Physiological monitoring for healthy military personnel

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ABSTRACT

Military employment commonly exposes personnel to strenuous physical exertion. The resulting interaction between occupational stress and individual susceptibility to illness demands careful management. This could extend to prospective identification of high physiological strain in healthy personnel, in addition to recognition and protection of vulnerable individuals. The emergence and ubiquitous uptake of 'wearable' physiological and medical monitoring devices might help to address this challenge, but requires that the right questions are asked in sourcing, developing, validating and applying such technologies. Issues that must be addressed include system requirements, such as the likelihood of end users deploying and using technology as intended; interpretation of data in relation to pretest probability, including the potential for false-positive results; differentiation of pathological states from normal physiology; responsibility for and consequences of acting on abnormal or unexpected results and cost-effectiveness. Ultimately, the performance of a single monitoring system, in isolation or alongside other measures, should be judged by whether any improvement is offered versus existing capabilities and at what cost to mission effectiveness.

INTRODUCTION

A recent 'Images in clinical practice' paper described a 34-year-old manwith paroxysmal atrial fibrillation (PAF), who undertook a 12-mile run while wearing a wristwatch monitor of HR.[1] Data from the run showed the cardiovascular 'strain' response to the physical stress of running, in the form of an exercising tachycardia. The recording also indicated an acute escalation in HR to 230 beats per minute after approximately 5 miles of continuous running, at which point the subject felt light-headed and experienced palpitations. He responded by stopping exercise, resting and employing a Valsalva manoeuvre to curtail the episode.

This case demonstrated the interaction between extrinsic (physical) stress and intrinsic (cardiovascular) susceptibility, with scope for pathological sequelae to threaten performance and health. This presents a dual challenge to organisations responsible for the well-being of personnel who engage in strenuous physical exertion, imposing requirements to be vigilant for, or even curtail, situations that may result in high physiological strain in healthy personnel and also to identify and protect vulnerable individuals.

The emergence of 'wearable' physiological and medical monitoring technologies, including smartphone-enabled applications, could prove advantageous in this regard, both to 'the Regimental Medical Officer (RMO) operating in an austere environment'[1] and to the wider Defence community. The most direct beneficiaries would be individual personnel, empowered by information about their own physical and training status. This paper addresses issues around such 'real-time' monitoring including the use of data captured from exercising military populations.

INTERPRETING PHYSIOLOGICAL DATA

Using the aforementioned case above as an example, how does the pretest probability of arrhythmia in this individual known to have PAF influence the interpretation of the tachycardia and the subsequent treatment of a presumed arrhythmia? As far as we are aware, this technology is not validated to assess cardiac arrhythmias in any population, least of all the military. In a fit, healthy military population, who typically have no prior history of cardiac arrhythmias, it is vital to understand the consequences of producing data that may influence perceptions of occupational suitability. Should an episode of tachycardia in an otherwise healthy individual mean that they are medically downgraded?

Many questions are raised, which extend to other types of physiological monitoring (box). As with any source of clinical information, the data made available to the clinicians sitting in judgement must be assessed for its quality and reliability. International standards exist not only for the methods by which physiological strain responses may be evaluated in healthy individuals, as used with personnel working under high thermal stress,[2] but also for the devices and software that are employed to monitor medical patients. There is the potential for misleading information to be provided and unnecessary interventions undertaken.[3] Thus, issues of central importance relate to the point at which an individual may be said to have fallen off the 'healthy' stress–strain curve and should henceforth be considered a casualty. In addition, it must be determined whether the system used to identify this departure from the healthy state is adequate for monitoring aberrant physiology in disease.

ACCESSING AND USING THE INFORMATION

Military personnel operate under a duty of care, in conditions and with constraints that may differ markedly from civilian populations. In the case described, the subject elected to continue running and covered the intended distance without further reported issue. In a military context, a number of constraints exist. These include the requirements to define who owns and uses the data; whether data is reviewed contemporaneously or in retrospect; how the individual is alerted to new information, as with an alarm or voice-activated advice; whether they could choose to disregard the information and how the RMO contributes to decision-making, be it through real-time monitoring or 'after-action' review of events.

Box 1 Questions pertaining to the use and interpretation of physiological monitoring in healthy military personnel

- What is an individual's normal physiological response to exercise?
- Are the results of monitoring reproducible?
- Could results reflect interference, as with motion artefact from exercising?
- What are the implications of false positives for disease (vs normal physiology) on a Service person's health, well-being and career?
- Does a cost-based analysis determine monitoring to be an effective use of resources?
- How often would personnel wear a monitoring system (continuously vs intermittently) and would they actually wear it when it really mattered (at times of peak risk)?

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Precedents from civilian life include both incidental and deliberate withholding of performance data from professional athletes by their medical and management teams, which may be considered necessary for optimising precompetition training or winning a race. In addition, there is the requirement for hospitalised patients and their relatives to apply to medical authorities, such as NHS Trusts in the UK, for the release of information collected during their inpatient admission. The additional ethical issues raised by capturing data from healthy military personnel extend beyond the more easily grasped beneficence and non-maleficence axis to challenge issues of personal autonomy. These include the freedom to achieve peak physical performance, which may on occasion fall a hair's breadth from physiological failure,[4] as well as justice, whereby limited resources may need to be targeted at those perceived to be at greatest risk.

MONITORING IN CONTEXT

Other challenging issues that may be of relevance in military settings include the scope for false reassurance. An example of this is a peripheral body measurement reading lower than true core temperature, the parameter of clinical interest in heat stroke.[5] In a similar vein, misdiagnosis of exertional heat stroke as supraventricular tachycardia has been described, whereby focussing on one measured variable and neglecting to address other important parameters resulted in incorrect management.[6] On the other hand, undue alarm from artefactual or methodological overestimation of a measured or derived variable could result in pre-emptive withdrawal of personnel from important activities, which they might otherwise have successfully completed.

In relation to heat stress and exercise, an issue of perennial military importance, it has been stated that '*Man is not a pulse rate, a rectal temperature, but a complex array of phenomena*.'[7] In trauma research, HR monitoring in isolation has shown no value in differentiating injury from exercise-induced tachycardia. However, a non-invasively monitored combination of HR, blood pressure, stroke volume and pulse oximetry was able to reliably predict blood volume in a model of acute haemorrhage.[8] The lesson is that, as in clinical practice, more than one variable may be required to support diagnosis and decision-making. Tools to analyse variability and changes in the complexity of recurring signals, such as 'rolling' HR over time, may help to characterise physiological strain, impending decompensation[9] or overt illness[10] and could mature to have practical utility in the future. On the battlefield, it may become possible for learning algorithms to help to identify and triage wounded military personnel according to the degree of deviation from 'healthy' physiology highlighted by monitoring, thereby producing an automated form of personalised medicine.[11 12] However, any such approach must first be validated in populations representative of the military, before attempting to translate or extrapolate their use into occupational and clinical practice.

IMPLICATIONS FOR DEFENCE

Wearable technology represents an appealing and potentially hugely beneficial enhancement to the equipment currently used by UK military personnel, which could improve healthcare across a number of domains. It may prove possible to close a number of declared capability gaps in diverse areas. This includes managing heat illness in the jungle and other prehospital environments,[13] predicting post-traumatic stress disorder in advance of operational deployment[14] and optimising rehabilitation following musculoskeletal injury.[15] The breadth, depth and accuracy of physiological data capture may be further increased by moving beyond the body surface to use indwelling devices. This may include implantable loop recorders to detect bradyarrhythmias and tachyarrhythmias at high altitude[16 17] or continuous interstitial sampling to monitor clinical chemistry, such as lactate concentration during high-intensity exercise.[18]

Just because technology exists, however, does not mean we are mandated to use it. Rather, we must define the questions we wish to answer. Hypothesis-driven research must determine if the wearable technology in question can answer our specific questions and whether it benefits the wearer or, ultimately, the mission. The data obtained must then be validated and proven to be reliable and reproducible. Examples of ongoing work towards such outcomes include instantaneous evaluation of physiological responses to prolonged endurance exercise in female military personnel crossing Antarctica, investigation of the effects of high altitude on energy and metabolism using subcutaneous continuous glucose monitoring and characterisation of heat acclimatisation status by analysis of HR variability. Importantly, these projects have benefited from direction, guidance and coordination from the Academic Departments of the Royal Centre for Defence Medicine. Additional collaboration has occurred with subject matter experts at established homes of physiological research within Defence, including the Institute of Naval Medicine, the Army Recruiting and Training Division and Royal Air Force Centre for Aviation Medicine.

CONCLUSIONS

Although the burgeoning availability of biological sensing and surveillance technologies presents exciting opportunities to evaluate novel devices in military populations, this should not detract from ongoing efforts to develop, improve and validate practical 'low-tech' tools that might optimise performance and improve clinical outcomes.[13] Nor should the value of clinical acumen in diagnosis and discerning, individualised management by experienced Medical personnel be diminished. Where physiological monitoring does find a place in the military wardrobe, it will remain beholden on Commanders and Medical professionals to develop and maintain their own risk stratification and surveillance abilities.[19] It will also remain necessary for their subordinates and patients listen to their bodies and share their day-to-day vulnerabilities, whatever their smartphone is saying.

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