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Biosensors supporting healthcare in missions — expert consensus on the status of implementation in the military and future tasks

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Original article

Abstract

The monitoring of physiological parameters using wearable (bio-) sensors of military personnel is a progressing process within the military environment. It sets high demands on such devices, in order to support healthcare and performance of the personnel. To get an ovierview of the current status of the use, the evaluation and the implementation in the military, in May 2021, the Multinational Medical Coordination Centre / European Medical Command has organized an expert workshop about 'Biosensors Supporting Healthcare in Missions'. Three thematic clusters were addressed: 'Human Performance and Readiness'; 'Health and Medical Management Applications' and 'Ethical and Legal Aspects of the Use of Biosensors'.

Keywords

- wearables
- sensors
- soldier readiness
- biosensors
- healthcare
- physiological monitoring
- triage
- wearable devices
- biosecurity
- data reliability

Contribution

A – the preparation of the research project
B – the assembly of data for the research undertaken
C – the conducting of statistical analysis
D – interpretation of results
E – manuscript preparation
F – literature review
G – revising the manuscript

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Background

The use of wearables and medical sensors (biosensors) to monitor the physiological status of athletes or individuals is common in the health and fitness sector and are developing rapidly. The physiological status monitoring of military personnel is also progressing steadily, but the military environment set high demands on wearable devices and the use of biosensors to support healthcare and performance.[1] For example requirements of integrity, security of data, transfer and transformation of data are much more sensitive than the available commercial systems are able to cover and unsecure and proprietary architectures can not be easily intregrated into tactically secure and independent systems.[1] Wearable devices have been tested and evaluated in various settings and areas of application. Within the military, the focus is set on 'soldier performance and readiness' as well as 'health and medical management applications'.[1] The focus is predominantly on training science, as soldiers and athletes are subject to similar demands (heat, hypoxia, physical fatigue limits, etc.). With the expanded mission requirements of the military, the health and medical management area is just given as much importance and has it's focus on casualty detection, chemical or biological threat agent exposure and remote triage. The usage of wearable sensors to maintain and manage health related issues also gets a boost from the current pandemic situation.

To get an overview of the current status of implementation of wearable biosensors in the military, the Multinational Medical Coordination Centre / European Medical Command has organized an expert meeting adressing the thematic clusters: 'Human Performance and Readiness'; 'Health and Medical Management Applications and Ethical and Legal Aspects of the Use of Biosensors'. Following the meeting, a questionnaire about 'Biosensors Supporting Healthcare in Missions' was carried out to summarize the key findings and and get an overview about future aspects.

Methods and selection of tools

Meeting

The Multinational Medical Coordination Centre / European Medical Command is a multinational institution of the German Army Medical Service and has 18 member nations from NATO and EU. To get an overview of the current status of implementation and bundle knowledge in this subject area, the organizing committee of the meeting invites every nation to join with subject matter experts.

Survey / Questionnaire

Following the meeting, a questionnaire was distributed to the registered participants in order to be able to summarize and evaluate the meeting and get a better view about recommendations for action and future research areas. The questionnaire itself was created on an online survey platform (www.surveymonkey.com) and was designed to take 10 minutes to complete. The questionnaire had 19 questions, which were predominantly closed-ended with a predetermined set of answers or were created in the form of a Likert 5 scale, that the answers could be evaluated in a standardised manner.

Participants

130 participants from 20 nations registered for this three-day event. Around 100 participants were online on the first two days and about 80 on the third day.

Topics

According to literature reviews, the topics focused on the application of biosensors in the military.[1] The first dealt with the implementation of biosensors in the area of 'human performance and soldier readiness' and the second focus was set on 'health and medical management applications'. A third focus was set on 'legal, ethical and data security aspects' because legal and ethical implications during decision making processes under very demanding tasks for example has an even higher priority than in other fields of action and must be taken into account in further development. Data security is another crtical element in designing sensors for a military environment.

Statistical analysis

The expert consenus will be summed up exploratively in the three clusters, the key results of the questionnaire will be presented are also analysed qualitatively and are presented as percentage of respondents.

Results of the meeting

Human performance and soldier readiness

Focal points in research are set in improving or rehabilitating the performance of individuals with physically

very demanding tasks, such as Special Operation Forces and operations in extreme environments (pilots, reconnaissance units or medical first responders). Also studys in supporting decision making processes with the focus on tactical level command and control algorithms, giving the military leader a real-time overview over the physical (and possibly mental) status of his / her soldiers were in research focus.

The experts highlighted different sensor techniques or devices and predominantly commercially available wearables. Various 'in-ear technologies'[2], wristband methods[3] and customized made solutions[4] were tested or will be tested within different military settings. However, most of the studies are still basic research studies including various application areas. Several researchers highlighted the use of in-ear wearables to measure different individual parameters and reducing the risk of sensory malfunction, a common issue with wrist-worn or chestband-worn sensors.[2,3] A researcher team from Switzerland monitored physiological and mental parameters during a 100 km march with different commercial available smart devices and came to the conclusion that data quality is inconsistent between sensors and validated sensors are needed to detect fatigue and support soldiers performance in a military environment.[5]

Health and medical management applications

The multinational experts developed a clear vision and viable way ahead on how to support emergency military medical care using biosensors in missions. The gap between the Point of Injury (POI) and the currently available diagnostic options at the first point of care could be bridged by using biosensors as point of care medical diagnostic tools.[6-8].

There was a consensus among the experts, that two different methods were suitable: Wearable biosensors either could be placed on the injured person (by the care provider) to receive vital data or data could be transferred to the provider from already worn devices (by the soldier), thus supports the medical decision-making process through real-time data of the injured person.

Wearable biosensors can also be used to support in a chemical biological radioactive and nuclear (CBRN) related setting. Some experts from the civilian and military field highlighted repeatedly, that a biosensor can also detect various chemical and biological agents, thus protecting the user and transmitting data to higher echelons of command and control.[9,10]

Legal, ethical and data security aspects in the use of biosensor

Legal and ethical issues regarding the impact and effects of using biosensors in military settings to support tactical decision-making appeared to be not sufficiently consolidated with regard to multinationally agreed and binding standards. Both, ethical and legal issues were addressed by several speakers of different nations highlighting the need for further discourse. Main research fields are furthermore the use and ownership of biosensor-collected data and battlefield decision-making.[11]

Regarding cybersecurity, the main fields of research are also the use of ownership of biosensor-collected data, the associated risks with biosensors related to cyber-attacks or the manipulation of generated data, as well as the evaluation and feedback of the medical data into the command-and-control cycles of i.e. warfighters.

Summary of the presented lectures and outcomes of the survey

66 applicants (48 male; 18 female) completed the survey after the meeting. There was consensus among the experts that the commercially available wearables (e.g. smart watches) are not yet sensitive enough to meet the key elements for the use of biosensors in a military environment. This includes data safety.

As in line with this key result of the presented lecures, according to the evaluation of the questionnaire, the greatest need for further development lies in biosensor quality, reliability and validity of data (79.7%; 51/64, Figure 1) followed by data protection and data security (60.9%; 39/64) and sufficient robustness of biosensors (59.4%; 38/64) in a military environment (Figure 1).

Sensor quality, reliability and validity of data sets the focus on the biosensor, that the sensor generates data which is useful, valid and reliable and allow inter- and intraindividual comparisons and supports the decision making process. Sufficient robustness means, that the military environment set high demands on a sensor regarding the sensitiveness against the operating environment (heat, dust, soldier equipment, battery life, battlefield scenarios, sweat, etc.). Data protection and security are vital enablers in a military operation because the data has to be transferred as secure as possible and be protected against cyber attacs or manipulation. The technical infrastructure set much higher demands than commercialy available wearables can cover yet.

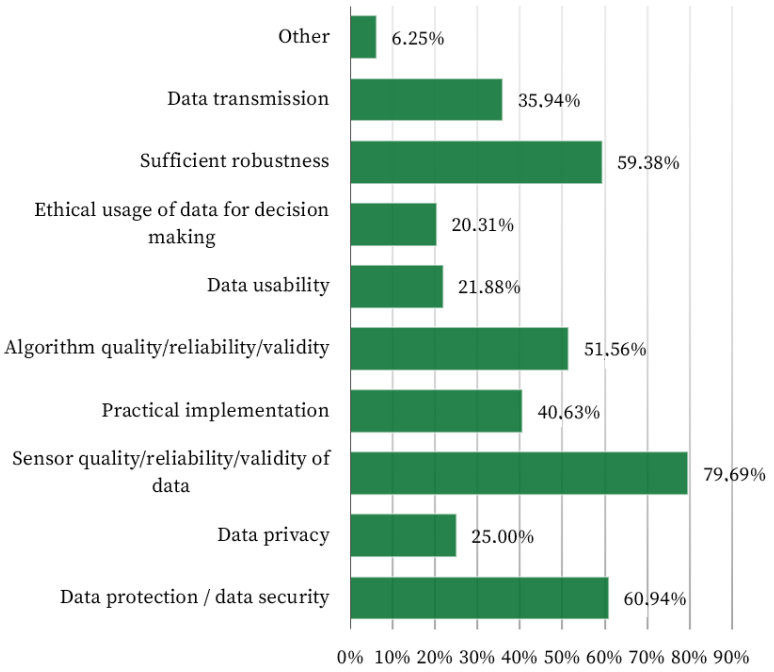

Figure 1. Results of the question, were the experts see the most need for development in this subject (64 responses, multiple answers possible)

Data transmission means the technical data transmission channels (wireless, wired etc.) and the technical data transmission protocols (how the data is encoded). Ethical usage of data for decision making means that the generated results has to be in line with ethical principles to use it in for decision making processes. Data usability means, that the data has to be valid and easy to understand to react on and with it. Algorithm quality / reliability / validity means that the algorithm of the measured parameter itself has to be reliable and valid and sensor quality. Practical implementation means that the sensor has to fit in the military environment and operation and is easy to involve in a realistic setting. Data privacy means that the personal data has to be protected and be in line with data privacy requirements.

Following the experts opinion, the greatest advantages of the use of biosensors in a military environment lie in 'medical application for maintaining the health of soldiers in general' (32,8%; 21/64, Figure 2), but special use cases like biosensors supporting in in the field of human performance and soldier readiness (20,3%; 13/64) and tactical medical care / emergencies (18,8%; 12/64) are also important and nearly all fields of action are equivalently important (26,6%; 17/64) (Figure 2).

There is also an urgent need for better information and multinational exchange in this innovative field of development: More than 80 percent of the respondents endorse the additional need for further multinational cooperation / coordination when facilitating the use of biosensors in the military. A platform for a Community of Interest (CoI) could and should be generated to facilitate this purpose. This CoI will consist in a network of military and civilian expertise, in combination with the European Union and NATO.

An implementation of biosensors into the military environment would need to coincide with the development of key principles of cybersecurity in an early stage of the development of wearable biosensors themselves. Since the field of cybersecurity itself is undergoing constant technical and legal evolution, the technology of biosensors, especially when regarding the issues of data transmission, needs to be considered accordingly.[12]

The military could also use wearable biosensors in support of the tactical level command and control algorithms, giving the military leader a real-time overview over the physical (and mental) status of the soldiers.

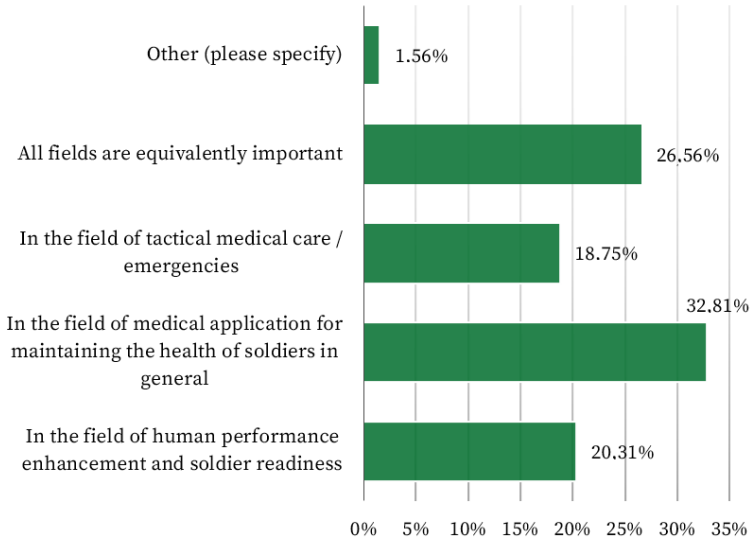

Figure 2. Results of the survey were the experts see the greatest advantages in a military environment when using wearable biosensors (64 responses, multiple answers possible)

Discusssion

The overall conclusion was that the existing wearables are not yet sufficiently sensitive for military environments. This is also in line with existing studies on this topic.[1,13,14]

Focus on basic research is needed to reduce the perceived hesitance in 'trusting' wearable biosensors and machine learning / artificial intelligence in a military setting. This appeared to signify a general trend when applying commercially available biosensors to an environment they were not originally designed for.

Especially the military environment during deployments (extreme operational conditions) needs more valid and evicence based data to compare it with available research under extreme conditions (heat, hypoxia, stress etc.) with the aim to develop wearables which are suitable, robust and sensitive enough for soldiers and their specific tasks.

A generalized approach to the use of biosensors will not be feasible in the immediate future, because of this lack of validity and reliability, especially when regarding medical data. An extensive and long-term monitoring of different parameters of individuals by different biosensors would be necessary to generate valid data on soldiers (the s.c. ground truth) and deduce recommendations for action.[5] However, this would only be applicable for smaller groups of soldiers in particular missions and specific, context-based situations.

The individual situation in which biosensors are needed should set the demand and afterwards the demand should define the requirements of the biosensors. For example, biosensors to support triage situations - in special operational conditions like deserted unstable areas - should be designed thinner, maybe integrated in textiles and easy to use and understand because the groups are smaller, a medical advisor maybe not available and the time to act is often very short. However, if a medical advisor is part of the team and there are vehicles to carry the medical equipment, a point of care sensor is also suitable which is easier to develop and at the current research status rather available in the near future.

Future research

Following the survey results and presentations of the speakers, the following questions and challenges and needs should be addressed in future with a particular focus:

- How do we define 'biosensors' and what are the main characteristics, similarities and differences?
- How does the collected data support the decision making of responsible personal?
- How can the validity, quality and reliability of the data generated by biosensors (trustworthy data) be measured and improved in a military enivronment?

- What are the possible side effects of the resulting new technologies on ethical principles?
- Do these systems offer sufficient robustness (heat, movement, uniform-fitting etc.) for military requirements?
- Do these systems continue to work when one if its different sections / sensors should be damaged or destroyed?
- Are the issues of data security and protection, data transmission and cyber-security properly addressed in the military environment?

Some of the commercially available devices can be used to monitor physical activity. In order to use biosensors in a specific environment, or even to support medical care during missions, the user requirements have to be defined thorougly. These should be preferably generated in cooperation with the civilian sector.

Obviously, these innovations and solutions require more consultant (military) medical expertise and guidance in order to be able to be successfully implemented in a military setting.

For the success of further development and evaluation of any biosensors and multinational projects, it is of critical importance that ethical guidelines are included and implemented in the development from the very beginning.[15]

Conclusion

Closer cooperation between the civilian sector and military specificity is one of the key enabler to gain advantage of existing technical capabilities and create synergies. A detailed case analysis of the situation in which biosensors are needed is necessary to define the requirements of sensors. For this aim, the MMCC/EMC will organize a follow up workshop with the focus on wearable biosensors in casualty care and try to address the questions mentioned above.

List of abbreviations

CoI	Community of Interest
CBRN	Chemical, Biological, Radiological, Nuclear
d	effect size Cohen's d
MMCC/EMC	Multinational Medical Coordination Centre / European Medical Command
NATO	North Atlantic Treaty Organization
P	probability
*	significant

Availability of data and materials

The datasets used and / or analysed during the current study are available from the corresponding author on reasonable request.

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