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# Telemedicine and mHealth Odyssey: A Journey from the Battlefield to Academia

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## ABSTRACT

Since 1992, military medicine has considered the relevance, sustainability, and promise of telemedicine in the context of its mission and obligations for service members at home and in war zones. The US Army telemedicine program covers 22 time zones and generates over 5000 tele-consults per month for over 20 medical specialties. More recently the advances in mobile computing and increased adoption of the Smartphone with evolving capabilities for imaging and body-worn sensor integration has emerged in the field called mobile health, or mHealth. This presentation highlights the first 10 years of the U.S. Army mHealth program and includes how similar technologies have translated to wide-scale civilian health care implementation, including a relevant project for Veterans at the University of Pittsburgh. Examples include the successful US Army "mCare" program developed to augment soldier rehabilitation management with US-based geographically dispersed providers that utilizes secure mobile messaging and the soldier's own cell phone. Additional research interests will describe the use of smartphones on the battlefield enabling capture of operational medical data to improve casualty evacuation and outcome. A DoD-funded traumatic brain injury research project developed for Veterans at the University of Pittsburgh includes a mobile health application that demonstrates the effectiveness of communicating with patients through their personal mobile devices with care managers. Preliminary data for all the projects presented are encouraging for adoption and utilization of a mobile telemedicine platform to meet the complex needs of casualties injured or recovering from a broad range of injuries in unique geographic settings.

**Keywords:** Telemedicine, Mobile Health, mCare, Breathe2Relax, Text4Baby, military, traumatic brain injury, post-traumatic stress

## 1. INTRODUCTION

As a complex health care system with a diverse beneficiary population, the Department of Defense (DoD) $40 billion Military Health System (MHS) seeks to offer high quality and accessible healthcare services to its 9.6 million beneficiaries. It does this through a global direct care network comprised of over 240 Military Treatment Facility (MTF) hospitals and clinics, supplemented by a purchased care network of community clinical providers. Access to care remains a challenge for MHS, as many MTFs struggle to meet access standards and as the number of beneficiaries living distant from MTFs, or even TRICARE network points of care, continues to grow.

The DoD has identified telehealth (TH) as a potential means of achieving efficiencies and better care coordination by leveraging resources across medical treatment facilities (MTFs), Services, and Agencies (e.g. DoD/VA coordinated care), and by reducing reliance on purchased care through TH mediated expansions to Direct Care services. The goal in providing TH services is to improve access to care and avoid beneficiaries being referred to civilian providers thereby reducing purchased care costs.

DOD health care is managed at the tri-service level by the Military Health System (MHS), which provides programmatic funding and serves as the policy arm for the MHS. Health care delivery is a service specific responsibility. This is an important distinction to understand as it impacts on delivery of a standardized Telehealth solution across the DoD with

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each Service's active participation critical for success. To date, Telehealth in the DoD is primarily being done by the U.S. Army which accounts for over 90% of all DoD Telehealth activity and averaging over 5000 telehealth consults/month across 22 time zones for 20 different medical specialties.[1]

Since 1992, the U.S. Army Medical Department has been active in the development of telemedicine programs for both stateside and overseas locations in deployed settings.[1] Success in demonstrating improved access and quality of care as well as the rapid advances in smartphone technologies led to initial development in 2008 of mobile health (mHealth) applications in the U.S. Army in a similar health care settings – garrison and overseas operational bases. Initial efforts focused on standalone applications to improve coping skills with behavioral health problems (stress, anxiety and mood disturbance).[2,3] The National Center for Telehealth and Technology Program Office (T2) at the Defense Center of Excellence for Psychological Health and Traumatic Brain Injury (DCOE) developed and tested applications focused on self-management tools, initially with breathing relaxation techniques (Breathe2Relax). Breathe2Relax was launched in 2011 and is a portable stress management tool. Breathe2Relax is a hands-on diaphragmatic breathing exercise to help with mood stabilization, anger control, and anxiety management. Breathe2Relax can be used as a stand-alone stress reduction tool, or can be used in tandem with clinical care directed by a healthcare worker. [3, 4]

Other mHealth applications evaluated in the U.S. Army included a self-management and education text message service for obstetric care outreach for pregnant and postpartum women called Text4Baby.[5] A randomized trial of Text4Baby was conducted among female military health beneficiaries at Madigan Army Medical Center, Tacoma, WA. Participants provided consent, completed a baseline questionnaire, and then were randomized to enroll in Text4Baby or not. They were followed up at 3 time points thereafter through delivery of their baby. The main finding was a significant effect of high exposure to Text4Baby on self-reported alcohol consumption postpartum (OR 0.212, 95% CI 0.046-0.973, P=.046). The Text4Baby participants also reported lower quantities of alcohol consumed postpartum. This study, though limited in statistical outcomes, offer important lessons for future scalable mHealth programs and suggest the need to study dose-response effects of these interventions.[6]

## 2. BATTLEFIELD MOBILE HEALTH APPLICATIONS

The delivery of evidence-based medical care in a remote and deployed setting is a major challenge for military providers. Currently, research in Military Medicine, together with the advent of the "smartphone" in 1997, is revealing promising technologies that offer real-time electronic capture and transfer of data between the patient at point-of-injury (POI), Point of Care (POC), the medic, and providers, as well as enabling both the practice of telemedicine in forward deployed areas and the integration of algorithmic alerts and advice into patient monitoring and encounter documentation systems.[7]

With funding provided by the Assistant Secretary of Defense for Health Affairs Joint Program Committees for Informatics and Combat Casualty Care, the Telemedicine Advanced Technologies Research Center (TATRC) has collaborated with the US Army Communications & Electronics Research Development & Engineering Center, the Army PM Medical Communications for Combat Casualty Care, the Marine Corps Warfighting Laboratory, and the US Army Cyber Center of Excellence to evaluate integration of telemedicine & medical information exchange technologies over tactical radio networks between ground & air ambulance vehicles and forward deployed medical facilities on the battlefield.

Within US & NATO military forces, future missions aim to provide useful telemedicine and medical informatics assistance to combat medics, capture accurate records of first responder patient encounters, and communicate relevant patient information up the medical evacuation and treatment chain. The challenges in providing "operational medical data" without negatively impacting the medics' primary mission to provide quality field medical care have been elusive goals.[8]

Research is being conducted to evaluate enabling technologies for wireless acquisition and exchange of medical information over current and future force tactical radio network to far forward health care locations from dismounted medics and corpsman and from prehospital evacuation vehicles. In certain cases this has required exploration of "cross-domain" solutions to facilitate exchange of unclassified medical information over the secure internet protocol routed

network (SIPRNET) with extension to unclassified systems operating on the non-secure military internet (NIPRNET). Patient data included an electronic Tactical Combat Casualty Card (TCCC), imaging, and time-phased physiological monitoring and telemetry data, which in the case of dismounted medics, was captured wirelessly from soldier worn monitors. Patient demographic data was wirelessly uploaded from patient ID cards and digital "dog tags" to the TCCC cards on android mobile phones (referred to as end user devices - EUDs) using both RFS (radio frequency systems) and NFC (near field communications) technologies. TCCC cards could optionally be "bumped" using NFC or secure ultra-wideband transmission from the ground medics' EUDs to those of the evacuation vehicle medics. After being transmitted to medical treatment facilities, patient records were automatically uploaded through the DoD electronic medical record - Armed Forces Health Longitudinal Technology Application - Theater (AHLTA-T) and the Theater Medical Data Store for posting to the service members permanent military medical record. Transmission range for remote monitoring and transmission of encounter documentation was significantly increased for both tactical radios and mobile 4G cellular networks by using an Aerostat airship like those originally deployed in Afghanistan as well as satellite communications (Figure 1). All user evaluations were conducted in the field at Fort Dix, NJ during squad level tactical operations.[9]

In 2013, the Joint Tactical Combat Casualty Care (TCCC) Committee revised the TCCC casualty cards to conform to the Joint TCCC Guidelines and forwarded to DoD leadership (Health Affairs) for staffing with the Services and Combatant Commands as the proposed new pre-hospital casualty care card (DD Form 1380) for the US military. The new card was immediately adopted in the Central Command region.[10] It was subsequently adjudicated and approved through all of the uniformed Services, the Combatant Commands, and NATO and thereby established as a standard for electronic patient encounter capture on the battlefield that is applicable to populating the Joint Trauma Registry as well as posting to the patient's permanent military electronic health record (EHR) in both the current form (AHLTA/AHLTA-T) and future MHS cloud-based EHR acquired from CERNER, the recently approved vendor for the new DoD EHR.[11]

TATRC-based research has incrementally advanced the state-of-the-art in En Route Combat Casualty Care assessment, monitoring, and intervention using secure wireless communication capabilities. It is now technically possible and operationally feasible to combine physiological monitoring, encounter documentation, and tele mentoring technologies during en route care within and among various wireless EUDs over secure military tactical networks. The goal is to combine these capabilities in both form and function, thereby potentially reducing the footprints of both forward combat casualty care providers and their supporting equipment potentially 1) making the Medic's job easier to initiate POI/POC data capture to an electronic medical record while en route to higher Roles of medical care, 2) reducing the number of redundant procedures, and 3) reducing the need for transport costs and personnel resources by providing real time analysis of the patient's condition. This will allow for the triage of those patients that can be managed at or near the point of injury or point of medical evaluation especially during periods of operationally necessitated prolonged field care.

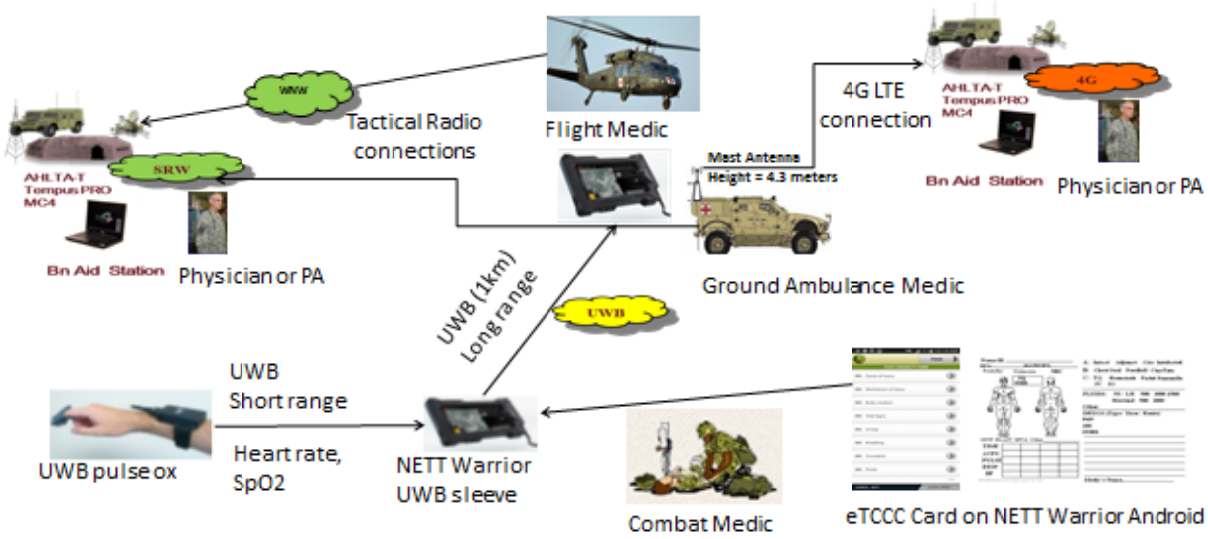
Intelligent Trauma Registries are currently used for "strategic" medical purposes to enable determination of optimal practices that provide the best medical outcomes as opposed to having tactical utility. The Office of the Secretary of Defense/Health Affairs directed the services to implement the "Joint Theater Trauma Registry" (JTTR) in December 2004, and more recently evolved into the DoD Trauma Registry (DODTR).[12] The DODTR has had a major impact in documenting the types of wounds and treatments rendered, resulting in clinical process improvements and standardization of provider practice for hospital care. However, still lacking is a comprehensive and integrated system for data collection and analysis to improve performance at the pre-hospital level of care. Capture of the TCCC based casualty cards, after action reports, and unit-based pre-hospital trauma registries, linked with novel sensor biomarkers need to be implemented globally and linked to the DoD Trauma Registry in a seamless manner that will optimize pre-hospital trauma care delivery.[13] It is the use of smartphones/EUDs at the POI/POC on the battlefield that will enable this capability.

A future value of the data registry is to capture with EUDs/smartphones more granular medical data to determine the optimal protocol to perform for a specific poly-trauma event. This could be called an "Intelligent Registry" where the product is a catalog for event-driven, goal-directed care using "operationalized" medical data (captured from point of injury to Role 3 Combat Support Hospitals) across the evacuation continuum and added to the JTTR. Such an "Intelligent Registry" would not only include current critical care physiologic data elements (i.e. vital signs, treatments rendered) but also integrate novel biomarkers (i.e. arterial vasoconstriction measurements) in a robust dataset that over time can leverage machine learning approaches to enable predictive analytics and improved clinical outcomes. A critical

requirement is the need to capture medical data at the POI/POC from interventions performed by the Medic on the patient. Another important component of the "Intelligent Data Registry" is the knowledge-building aspect of the registry that focuses on building a predictive capability for the efficacy of an intervention performed on a specific patient type exhibiting a specific clinical event. Development and sharing of civilian trauma registries with DoD operational medical data registries will accelerate the critical mass of evidence-based medical data needed to more rapidly refine the discriminatory accuracy of trauma events to achieve optimal interventional strategies.[14]

Based on a series of US Army field exercises from 2010-2014, using EUDs, integration of patient monitoring, encounter documentation, and tele-mentoring was shown to be feasible in tactical environments in support of dismounted medics as well as during pre-hospital evacuation.[9] Additionally, a reliable hands-free data entry method is nearly essential for effective medical information exchange during forward combat casualty care. The research conducted by the TATRC and coordinated with collaborating US Army and joint research organizations has made rapid progress toward filling military health system gaps in medical information documentation and exchange at the point of injury, during pre-hospital evacuation and at far forward field medical settings. The DoD evaluations validated the research strategies of adopting and adapting both commercial and government developed technologies rather than developing them from scratch; maximizing integration of convergent technologies to enable multiple applications within a single device; implementing medical applications on common user devices and networks; and exploiting operational technology assessment venues funded by non-medical acquisition programs for evaluating operational and intelligence applications. Given the impending across the board cuts in defense research, this approach may be the only feasible way to accelerate development of deployed mHealth solutions.

**Figure 1. Data flow from point of injury to echelons of care over various communication platforms**




## 3. GARRISON MOBILE HEALTH APPLICATIONS – "mCARE"

In response to unmet needs of Service Members in the U.S. Army Reserves, particularly those with behavioral health problems, Post-Traumatic Stress (PTS) or Traumatic Brain Injury (TBI), the Telemedicine and Advanced Technology Research Center (TATRC), of the U.S. Army Medical Research and Material Command (USAMRMC), developed in 2009 a mobile phone application, called "mCare". The main goal of this application was to augment the standard care provided throughout the geographically dispersed community-based clinics caring for soldiers across the U.S. in a

rehabilitation medical hold status, by adding secure messaging to/from patients and care team members. mCare was based on the ideas that a) patient engagement is active (as opposed to passive) with directed participation (as opposed to compliance) in the rehabilitation process, and b) the treatment provider and his/her collaboration with the patient is essential to increasing patients' engagement.

From 2009-2011, the US Army Medical Department conducted an mCare pilot project to determine the requirements for coordination of care for Wounded Warriors across 18 states utilizing secure mobile messaging.[15] The primary objective was to determine if a secure mHealth intervention would improve contact rates between patients and providers, and positively impact the military healthcare system. Over twenty-one months, volunteers enrolled in a HIPAA-compliant mCare project using secure mobile messaging. The mCare program utilized soldiers' own cell phones and the intervention included: appointment reminders, health and wellness tips, announcements, and other relevant information to this population of rehabilitating wounded warriors exchanged between care teams and patients. The mCare pilot project demonstrated the effectiveness and affordability of communicating with patients through their personal mobile devices with their care managers.[15] The initial mCare intervention consisted of a performance improvement study, which included validation and end user assessment of the technology intervention

To further evaluate the impact of the mCare system, a multi-center, prospective, randomized, controlled trial of U.S. Army Soldiers conducted between April 2011 and October 2012 to measure: recovery goal awareness, contact rates; symptom inventory severity; satisfaction, general well-being, and usability.[16] All Service Members receiving care had some type of illness or injury, and therefore required long term management as they progressed through the rehabilitation process and eventually transitioned into retirement, discharge or returned to duty. However, engagement with mCare among people with behavioral health problems, PTS and/or TBI were particularly of interest in this analysis because these conditions can include debilitating cognitive (e.g. deficits in attention, concentration, memory, speed of processing, new learning, planning, reasoning, judgment) and emotional (e.g., depression, anxiety, agitation, irritability, impulsivity, aggression) signs and symptoms that make the monitoring and support provided by community based providers simultaneously more difficult and more necessary. Observation of the raw data by week showed that participants' exposure to mCare declined systematically as they out processed from rehabilitation, irrespective of presence or absence of a behavioral health problem, PTS or TBI. Also, this examination showed that, over the course of the study, the percentage of questionnaires that study participants responded to was at least 60%, except for participants with behavioral health problems plus PTS and/or TBI. Time to respond was generally ten hours or less, and some weeks, the average response time was less than one hour.[14] Again, mean response time was longer for participants with participants with behavioral health problems, with or without PTS and/or TBI. The regression analyses found that presence/absence of a behavioral health problem, PTS, and/or TBI was not statistically related to total exposure, total percentage of questionnaires responded to, or total mean response time. Study results also showed a statistical difference in contact rates for soldiers with the mCare group receiving seven times the contact rates compared to the "usual care" control group.[16] Altogether, these findings suggest satisfactory mCare adoption and used by Service Members in a community setting, even those with cognitive and emotional difficulties. As a result of this landmark research in mobile health, the mCare research team was the recipients of the U.S. Army Greatest Inventions in 2010 for the mCare Project.

Future analyses of the mCare RCT will address participant response to these other components of mCare, as well as treatment group differences in health outcomes and traditional contacts with care team members. Moreover, follow-on studies are scheduled to evaluate specific elements of mCare where frequent provider contact and patient engagement could aid in the rehabilitation process. One study centers on pain and goal awareness in wounded Service Members. Another is an evaluation of the mCare system for chronic care management of people with diabetes. The latter study will expand mCare functionality to include biosensors and patient health record, allowing for a more informed picture of the patient's treatment compliance in the home environment.

## 4. ACADEMIC MOBILE HEALTH DEVELOPMENT FOR TBI

Traumatic brain injury (TBI) is a heterogeneous disorder with numerous clinical challenges for civilian and military populations. "TEAM-TBI: Targeted Evaluation, Action and Monitoring" is a DoD-funded research program established in 2014 that implements multiple monitored clinical interventions for TBI patients. A key objective of this research is the development and initial testing of a patient protocol for integrating these multiple interventions. The goals of TEAM TBI are to offer a novel approach to TBI care that will provide: (1) Comprehensive intake assessment using best-available

testing across behavioral health, cognitive, and psychiatric domains to inform diagnostic clustering of patients into specific TBI subtypes; and (2) Precision Medicine with targeted therapies for individual TBI war wounded chosen on the basis of objective and quantitative metrics. Research protocols have been written and approved by both the University of Pittsburgh and the DoD with a start date of January 2014 for patient enrollment.

With advanced evaluation methods, a multi-disciplinary team of clinicians, scientists and researchers identify and prioritize evidence-based therapies for patients who have sustained a TBI, assessing each patient across multiple *trajectories*, identifying relevant symptoms, and providing a sequenced, individualized treatment program to be monitored over a six-month period. Continuity of care between clinical and military coaches and the primarily Veteran study population leverages existing mobile applications as recommendations to target the specific TBI trajectories that are impaired for each patient. The study was designed for monthly follow-up, allowing both online survey data collection and telephone conversation with clinical coaches; however, the complexity of both symptoms and treatments required more frequent communication from coaches, revealing a clear need for easy mobile access to study information (identified trajectories, treatment recommendations, contact information, access to surveys, documenting medication changes, etc.).

The study populations are Veterans with documented TBI refractory to treatment, who travel to University of Pittsburgh and University of Pittsburgh Medical Center (UPMC) to undergo a 3.5-day comprehensive evaluation, completing assessments of sleep, mood, and vestibular, oculomotor, and neuropsychological function, as well as advanced neuroimaging studies. After testing, a multi-disciplinary case review identifies trajectories of concern, individualized goals, and treatment recommendations. Participants then depart Pittsburgh with a customized mobile TBI Toolkit, which includes: iPad with preloaded applications (e.g., Breathe2Relax for relaxation with diaphragmatic breathing; an object locator app), activity monitor, sleep kit, and object finders, along with targeted interventions (e.g., cognitive rehabilitation, specific sleep treatment, vestibular exercises, ocular-motor program). An app developed in the research group is used with the clinician team to present *neuroimaging* of the patients scans on a mobile device[17]. Clinical coaches provide telemedicine support and work with treatment providers for coordination of care. Clinician-to-patient communication occurs via telephone, email, online surveys and/or text messaging and encompasses individualized prescribed treatment(s), outside referrals, goals, medication changes, and a review of monthly survey data to assess various TBI-related symptoms.

As of March 2016, 48 patients (female=12; male=36) have been enrolled, with planned total enrollment of 120. Of these, 28 have completed the goal-setting intake and initial progress monitoring process. All patients were assigned to one or more trajectories: the trajectories most often identified across subjects were Sleep (n=19), Ocular-Motor/Vestibular (n=20) and Mood (n=21). Cognitive (n=3) and other trajectories (n=4) were also identified. Further evaluation and/or treatment recommendations were made for each identified trajectory. Of the 7 patients who completed goal-setting intake and progress monitoring and also completed the protocol, 5 met their goals, 1 made incremental progress, and 1 did not complete follow-up. One example subject identified goals related to fatigue, vestibular/oculomotor, and cognitive TBI symptoms. This subject followed relevant treatment recommendations over the 6-month monitoring period, with coaching that adapted to an initial need for more frequent communication, and reported decreased fatigue, vestibular disturbances, and vision difficulties, which were associated with improvement in cognitive neuropsychological test scores in the absence of direct cognitive rehabilitation. In the sample who have completed the intervention (N = 20), the trend has been a substantial PCSS score from screening (mean PCSS = 71.5, SD = 13.8) to follow-up (mean PCSS = 39.6, SD = 25.7) This research study is ongoing with planned completion in March 2017.

Having identified patient and coach needs, the ongoing mobile development is adapting an established mobile app platform to allow coaches to administer specific exercises, monitor progress and app usage, take notes, and communicate with patients, as well as providing reminders and daily schedules for patients. This central app will include: *notes,* both clinician-only or patient-and-clinician; *scheduling functions,* with coaches/providers selecting exercises through a portal, patients receiving instructions to perform them via app, and therapists/coaches monitoring patient performance; and *reminder functions* using push notifications to improve adherence. Key patient features include: *exercise schedules* and *instructions*, a *repetition counting tool*, and *patient feedback*. At monthly follow-up, coaches will be able to monitor patient performance on specific exercises, progress with outside referrals & recommendations, and survey results, as well as additional surveys 'ordered' for a patient by the coach,

alerts/reminders for patients yet to complete, and a relational database of results. Upon completion, data analysis will compare coaching with this central platform to coaching alone.

A comprehensive assessment is imperative to identify and prioritize primary areas of concern and effective treatment recommendations following TBI. Because multiple healthcare specializations are required for this comprehensive assessment and treatment approach, challenging, time-consuming clinical coordination of care is essential for patient compliance and accurate follow-through. A mobile platform will better support this multi-clinician, multi-treatment process, allowing a patient's "health story" to be shared by the patient and his/her treatment team. Sharing via mobile telemedicine encompasses both access and authorship. The application's primary purpose is to support care delivery, which in turn, will support better health. Preliminary data are encouraging for adoption and utilization of a mobile telemedicine platform to meet the complex needs of those recovering from TBI.

## 5. SUMMARY

In a 2015 Pew Research Center study, 64% of American adults own a smartphone, up from 35% in 2011.[18] In addition, 62% of Americans use a smartphone to access health care information.[16] As the use of smartphones continues to increase, its use in the day to day lives of end-users to access medical information and engage with the medical health care team will subsequently increase. In addition, the smartphone will be an important tool to effect behavior change for unhealthy lifestyle choices (e.g. smoking cessation programs) and real-time data capture to improve clinical outcomes (e.g. hospital readmissions) for home based care for chronic diseases (e.g. diabetes, congestive heart failure). mHealth use in the military and Veteran population mirrors the civilian sector with similar expectations planned for increased use in all settings with widespread technology insert in DoD/Veterans health care. The mHealth projects highlighted in this paper demonstrate the military, civilian, social and clinical benefits of mHealth, but more studies are needed on how to optimize programs, including optimal timing of messaging, dose of exposure, and value of interactive features in well-designed research studies.

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