the healthy worker effect.

In a unique study, Reid [38] studied the pattern of noise exposure of RAF police dog handlers and whether dog noise was an occupational risk factor for NIHL. Noise surveys on areas of concern, highlighted by task analysis, were conducted and a questionnaire and medical record review were performed on a group of qualified dog handlers and compared with non-exposed personnel. The noise survey revealed areas of concern particularly with regard to noisy dogs travelling in vans and exposure to aircraft noise during foot patrol. Questionnaire data confirmed that the groups were similar in exposures to the variables of primary interest and the likely confounders. Five (9.4%) of the total sample population had an age-corrected hearing loss exceeding 10 dB, averaged over the 4- and 6-kHz frequencies and this only affected the left ear. Logistic regression analysis was unable to show associations between this outcome and the police dog handling duties.

A Defence Hearing Working Group is presently considering further basic science and intervention research.

Musculoskeletal injuries
The research team at the ARTD has concentrated on this topic and a summary of their recent contributions to Army OH follows.

All medical discharges occurring during training are confirmed by the consultant occupational physician at ARTD. These figures, together with information from RIs, are used to help identify the research priorities for improving first time pass out rates, reducing training attrition and improving overall retention of military recruits.

Injuries during military training are an inevitable occupational hazard. Nevertheless, their occurrence contributes to significant morbidity and loss of operational
effectiveness. Presently, they account for 47% of all medical discharges during phase 1 and 2 training and 20% of these are overuse and MSIs [39].

Both Gemmell [40] and Noon [41] investigated the factors associated with MSI in Army recruits to evaluate their significance as predictors of injury. Subsequently, ARTD commissioned retrospective studies in 2005 to determine the incidence and causes of MSI in British recruits from different populations—male/female, junior/standard entrants [42–44]. The outcome of the studies confirmed the main body of published studies from other military populations that gender, low aerobic fitness (determined from the 1.5 mile run time), low strength, low body mass and cigarette smoking were significant risk factors for overuse MSIs. Fewer physical performance or lifestyle characteristics were associated with injury risk in junior recruits and the only significant risk factor was slower 1.5 mile run time in males and oral contraceptive use in females.

While these findings suggest that countermeasures for injury may not necessarily be effective in all military populations, gender and low aerobic fitness are common risk factors. Two training initiatives were subsequently evaluated during phase 1 training: Gender-fair training in single-sex platoons [45] and soldier pre-conditioning (providing additional aerobic and strength training to the lowest quintile of fitness ‘passes’ [46]). Early findings indicate that since these initiatives were introduced, pass-out rates have improved in both sexes and medical discharge due to training injuries has decreased in female recruits.

Identifying the risk factors for MSI and developing appropriate, evidence-based preventive measures remains an important component of the ARTD research programme. Ongoing and planned research activities also address specific and the most common training injuries resulting in discharge, e.g. anterior knee pain and stress fractures. However, a knowledge gap remains on the impact of training injuries in recruits who are not medically discharged and future efforts will be made towards obtaining this information.

Specialized OM research

Brevity of this review precludes a comprehensive discussion on specialized areas but the headline findings of selected works are highlighted in Table 2.

Conclusion

The Armed Forces will face many challenges in the 21st century and are likely to be involved in an increasing number of smaller scale, complex conflicts at considerable distance from the UK. To meet these challenges, Armed Forces OH practitioners must continue to provide the best evidence-based advice to enhance force preparation and sustainment. All consultations in the Armed Forces involve an OH consideration from the simplest consultations through to the input from specialist OH practitioners. While the assessment of fitness to work in home bases and on deployed operations remains the primary output of OH, the provision of support to command policy, procurement and research are also key to the ability to operate worldwide.

Conflicts of interest

None declared.

References

7. BR 1750A Handbook of Naval Medical Standards (Application of the PULHHEEMS System). Medical Director General (Navy) 2009.
12. The Medical Examination and Assessment of Divers (MA1) HSE April 2008.
18. Walters PL. The effectiveness of exercise based inpatient rehabilitation in the British Army in returning soldiers to fitness for
20. Journal of the Royal Army Medical Corps, Regimental Headquarters RAMC, FASC, Camberley, Surrey, GU15 4NP.
21. Journal of the Royal Naval Medical Service. JRNMS Office, INM, Alverstoke, Gosport, PO12 2DL.
34. Folkes SP. Audiometric survey of junior and adult recruits at the start and end of basic training. Dissertation, Membership of the Faculty of Occupational Medicine. 1995.