Options for Future Military Health Surveillance Systems

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SUMMARY: This paper examines the requirement for health surveillance systems for military forces. Military health surveillance is the routine systematic collection, analysis, interpretation, and reporting of standardised, population based data for the purposes of characterising and countering threats to a population's health, well-being and performance. The fundamental components of a health surveillance system should enable concurrent or retrospective analysis of health effects in military personnel using a cohort study design. Military hazards include trauma, infection, toxic effects, radiation, psychological stress and ergonomic stress. Variations in distribution of the hazard, distribution of the population, fragility of the cohort, and the variation in the duration and magnitude of exposure, compound definition of the exposed cohort. The measurement of biological effect is complicated by limits in knowledge about the relationship between exposure to the hazard and effect. A biological model that explains detection, causality, pathological process and health effect should support this knowledge. Lastly the definition of health effect needs to consider the difference between clinical activity rates and true measures of health outcome.

The UK has a number of health surveillance systems including sentinel reporting, a population-based primary care reporting system and measures of medical discharge and death. The US Army is developing IT-based surveillance systems to link hazards personnel and medical databases. The paper suggests a conceptual model for such a system in the UK military.

Introduction

The Army is a large workforce with a wide range of occupational exposures. It has a duty as an employer to monitor the effects of these on health and to reduce adverse effects as much as is reasonably practicable. In addition adverse effects on a soldier's ability to work may have an economic impact. Military commanders rightly have to be kept informed about the health of their troops as this is one of the key components of their military capability.

The Army has a long history of collecting routine records on morbidity and mortality based on hospital activity, medical discharges from service and deaths(1). This activity has often been supplemented by “one-off” surveys conducted for research. Such projects have been valuable in describing numbers of cases attributable to a variety of conditions including heat illness(2,3), deafness(4) and post-traumatic stress syndrome(5). The value of the hospital-based information is diminishing because an increasing volume of medical activity is being performed in primary care, outpatients or as day-case admissions, none of which is routinely captured. Furthermore it is often very difficult to define populations at risk or control populations in order to measure rates or relative risks. In the past, study design has been limited by the lack of a suitable, overarching information strategy.

The British Army has developed a population-based system for health surveillance called J95(6,7,8,9). This system has proved the value of health surveillance to military commanders and has been extended for use by NATO(10). This is a low-technology, interim solution pending further development of an integrated health surveillance strategy.

The aims of this paper are: to present a method of identifying health problems associated with military service, to discuss problems associated with data capture and to suggest a model for the design of military health surveillance systems. The paper builds on work presented by Hawley(11).

Health surveillance

Health surveillance is defined as the routine, systematic collection, analysis, interpretation, and reporting of standardised, population based data for the purposes of characterising and countering threats to the health, well-being and performance. This definition is conceptually separated from alternative definitions of health or medical surveillance, which include the observation and recording of individuals’ health by medical examination.

Health surveillance aims to measure the relationship between populations, exposures to external agents, health effects and outcomes. Human populations are constantly exposed to a wide variety of environmental challenges each of which may have a biological effect. These biological effects may lead to a detectable illness. This paradigm leads to the theoretical design of a cohort study as shown in Figure 1.

![Fig 1. Cohort Study Design](attachment:image.png)

Health surveillance systems can measure these relationships by defining populations, observing exposures, detecting biological effects and recording ill-health. Each of these components will be discussed further below. Health surveillance systems should be a critical element of the military medical decision cycle. The potential uses for such systems include: detecting exposure to health hazards by observing variations in health, detecting effects of exposure to hazards by comparison of health outcomes between exposed and non-exposed groups, resource allocation by measuring demand for health services, medical planning by reference to historical trends and academic research.

Populations

The first element in the design of a health surveillance system is the definition of the population to be observed. Populations that have been covered by military health surveillance systems include those defined by: geographical location, type of activity (e.g. Basic training, operational deployment), military unit, occupational group (e.g. Pilots) and attendance at medical specialty (e.g. Primary care, Secondary care, physiotherapy, genito-urinary medicine).
The critical element of a surveillance system is the ability to make comparisons between population sub-groups defined by exposure and health outcome. This principle is shown in Figure 1 whereby comparisons may be made between each of the groups shown. The ideal surveillance system would observe all military personnel on an individual basis and record exposure and health outcome continually. Unfortunately this is not usually possible and a larger unit of observation (e.g. Military unit, medical practice etc.) may have to be chosen. This may lead to methodological problems with cohort definition as shown in Figure 2.

- Definition of the cohort
- Fragility of the cohort
- Variations in distribution of hazard
- Variations in distribution of population
- Variations in duration of exposure
- Variations in magnitude of exposure

Fig 2. Problems with cohort definition

Military forces deployed on operations are increasingly likely to be specifically 'packaged' and may include naval and air force personnel. Therefore a surveillance system defined by peacetime military structures may not correctly capture the observed populations. Similarly, military populations are very 'fragile' because of continual movement of individuals in and out of the group. Thus it may be difficult to demonstrate that the observed differences between groups are not affected by this turbulence. One of the elements for determining the effects of exposure to an external agent is a measure of duration of exposure. This is usually expressed in terms of 'person-time'. The disruption to the population group by turbulence makes estimates of the magnitude of exposure very difficult to achieve. In addition it would be unusual for all members of the same population to be uniformly exposed and so measures of effect based on population exposures are likely to be unreliable.

Hazards and Exposures

Clearly there is a considerable range of external agents present in the military environment that could have a biological effect. In addition to conventional weapons of war, such as bombs, bullets and explosives, many countries have developed more insidious weapons using biological or chemical agents. In addition to military weapons there are many other environmental hazards that may affect the health of soldiers. These are summarised in Figure 3.

- Traumatic
  - Battle injury
  - Non-battle injury
- Infective
- Chemical
- Environmental
- Radioactive
- Psychological
- Ergonomic

Fig 3. Range of military hazards

Overall it can be seen that it is likely to be impossible to create accurate exposure histories for every agent to which individual soldiers might potentially be exposed. Alternative models may need to be developed which link a system of individual tracking with environmental monitoring and record keeping. In this way the information is disaggregated but linked so that it is possible to create retrospective exposure histories.

Relationship between exposure and health effect

One of the principle uses of a health surveillance system is to determine whether exposures to external agents cause variations in health between exposed and non-exposed groups. The relationship between exposure and effect must be considered in the design of a health surveillance system. If the exposure is known to have a health effect it is relatively simple to design a surveillance system to monitor the effect. If variations in health outcomes between groups are observed, this may lead to a hypothesis that the difference is the result of variations in exposure to an undefined external hazard. However it can be very difficult to retrospectively identify the hazard responsible.

In addition to the problem of multiple external agents in the military environment, each hazard may have a variety of clinical effects e.g. blister agents (a type of chemical weapon) may cause delayed cutaneous effects, acute and chronic pulmonary effects, inhibition of immune system, and carcinogenesis. There may be a considerable range in the time between exposure and the potential onset of symptoms. Surveillance systems should be designed with this in mind. For instance a survey designed to measure training injuries in a basic training establishment will probably detect acute injuries efficiently. Long-term outcomes are likely to be missed because these may only have an effect once the individuals have left the training unit. Therefore any medium-to-long term epidemiological system should be based on individual patient tracking. Thus the design of military health surveillance systems for the detection of health outcomes must be capable of recording immediate effects and yet also be able to follow-up military personnel beyond their military service and may even need to detect genetic effects in their offspring. Figure 4 shows the range of pathological processes and time between exposure and health effects associated with military hazards.

- Immediate e.g. traumatic effects of munitions
- Short acting e.g. chemical weapons
- Medium acting e.g. psychological effects
- Delayed e.g. infectious disease
- Long-term health effects e.g. carcinogenic
- Reproductive effects e.g. genetic mutations

Fig 4. Range of pathological process associated with military hazards

Outcome measures

A military health surveillance system must be designed to measure biological effect in order to validate a link between exposure to a harmful agent and a change in health. Figure 5 shows that biological effects can be measured in a large variety of ways.

- Changes in biological activity
  - e.g. Enzyme activity, DNA adducts
- Changes in clinical activity
  - e.g. Primary care attendance, hospital admission
- Changes in health outcome
  - e.g. Medical fitness, discharge on medical grounds
- Surrogates for health
  - e.g. Physical fitness, divorce, criminal record

Fig 5. Options for measuring biological effect

The method for measuring adverse health outcomes must be designed to detect changes in the patterns of all indicators of
health. It may be necessary to consider surrogates of health outcome if these are more easily measured than true clinical diagnostic categories e.g., disciplinary records maybe a more sensitive indicator of the psychological health of a population than the rate of psychiatric referrals. This may include biological records such as stored blood samples. These could be analysed to detect the effect of external agents before there is clinical disease.

Current and future pressures on the design of health surveillance systems

The publicity surrounding the ‘Gulf War Syndrome’ represents a watershed in public expectation regarding the effects of military service on health. There has been public concern regarding the effects of military service on serving personnel and veterans in other countries, particularly in the United States with Agent Orange. In Britain it was probably the size of the deployment to the Gulf and therefore the potential numbers exposed that led to the publicity surrounding the ‘Gulf War Syndrome’.

Investigation into the possible effects of service in the Gulf War has shown the fragility of paper-based, short-term health records(12). Furthermore it has shown the difficulties associated with measuring exposure to environmental agents many years after the event, identifying cohorts of comparable controls and tracing health outcomes for personnel who may not even remain in service.

The impact of the publicity associated with ‘Gulf War Syndrome’ has resulted in public expectation that the Army should have a robust health surveillance system. The Army will need to be able to observe the health outcomes of personnel after any future operational deployment in order to identify an excess risk associated with such a deployment.

Principles of health surveillance system design

Before proposing a design for a future health surveillance system, it is important to identify any key principles required. Figure 1 showed in schematic form the key components of a cohort study design, namely the identification of the study population, measurement of exposure, measurement of biological effect and measurement of health outcome. Figure 6 identifies the design principles for a military health surveillance system.

- Joint ownership and responsibility between military commanders and medical staff.
- Use of database linkage of disaggregated information e.g. personnel location indicators.
- Use common individual identifiers e.g. Military number, NHS number.
- Use of surrogate records as indicators of exposure e.g., hazardous duty pay, separation allowances.
- Ensure: Flexibility, security and accessibility.

Fig. 6. Design principles for a military health surveillance system

A military health surveillance system should be jointly owned between military commanders and their medical advisers. Although the medical staff will advise on the design of the system and the analysis of the information, it is the military commander who finally uses the information. This must lead to a shared responsibility for data capture particularly as it will be the personnel administration systems that record population based information and exposures. The almost limitless capability of electronic systems to record information must not be allowed to overwhelm the capability for analysis and interpretation. This leads into the critical conceptual component of a modern health surveillance system, which is the ability to link databases, and so aggregate widely distributed personnel records, exposure records, health record outcomes and outcome measures. This can only be achieved through the use of common unique person identifiers that can transcend military databases in order to link with other governmental data such as social security and health records. This will enable surrogate measures of exposure (e.g. hazardous duty pay) and surrogate measures of outcome (e.g. receipt of War Pensions) to be linked and to augment purely clinical records. Consideration should also be given to the use of repositories of biological records such as serum samples as measures of health and health outcome to augment text-based clinical records. Tied with this would be the concepts of epidemiological and sentinel reporting to provide early-warning indicators of adverse health outcomes, target more detailed examination. Finally the information system designed to deliver the health surveillance capability should be flexible, secure (from a medical and military perspective) yet accessible to users.

It is clear from the foregoing paragraph that a single health surveillance system is unlikely to meet all requirements. A series of complementary systems should be designed to meet the information requirements of users.

Options for future military health surveillance

The proposed system is composed of 4 elements shown in Figure 7. The lowest level of reporting is ‘sentinel reporting’ based on a system similar to public health notifiable disease reporting. In principle the senior medical adviser for a defined population identifies a series of system complexes or diagnostic categories that should be reported by all medical personnel. Although this is the simplest surveillance system, it is also likely to be the most responsive because any change in population health is likely to be detected on the basis of anecdotal reporting before it can be proved by epidemiological analysis. This must be augmented by a training programme to emphasise the importance of the system to medical staff. Incomplete reporting may seriously mislead the medical command structure.

- Sentinel reporting.
- Epidemiological sampling.
- Information repositories.
- Off-line investigation.

Fig. 7. Elements of proposed military health surveillance system

The second level of health surveillance would be based on a simple ‘epidemiological sampling’. This level of surveillance needs to be extremely basic, even paper-based, so that there is no barrier to data capture. This system would be an extension of the sentinel system in that only very crude health outcomes are recorded. The principle difference between this and sentinel reporting is that the population at risk is defined and so comparison between rates is possible. The reporting frequency for this system should be designed to detect important events e.g. if the use of highly infectious biological agents were to be detected then the reporting frequency should be shorter than that to detect trends in overuse musculoskeletal conditions. The validity of this system is limited by the stability of the population and thus is best suited to short deployment when military units remain relatively intact. The EPINAT health surveillance system is one example of such a system.
The final element of the health surveillance system is based on the linkage of information repositories. This allows ‘off-line’ epidemiological analysis by the retrospective creation of exposure cohorts with appropriate controls and systematic follow-up to detect variations in health outcome. For prolonged exposures, ‘time-weighted exposure’ calculations can also be obtained using person-time records.

Conclusions

This paper has further confirmed that military health surveillance is an operational imperative. Existing systems have been reviewed and their limitations identified. There are a number of problems associated with data capture including cohort definition, assessment of exposure to hazards and measurement of effects. It is concluded that it is unlikely that a single health surveillance system will meet all requirements and therefore a hierarchical approach to military health surveillance is required. This paper proposes 4 levels of activity: sentinel reporting, epidemiological surveillance information repositories and finally ‘off-line’ investigation. A structure for the linkage of information repositories is proposed as a starting point for academic debate. The introduction of formal health surveillance into military medicine will only be successful if there is a large corporate understanding of its conceptual basis.

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