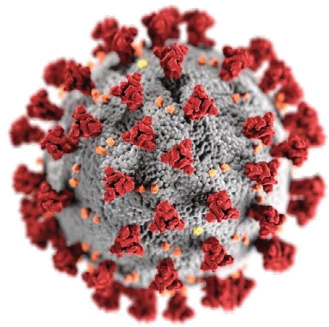

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Wearables: Useful Sentinels of Our Health?

By Matthew S. Austin

Abstract

As U.S. Coast Guard units develop strategies and policies aimed at safely reconstituting forces in the next phase of the COVID-19 pandemic, the ability to identify and isolate personnel who may be infected as early as possible is critical to protecting the organization's most critical resource. Existing wearable technologies provide the ability to monitor physiological data markers accurately and continuously. While unable to provide a direct diagnosis of COVID-19 infection, these markers may present a viable means for remotely identifying early onset of COVID-19 symptoms, and isolating potentially infected and infectious members. Additionally, the use of wearables has shown potential in some studies to act as a behavior change catalyst, which could enable workforce members to develop improved health and rest habits, leading to a more resilient and virus-resistant workforce. As a military entity, the Coast Guard possesses unique and previously untested authorities regarding the ability to impose a mandatory monitoring program on its members. However, given the political implications of such a strategy, a voluntary program may provide a better option for expeditious implementation. As the Coast Guard seeks short-term ways to protect its members from COVID-19 exposure and long-term strategies to facilitate the development of a more resilient workforce, wearables may provide a supplemental advantage worth their financial investment, though more study is necessary to validate their utility toward that end.

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Introduction

The rapid spread of the coronavirus disease 2019 (COVID-19) aboard the USS *Roosevelt* in March of 2020 served as a cautionary demonstration of the crippling operational impact that the virus is capable of exacting on U.S. military forces.[1] As U.S. Coast Guard units develop strategies and policies aimed at safely reconstituting forces in the next phase of the COVID-19 pandemic, the ability to identify and isolate personnel who may be infected as early as possible is critical to protecting that operational capability.[2] The Coast Guard's July 1, 2020 introduction of Off-Duty Risk Management (ODRM), an initiative encouraging individuals to take proactive steps to protect themselves away from work as well as on-duty, highlighted the operational importance of individuals identifying the onset of illness early and isolating at home in order to protect other members from potential virus exposure.[3] In addition to encouraging members to maintain a qualitative awareness of their health, an effective strategy should provide them with tools to assess their wellbeing quantitatively, and to identify the potential onset of illness.

Existing technologies provide the ability to monitor accurately physiological data markers, and these devices have been used by fitness enthusiasts for more than a decade.[4] While unable to provide a direct diagnosis of COVID-19 infection, these wearable devices, or "wearables," may present a viable tool for remotely identifying early changes in subtle physiological markers, which can be used to isolate potentially infected and infectious members—even those who otherwise appear asymptomatic. This essay will determine whether wearables are technologically capable of providing accurate early warnings of COVID-19 symptoms, how policies and procedures could leverage early warnings to protect workforce members, and what legal or political challenges those policies may encounter. In the end, research will support the conclusion that as the Coast Guard seeks short-term ways to protect its members from COVID-19 exposure and long-term strategies to facilitate the development of a more resilient workforce, wearables may provide a supplemental advantage worth their financial investment, though more study is necessary to validate their utility toward that end.

What Are Wearables?

Wearable technologies focused on fitness and activity tracking first entered mass markets in early 2007, with the introduction of Fitbit Tracker, an electronic device worn on the user's wrist to measure and record steps taken, heart rate, and sleep information.[5] Today, wearables are able to measure and record body signal parameters, including heart rate, heart rate variability, respiratory rate, temperature, sleep phases, movement, GPS position, and mechano-acoustic signatures (swallowing and breathing sounds normally observed with a stethoscope) with varying degrees of precision and reliability.[6] Many of these devices work in tandem with smartphone applications, enabling the device to transfer and store physiological data on the phone or on cloud-based servers.[7]

Not all wearables provide the same level of accuracy or efficacy. For instance, while a number of tests determined that some wearables were not capable of providing accurate measurements of basic activity level for informing health care or fitness decisions, studies of other products have validated their ability to measure accurately electrocardiogram (ECG) information (including heart rate and heart rate variability), respiratory rate, sleep phases, and even predict the onset of atrial fibrillation.[8] Additionally, the software through which wearables provide actionable feedback to users varies from device to device. While some wearables designed for fitness markets provide raw numbers, others utilize algorithms to merge various physical markers to create a simplified "score," providing the layperson with a quantitative representation of some aspect of their physical state, including physical activity, rest, and illness.[9] By integrating a combination of measurements (as will be discussed at the end of this section), these scores exhibit a higher signal-to-noise ratio than the individual raw measurements alone, and consequently provide a higher predictive value of impending illness.[10]

While existing technologies provide accurate measurement of what may be key COVID-19 signal parameters, the utility of any policy aimed at leveraging wearables as an additional layer of COVID-19 protection must first validate the accuracy of the specific devices used by the organization, and ensure that those tools are capable of monitoring relevant physiological metrics.

What to Measure

With the objective of early COVID-19 detection in mind, strategies should prioritize monitoring indicators that provide early presentation of COVID-19-specific symptoms. The following subsections will identify key physiological metrics that may indicate the early onset of COVID-19: cardiovascular metrics, respiratory rate, temperature, and blood oxygen saturation. Due to the novelty of the virus, many of the studies seeking to validate the use of these metrics toward that end are presently in the clinical trial phase of research.[11] However, these ongoing studies draw on lessons from earlier work, like Jennifer Radin et al.'s early 2020 study that correlated changes in heart rate to the onset of influenza, using data from wearable devices.[12]

Cardiovascular Metrics: Heart rate (HR), heart rate variability (HRV), and heart rhythm may provide indications of COVID-19 onset. At the most fundamental level, patients with a viral illness often present with an increased HR as their body deals with increased physiological stress, and in many cases this increase can be identified hours or even days before the onset of other more noticeable symptoms.[13] HRV, the small variance of the time between heartbeats, serves as a useful metric for measuring an individual's physiological stress or recovery. Changes in this marker can occur in response to a number of causes, including illness, lack of sleep, overexertion, alcohol use, or generalized stress.[14] While there is a dearth of established clinical evidence for use of HRV as a predictive metric for virus detection, its established utility as an indicator of overall physiological stress supports the notion that it may serve as a useful predictive tool. Scientists at the Scripps Research Institute are currently studying the potential prognostic use of HR and HRV, comparing wearable data from 100,000 subjects to identify correlations in cardiac markers before and during the onset of viral symptoms.[15] Finally, ECG measurements can identify the onset of irregular heartbeats, an increasingly recognized COVID-19 symptom.[16] A 2020 study by Madhavan Driggin et al. found that 19.6% of hospitalized COVID-19 patients and 44.4% of intensive care patients presented with tachycardia or fibrillation.[17] While cardiac metrics are useful, a more COVID-19-specific marker is necessary to better assist leaders in the early identification and isolation of potentially infected personnel. For instance, over–reliance on HVR has the potential to falsely identify members who are simply under-recovered from a week of physical training, and works best when monitored in tandem with other physiological markers, specifically respiratory rate.[18]

Respiratory Rate (RR): An April 2020 study by William Ottestad drew upon lessons learned from aviation medicine to identify increased respiratory rate, above an individual's personal baseline, as a key early indicator of COVID-19 onset.[19] Ongoing studies at the Cleveland Clinic indicate similar findings.[20] As a lower respiratory tract infection, COVID-19 causes damage to the lungs and decreases the patient's ability to breathe efficiently. As a result, the individual must take a higher number of less effective breaths in the same period, increasing their RR. Importantly, increased RR is not commonly associated with other viral infections, like the cold or flu, as they affect the upper respiratory tract, and do not have the same detrimental effect on respiratory efficiency. An ongoing study by Central Queensland University and the Cleveland Clinic is measuring subjects' RR during the course of COVID-19 contraction and recovery, testing the hypothesis that RR may provide an early predictive metric, ahead of more noticeable COVID-19 symptoms, like coughing or chills.[21] While increased RR is still not exclusive to

COVID-19 patients, as increased respiratory rate also presents in other SARS or hypoxic subjects, it does narrow the scope of potential causes and could provide a more reliable indicator than previously prioritized signals, like increased body temperature.[22]

Temperature: While body temperature monitoring and screening served as an early protective measure for identifying and isolating infected personnel, more recent research revealed that while temperature is still an associated COVID-19 symptom, large percentages of COVID-19 patients (up to 70%) do not present with increased fever.[23] Additionally, while a 2017 study noted marked increase in skin temperature preceding viral infection, it also noticed a large variance in personal skin temperature depending on activity level and ambient temperature.[24] With this in mind, temperature is best included as one of several inputs into a COVID-19 detection algorithm, including those noted above, but does not provide sufficient insight on its own.

Blood Oxygen Saturation (SpO2): Similar to the resultant increase in RR, COVID-19's early detrimental effects on patients' lower respiratory tract cause a decrease in blood oxygen saturation. A study by Hui Dai et al. noted SpO_2 levels below 90% in hospitalized patients during the early onset of the virus in China.[25] Despite this metric's potential utility, it is of less value to wearable monitoring efforts, as accurate wearable hardware is not yet available.[26] Some smartphone-based technologies sought to measure SpO_2 using the device's camera, but published studies invalidated their precision.[27]

As noted above, wearable monitoring strategies provide a significant benefit in the form of simultaneous and continuous monitoring of multiple physiological metrics. By leveraging these metrics through algorithms, wearables can reduce the symptomatic signal-to-noise ratio to provide a more early and accurate indication of viral/COVID-19 onset.[28] One wearable company claims that analysis of data from its self-reporting COVID-19 users enabled it to detect infection up to two days before users noticed any apparent symptoms.[29] Additionally, while existing in-clinic methods of vital sign analysis provide a snapshot of an individual's state at a specific moment, the continuous nature of information provided by wearables creates an individualized baseline of specific indicators that can be monitored to identify anomalies specific to the individual, instead of simply comparing to generalized standards.[30] The use of a personalized physiological profile can more accurately detect more subtle changes in an individual's markers, leading to a greater likelihood of early detection.[31]

Mitigation in Addition to Detection

While many companies move to develop or leverage existing wearables for the purpose of detection, another benefit of the devices' employment might be the prevention of preconditions that worsen the potential contraction of COVID-19 or predispose COVID-19 patients to high rates of mortality, specifically obesity.[32] While ties between obesity and morbidity in COVID-19 patients are more well publicized, correlations also exist showing an increased susceptibility for infection, prolonged duration of illness, and even increased contagiousness.[33]

As previously noted, a number of the most popular wearables were originally designed for use as fitness and activity trackers, providing users with a quantitative insight into their level of wellness by measuring HRV, sleep quality, and activity levels. While the effectiveness of such tools at improving personal fitness and wellness levels is logically dependent on the respective user, recent studies showed that wearables can play a beneficial role in facilitating behavior change techniques (BCT).[34] Put simply, wearables may provide the ability to create a more COVID-19 resistant workforce. If utilized effectively, they could provide the simultaneous benefits of monitoring personnel for early COVID-19 onset symptoms while enabling users to develop more resilient lifestyle practices, including improved activity levels and prioritized sleeping habits.[35] In fact, should COVID-19 detection become a lesser priority for policy makers in future years, the BCT benefits and quantification of performance markers (HRV and sleep performance) may prove to be a beneficial primary utilization of wearables for personnel conducting extensive physical training and/or risk analysis as part of operational missions.

The Cost of Monitoring

While the use of wearables to identify early onset COVID-19 symptoms is novel, federal organizations' desire to monitor physiological readiness is not new, particularly within the Special Operations community. A number of companies have existing contracts with federal and military agencies.[36] A review of one company that provided no-cost hardware with a monthly software access contract showed the one-year cost for a single user of approximately $360.[37] Other devices provide free access to software with the one-time purchase of a wearable device, at the cost of $299.[38] Compared to the expense of repeated COVID-19 testing, ranging between $35-$51 per test, the cost of one year's worth of wearable monitoring equates to less than one week of daily tests. While the information provided by wearable devices is not sufficient to replace testing as a means to diagnose COVID-19 patients, it could serve as a valuable tool for prioritizing the application of tests on specific individuals who might otherwise appear asymptomatic. Additionally, the ability to identify infected personnel earlier could prevent lost workdays due to the virus's spread and the resultant precautionary at-home isolation of contact-traced personnel. Using a hardware purchase model mentioned earlier, the cost to outfit the Coast Guard's full Active Duty and civilian workforce totals roughly $12.6 million. [39] While that number may seem excessive to some, it is less than the cost of COVID-19 federal assistance provided by FEMA to 44 different states, and is $7 million less than the City of New York spent on COVID-19 public relations and advertising.[40]

The Logistical Challenges of Monitoring

Should the Coast Guard determine that the potential benefits provided by wearables warrant their financial expense, the organization will then face the challenges presented by the potential acquisition and storage of the significant amounts of data that wearables acquire. The unauthorized access of the user's data through theft, hack, or leak present privacy risks to both the user and the organization.[41] The data acquired via many wearables does not currently fall under the data privacy and security protections of the Health Insurance Portability and Accountability Act (HIPPA), in part because companies are able to utilize "de-identification" methods to effectively disconnect the user's stored information from their personal identity.[42] Falling short of HIPPA standards, wearable data is regulated by the Federal Trade Commission, whose rules do not prevent the sale of personal health data or require apps to advise users if the personal information is disclosed to other entities.[43] With this in mind, the use of a commercial wearable should be largely contingent on the thorough understanding of the company's user agreement, and self-imposed data usage policies.

The acquisition and secure storage of additional data present a logistical burden for Coast Guard information technology (IT) systems. The 2015 breach of Office of Personnel Management databases and the 2020 hack of the Defense Information Systems Agency demonstrate the liability that troves of stored personal information can pose for federal IT security programs.[44] Coupled with the 2012 expansion of access retention and use of datasets including non-terrorism information, these vulnerabilities effectively discourage the federal ownership of the data that wearables could provide, based on the potential inability to secure it from external actors or other federal agencies.[45] While it may seem puzzling that the Coast Guard would have an interest in protecting personal information from other federal entities, the agency can only secure that data which it can control, and cannot be responsible for securing information if or when it is seized by other federal partners.

However, by acquiring commercial off the shelf (COTS) devices and making use of existing wearable companies' private data storage and protection processes, the cost of data security could be effectively outsourced. Also, as demonstrated by ongoing legal challenges between the FBI and Apple over the All Writs Act, private data may be safer from external theft and annexation by other federal agencies than data stored on government servers.[46] Due to the desired short-term acquisition and implementation of a COVID-19 wearable system and secure data storage solution, COTS devices present a preferred, actionable alternative to large-scale project development.

An additional area of concern, the global positioning system (GPS) mapping functions of some wearables can present security vulnerabilities, inadvertently charting military location or operations information.[47] In 2018, deployed military members posted GPS-tracked workout information to a public online fitness website, inadvertently publishing detailed maps of otherwise secret military facilities in Afghanistan, Djibouti, and Syria.[48] In light of the vulnerability provided by GPS position tracking, the potential benefits provided by this function, specifically contact tracing, may not warrant the risks posed. Some wearables provide contact tracing functions through the use of Bluetooth tracking to detect the presence of another device within the CDC's recommended six foot proximity, but are only effective if both subjects are wearing a similar device.[49] With these restrictions in mind, ideal wearables are stand-alone devices that do not possess intrinsic GPS capability, and are capable of operating without a continuous link to the user's smartphone or other GPS-enabled device. These characteristics reduce the risk of inadvertent position charting, if such data were posted or shared, while also separating the data gathered by the wearable from the extensive amounts of unrelated personal information stored on his or her phone.

The Policy Challenges of Monitoring

While the desire to monitor the entirety of the military workforce may tempt policymakers to enact mandatory use of wearable devices, the use of a voluntary program may prove to be a more politically expedient course of action. While the United States Court of Military Appeals holds that Fourth Amendment protections apply to members of the armed forces, except where explicitly or implicitly inapplicable, the Supreme Court has never ruled on the subject.[50] With this in mind, imposed monitoring of Coast Guard members while off duty *may* extend beyond the scope of military authority, though due to the untested nature of this area, no specific precedent could be found to limit the service's authority. Additionally, the Office of Civil Rights at the U.S. Department of Health and Human Services (HHS) temporarily relaxed enforcement of HIPPA privacy parameters in April of 2020, citing the greater public health benefit of expeditiously shared information to identify effective treatments and prevent the virus's spread.[51] While wearable physiological data does not fall under HIPPA regulation, as noted earlier, the relaxation of these enforcement practices serve as an indication that federal interest would (at least presently) trend towards prioritizing public health protection over personal information privacy.

However, while the Coast Guard may technically have legal grounds to impose monitoring as a military organization, the political costs of implementing a large scale off-duty oversight program on its members may outweigh the benefits of early virus detection. The National Basketball Association (NBA) implemented a wearable monitoring program in late June aimed at early COVID-19 detection for its players and staff. The skeptical reception by some players and media sources demonstrates notable cause for agencies seeking to implement similar models to opt for a voluntary program.[52] Seeking a middle ground, some wearable companies provide team monitoring dashboards, which users may opt into, allowing individuals the ability to share personal data of varying levels of specificity with supervisors.[53] Users can chose to simply self-monitor, to share generalized/simplified readiness or wellness scores, or to simply allow supervisors to be notified if their wellness score reaches a level at which infection may be likely.[54]

One downside of a voluntary monitoring policy is that members who choose not to participate create gaps in the proverbial "wall" of protection. While such issues would equate to a failed policy if wearables served as the sole means of detection and monitoring, the voluntary use of wearables as an *additional* layer within a robust organizational health policy would allow them to provide an added level of mitigation, even without 100 percent participation. Additionally, as noted in a University of London analysis of studies pertaining to the imposed use of body-worn cameras on law enforcement officers, mandatory monitoring programs often result in officers attempting to modify or temporarily prevent data collection.[55] In contrast, voluntary approaches would seek to leverage the wearer's willingness and motivation to use the device correctly and consistently to provide useful data, and reduce the wasted financial investment and inaccurate information that might otherwise be drawn from uncooperative mandatory users who fail to employ the devices properly.

Again, it should be noted that the U.S. Coast Guard presents a unique policy model. As a military organization, the legal aspects of implementing wearable monitoring program are limited compared those that would be applicable to other non-military entities. Even so, a voluntary wearable program within the Coast Guard could serve as a model for other agencies by further testing wearables' technical capabilities as applied to COVID-19 symptom identification, evaluating workforce acceptance of monitoring policies, and developing protocols to integrate self-monitoring and/or agency monitoring into health and safety processes.

Conclusions

The use of wearable technologies as a means of protection from COVID-19 infection represents an intersection of two extremely novel technological and scientific areas of study. As such, and as noted earlier, conclusive evidence supporting the use of wearables for that purpose does not yet exist, though numerous specific studies are ongoing.

The preceding months have shown that the immediate nature of the COVID-19 pandemic does not provide policy makers with the luxury of time, and many public health decisions can or must be made in the midst of some scientific ambiguity. With that in mind, the use of wearables presents a relatively low-cost benefit, potentially providing early detection of some infected members, and preventing the spread of the virus or precautionary isolation of exposed workforce members. Even if algorithms are not yet able to differentiate accurately between the onset of COVID-19 and other viruses, the benefit of isolating the spread of any illness will result in protecting the operational capability of the Coast Guard workforce, as quarantine precautions apply to all manner of sick members.[56] With these considerations in mind, the potential benefit of voluntary wearable monitoring is likely to warrant the requisite investment.

Additionally, the relatively new nature of wearable technology as applied to illness detection should encourage an incremental implementation of wearable self-monitoring programs. Lessons derived from the failed adoption of new and unproven homeland security technologies discourage a wholesale approach to adopting a relatively untested wearable monitoring program. For instance, the Department of Homeland Security-funded BioWatch program sought to leverage technological advances to provide constant monitoring for biological attacks in the early 2000's. After ten years and more than $1 billion invested in the nationwide program, the GAO identified it as lacking the ability to reliably detect any aerosolized biological attack.[57] Drawing lessons from such programs, a practical next step should include the implementation of small pilot programs to validate the accuracy of wearable data collection, gauge the compliance of voluntary users, measure the effectiveness of wearables in detecting illness at or before the onset of obvious symptoms (perhaps in cooperation with aforementioned clinical studies), and identify unanticipated policy implications.

As an organization, the Coast Guard is familiar with the operational benefit of providing security and protection beyond its perimeter. Based on the requisite security investment and inherent vulnerability of federally owned personal data, COTS wearable options present an expedient alternative to customized, service-owned devices and programs. While unable to provide acute medical diagnosis of personnel with COVID-19, wearables' ability to detect the virus's precursor symptoms through personalized monitoring may enable the organization to "push its borders out" effectively through early detection and isolation. To paraphrase the Coast Guard's founder, Alexander Hamilton, a few wearables, judiciously stationed on the arms of our personnel, might at a small expense be made useful sentinels of our health.[58]

About the Author

Matthew S. Austin is a Commander (CDR) in the U.S. Coast Guard with over 17 years of experience in counterterrorism, search and rescue, and law enforcement operations. Early in his career, he served as a Deck Watch Officer aboard USCG Cutter BEAR (WMEC-901), and later helped develop the Coast Guard's Maritime Security Response Team, the Coast Guard's premier counterterrorism unit under the newly established Deployable Specialized Forces. As an aviator, CDR Austin conducted search and rescue operations while assigned to Air Station New Orleans, LA, and executed multinational counternarcotic interdiction missions as a member of the Helicopter Interdiction Tactical Squadron, based in Jacksonville, Florida. CDR Austin served two years as a military fellow with the U.S. Senate's Homeland Security and Governmental Affairs Committee before reporting to his current assignment, as the Executive Officer of Air Station / Sector Field Office Port Angeles, WA. He graduated from the U.S. Coast Guard Academy with an undergraduate degree in Government and is a student at the Naval Postgraduate School's Center for Homeland Defense and Security Studies.
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