Current Epidemiology Reports
https://doi.org/10.1007/s40471-022-00312-w

Uses of mHealth in Injury Prevention and Control: a Critical Review

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Accepted: 17 October 2022

Abstract

Purpose of Reviews The purpose of this review was to summarize the current state of the literature on the use of "mHealth" (the use of mobile devices for health promotion) for injury prevention and control.

Recent Findings mHealth is being used to measure, predict, and prevent the full spectrum of injuries. However, most literature remains preliminary or in a pilot stage. Use of best-of-class design principles (e.g., user-centered design, theory-based development) is uncommon, and wide-scale dissemination of effective monitoring or intervention tools is rare.

Summary mHealth for injury prevention holds promise, but further work is needed across the full spectrum of development and translation.

Keywords Injury prevention · mHealth · Epidemiology · Social media · Text message · Mobile app · Digital health

Introduction

Over the last decade, access to mobile devices has burgeoned across the world: 97% of American adults reported owning cell phones, 85% owning smartphones, and 70% using social media as of 2021 [1]. Parallel to the rise of these devices, "mHealth," or mobile health, has emerged as a subset of the larger field of digital health. mHealth uses these near-ubiquitous devices to facilitate all aspects of health and public health, through techniques ranging from text messaging, smartphone applications, social media, and wearable sensors, to algorithms that use data inherent to these devices [2]. By supplementing or replacing resource-intensive, face-to-face assessments or interventions with mHealth, healthcare and public health systems may be able to allocate resources more efficiently while maintaining standard of care [3, 4]. mHealth may also alleviate barriers to access, such as stigma, logistical challenges, and cost [5].

The design and implementation of mHealth for public health—such as injury prevention—is viewed by many as an area of untapped potential [6]. The roles of mHealth in injury prevention could range from data collection (e.g., improving the accuracy of measurement of injury or near-injury; improving the collection of data on risk and promotive factors) to primary prevention (e.g., delivering education to parents or healthcare providers to reduce or eliminate risk), to secondary prevention (e.g., encouraging strategies to reduce the risk of recurrence or worsening of injury after a near-injury or initial injury), and beyond (e.g., tertiary prevention, including rehabilitation).

Overview of the Field of mHealth for Injury Prevention and Control

Over the last 3 years, there has been a surge in publications in both the peer reviewed and gray literature on the use of smartphone apps, wearables, and connected devices for injury

This article is part of the Topical Collection on *Injury Epidemiology*

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Published online: 09 November 2022

prevention and control. Overall, while there are a handful of randomized trials demonstrating the efficacy and effectiveness of mHealth approaches for prevention of injuries, the field is still in early development, with the majority of published works in the formative stages of feasibility, usability, and pilot testing.

In this manuscript, we describe the current state of the science for mHealth in injury prevention and control, provide an overview of some of the most promising recent literature, and outline an agenda for future work. Articles were identified through a structured search of PubMed using MeSH terms, review of citations in identified literature, and the authors' own knowledge of the literature. We decided to exclude literature on mHealth for opioid overdose, and mHealth for tertiary prevention (post-traumatic stress, physical rehabilitation), due to concerns about the broadness of both topics and the existence of other recent scoping and systematic reviews on these topics [7–11]. We extracted data using a standardized data form, and rated quality in accordance with Cochrane Review ROBINS-I criteria [12]. In accordance with injury prevention theory, we organize our discussion of these potential uses of mHealth based on three primary manners of injury: unintentional injury, self-harm, and violence (community or partner).

mHealth for Unintentional Injury Prevention and Control

Falls

Published works leveraging mHealth approaches to fall prevention primarily focus on the primary prevention of falls in older adults. Formative work includes using apps and wearables to track gait, fall risk, falls, and fitness over time [13, 14]. There is a paucity of literature around the translation of wearable and tracking technologies into fall prevention interventions. Tested interventions have primarily focused on leveraging apps to promote exercises at home intended to improve balance. One such randomized trial tested the addition of a tablet-based app to promote exercise among older adults to usual care that included home visits, finding that the app intervention led to a significant reduction of falls and falls leading to injuries at 24 months [15••]. A notable feature of the app intervention was embedded behavior change interventions including calendar prompts to regularly schedule exercise as well as goal setting. A limitation was that research staff monitored the app for gaps in adherence during the first 6 months raising questions about whether the effects are scalable without research staff. Future work using wearables and/or apps combined with behaviorally informed interventions to promote and sustain balance exercises hold promise preventing falls on a broad scale.

Sports Injuries and Concussions

mHealth technologies are currently being tested to prevent sports injuries and concussions, collect data on injuries at the population level, and deliver secondary prevention interventions to reduce the acute impact of these injuries. For example, one high-quality-randomized trial tested an app to promote unsupervised exercises to prevent tennis injuries and found no difference in the rate of injuries [16]. This aligns with previous literature finding little evidence of benefit of unsupervised exercise in most contexts with preventing sports injuries. There has been increasing interest in leveraging mHealth to collect real-time data on sports and leisure injuries, causative exposures, and frequent ecological momentary assessment of symptoms once they occur. This includes the construction of population-based cohorts that can be used for understanding injury patterns and conducting interventions at scale [17] and daily symptoms tracking to measure concussion recovery [18]. Given the need for frequent assessments of symptoms, there is also ongoing work to test different engagement strategies to promote more complete assessments [19]. Finally, there is emerging evidence on the benefit of mHealth-facilitated interventions for mitigating post-concussive symptoms. This includes adding app-based virtual reality training to in-person care for improving sensorimotor control [20] and a randomized trial of an app demonstrated to reduce post-concussion symptoms and psychological distress among war veterans [21]. There are ample opportunities for mHealth to be further developed to leverage passive data collection to track symptoms and use the data as well as patient-reported symptoms to provide automated guidance on return to baseline activities (e.g., sports, school, driving).

Childhood Injuries

mHealth apps have also been used to deliver educational interventions to reduce unintentional injuries among young children. There is randomized trial evidence of apps improving caregiver safety behaviors [22, 23]. However, these trials were not able to detect a difference in child injury rates [22] or injury rates were not measured [23]. Other apps tested in RCTs have been delivered to children themselves, with one finding improved safety knowledge and skills among 5–6-year-old children and increased frequency of safety conversations with parents [24]. Further research is needed to determine whether mHealth interventions can reduce unintentional injury rates among young children.

Motor Vehicle Crashes

There has been an explosion in industry activity and published works on using connected devices and now smartphone apps to measure real-time, telematic data on driving behavior. This includes using GPS, accelerometer, and other phone sensors to measure hard braking, hard accelerations, speeding, and phone use while driving. This is primarily driven by the autoinsurance industry which has found that telematics data on driving behavior is highly predictive of future crash claims and has found that pricing future insurance policies based on observed driving behavior via smartphone apps improves profit to loss ratios [25–27]. This model of "usage based insurance" is now offered by most major insurers with the promise of discounts for safe driving [28, 29]. While there are millions of US drivers currently that have smartphone telematics apps passively collecting data on their driving behavior on their phones, scientific research using these apps is just in its infancy. Early work has characterized novel measures of phone use while driving including rate of phone unlocks, duration of phone use, and the speed at which the phone was used [30••]. Two randomized trials have found that feedback combined with financial incentives can reduce risky driving behaviors and improve driving skills [31, 32]. Another RCT highlighted the importance of the timing and framing of feedback finding that immediate positive feedback produced unintended effects and suggests insurers should use a continuous function for incentives rather than a step function [33]. Two recent randomized trials found that simple text messaging goal-setting interventions reduced self-reported phone use while driving [34••] similarly increased seatbelt use relative to a control assessment text message. This highlights the potential of incorporating goal setting strategies into telematics enabled programs. Preliminary data indicate the potential benefits of framing incentives with insights from behavioral economics and with leveraging goal setting and social competition within usage-based insurance programs to reduce phone use while driving [35, 36]. There is a major opportunity for future research to optimize behavioral strategies that could be scaled within smartphone-based autoinsurance programs for reducing driving risk and preventing crashes. There is also a large need to measure the actual effect of mHealth or digital health interventions on crash incidence and severity.

mHealth for Prevention and Control of Self-harm

mHealth is currently being used to address the full spectrum of self-harm behaviors, ranging from non-suicidal-self-injury (NSSI) to secondary prevention of suicide. These uses fall, in general, into two categories: development of more accurate predictive models of likelihood of self-harm using mobile device data and implementation of tailored interventions for specific sub-populations, delivered through mobile devices.

Monitoring

Similar to the field of unintentional injury prevention, self-harm mHealth monitoring uses data from social media, wearable devices, or smartphones' own internal data systems (e.g., frequency of opening of the phone, frequency of phone calls, volume of the user's voice, geo-location) to predict or diagnose likelihood of self-harm. Some of the most promising predictive measures combine multiple data sources [37], although many such studies are still underway [38]. Researchers and private businesses have been advocating for the promise of digital data in predicting self-harm for well over a decade.

Interventions

Although "digital psychiatry" is an area of intense and productive research [39], the quality of evidence on mHealth interventions specifically for primary and secondary prevention of suicide and self-harm is less robust. Two recent studies show that although hundreds of apps relevant to suicide or self-harm are publicly available [40]; only a handful adhere to best practices for suicide prevention [41] and crisis management [42]. Moreover, according to a recent systematic review, only a handful of studies have evaluated efficacy or effectiveness of these mobile interventions [43]. Although some mHealth suicide prevention interventions have shown the ability to change intermediary psychological markers of suicide risk [44], including among traditionally marginalized populations such as indigenous Australian youth [45], none have demonstrated the ability to significantly decrease suicidal behaviors. Older papers and qualitative data suggest that some mHealth interventions may also be effective in reducing non-suicidal self-injury [46, 47], The most rigorous recent study, by Torok et al., is a double-blind RCT of an interactive dialectical-behavior-therapy-based application with 455 young Australian adults recruited through social media. [48••] This study showed significant decreases in suicidal ideation immediately post-intervention and at 3 months among users of the application, compared to control; however, nearly 50% failed to complete follow-ups.

In our opinion, some of the more promising uses of mHealth for suicide prevention address structural factors that increase the likelihood of a suicide attempt—e.g., a recent pilot study by Betz et al. of a mobile decision aid to reduce access of suicidal patients to lethal means such as firearms [44]. Most existing research includes a call for more user-centered design processes and more accurately tailored intervention timing and content to increase efficacy of these interventions.

mHealth for Prevention and Control of Violence

Intimate Partner Violence

Several recent reviews describe a growing number of mHealth research for intimate partner violence (IPV) [53–57]. Existing mHealth interventions for IPV include computer-based IPV screenings [58] web-based safety decision aids and self-help tools [59–62], and online-delivered psychological care [63].

The ways in which digital technology is utilized in IPV and dating violence prevention and intervention vary. [65] Some dating violence prevention programs for youth include technology-enhanced components, such as virtual role play skills practice, and video-role plays [66]. Computer-tailored dating violence interventions also exist [67]. Some mHealth contributions to violence prevention and response are as simple as the development of web platforms that allow for anonymous digital reporting systems and thereby increase accessibility of information and support. Although programs are high in feasibility and acceptability [68, 69], there is little evidence to suggest that mHealth interventions for IPV are superior to other in-person IPV prevention or intervention approaches [56]. Furthermore, a limited number of mHealth interventions prevent IPV perpetration [70, 71]. As discussed by Diaz-Ramos et al., there is increasing recognition of the need to enhance the cultural relevance of app-based safety decision aids for dating violence and IPV [72]. Thus, while there is enthusiasm for the use of mHealth to connect IPV victims to health care providers, further work is needed to develop primary prevention approaches for IPV delivered via mHealth [73]. Some argue that the patient-provider relationship is especially important in the provision of care for IPV victims, and—currently—mHealth may be best considered as a way to supplement rather than replace relationships with IPV providers [74]. In fact, qualitative research seeking to apply human-centered design principles in the design of an information and communication technology tool for victims of violence and their case managers also highlights how participants in violence interventions value not only personalized communication and online community, but also a close relationship with a case manager [75].

Sexual Assault

A growing number of mHealth interventions aim to ameliorate the consequences of sexual assault. These include web-based programs designed to prevent sexual assault [76], as well as mHealth interventions to reduce adverse consequences among survivors of sexual assault [77]. mHealth interventions for survivors take various forms. Downing et al. developed and piloted a text message follow-up program to address psychological distress, sexually transmitted infections, and pregnancy following sexual assault; it had high perceived utility among participants [78]. Lee and Cha report a signal of increased social support and suicidal ideation among survivors of sexual assault for "Sister, I will tell you!", which includes modules of reflective writing and mindfulness medication delivered via a mobile platform [79]. Loucks et al. evaluated the feasibility of a virtual reality exposure therapy program for survivors of military sexual trauma and documented significant reductions in PTSD in the context of a small pilot study among veterans [80]. Other web-based interventions designed to address the aftereffects of military sexual trauma also show promising results in facilitating treatment seeking [81].

Other Forms of Violence

The development, testing and refinement of mHealth solutions to address youth violence, child neglect and maltreatment, and community violence is also underway [82, 83]. A variety of personal safety apps have been designed to reduce risk of violence; these include phone-based alarm systems, location monitoring, evidence-capture, and educational information. Evaluation of these apps' efficacy has been limited, and users report concerns about their unreliability [84]. Other programs serve as secondary prevention interventions. For example, a pilot of an app to increase resilience and improve bystander capabilities in the face of online bullying/harassment had positive results on intention to intervene [85••]. A large factorial randomized trial of a promising CBT- and MI-based intervention to address peer violence, which includes 8 week of automated, tailored 2-way text messages following an emergency department room visit is also underway [86, 87]. Apps to facilitate communication between violence intervention specialists and their clients are also being designed, although reliability of data collected, and efficacy of app-based interactions have yet to be evaluated. Finally, mHealth is being used to measure both predictors and outcomes of violence. For example, a pilot study of ecological monitoring of 25 individuals who had recently been hospitalized for violent injury showed high response to text message–based surveys, moderate use of wearable biometric devices, and high satisfaction and usability of mobile devices for post-injury care and research [88].

Ethics and Privacy Concerns

A common theme across categories of articles was the importance of addressing the ethics of mHealth in injury prevention and control [49, 50]. For example, CrisisTextLine—a well-regarded non-profit that offers anonymous text-based crisis interventions (including for people with suicidal thoughts) across the USA—was recently, appropriately, criticized for using clients' data to inform the development of a for-profit company without client consent [51]. Similarly, although these mHealth tools offer private and real-time access to screening and support—like accessing a telephone hotline—it is important that mHealth interventions be confidential and inconspicuous, so as to reduce the likelihood that use of the digital tool places an individual at further harm (e.g., from an abusive partner) [64]. A recurring concern is that the field must more comprehensively consider, and address, mHealth developers' ethical obligations to the end-user, whether in the moment of crisis (such as during a mental health crisis), in terms of potential legal implications of disclosures of injury-related circumstances (such as surrounding a car crash or violent injury), or in terms of larger issues of data privacy that the field of mHealth is grappling with, in general [52].

Future Directions

Overall, the use of mHealth to measure, predict, and prevent injury is still in its infancy. Although the value of mHealth for this field is clear from the pilot and feasibility studies outlined above, future work must go further.

First, and most importantly, mHealth is not a panacea. If poorly designed or based on poor science, the end-result will rarely be effective. Ample evidence from outside of injury prevention as well as within it points to the importance of designing mHealth using both robust behavioral theory [89], and participatory design [90]. The best papers identified in this review drew from well-established behavior change theories. Future work on mHealth for injury prevention and control should consider behavioral engagement strategies from the earliest stage of development, to promote behavior change, sustain use, and increase uptake in highest risk and lowest motivation populations [91].

Second, much of the literature for mHealth in injury prevention and control—like mHealth, in general—is still in the formative and pilot stage; we expect to see more rigorous efficacy and effectiveness trials in the literature soon. We emphasize, however, that scalability is one of the greatest theoretical benefits of mHealth: the platform itself allows for wide dissemination. But to achieve this goal, our field needs to be intentional about dissemination and scale from the first wireframe. We particularly urge more time spent developing and testing mHealth-based injury prevention and control interventions that can be delivered at scale, without relying on research staff.

Third, we urge researchers and public health professionals to consider the variety of ways in which mobile data can be used to augment or accelerate accurate large-scale data and trial collection. In the wake of COVID-19, we are watching mHealth tools transform the practice of data collection for pandemic preparedness [92, 93]. Some of the studies described above outline a path forward for similar advances in injury prevention as well. Multi-sectoral collaboration and increased funding for our public health infrastructure is needed to pay for, train, implement, and then analyze such mobile data collection.

Finally, the field of injury prevention and control needs to deeply grapple with the ethical, privacy, and equity implications of the use of mHealth for often sensitive or stigmatized topics such as injury. Rural and historically marginalized populations experience the biggest digital divide, and it is essential that—consistent with the principles of the science of injury prevention and control—mHealth development address these inequities from the onset [94]. We found few discussions of issues of various types of equity (according to age, disability, race, sexual orientation) or privacy in the papers identified in this review.

Funding Megan L. Ranney reports receiving funding from NIGMS since the initial planning of the work, as well as unrelated grants within the past 36 months from NIH, CDC, and for participation on a Data Safety and Monitoring Board or Advisory Board from the University of Pennsylvania (self). Dr. Ranney further reports unpaid work within the past 36 months in leadership or fiduciary roles at the following institutes: Aspen at the AFFIRM Institute and the Institute for NonViolence.

Declarations

Competing Interests M. Kit Delgado reports contract payments, grant, and philanthropic donation from the FDA, CDC, and the Abramson Family Foundation, respectively, since the initial planning of the work. Dr. Delgado further reports grants from NIH, PCORI, and USDOT within the past 36 months. Lindsay M. Orchowski, Elizabeth Stettenbauer and Katherine Yao declare no conflicts of interest since the initial planning of the work, nor within the past 36 months.

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