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

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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...
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 breadth 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-concussive 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.

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Declarations

Competing Interests

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References

Papers of particular interest, published recently, have been highlighted as:
•• Of major importance

1. Mobile Fact Sheet Pew Research Center; Pew Research Center; 2021 [updated April 7, 2021. Available from: https://www.pewresearch.org/internet/fact-sheet/mobile/.
2. Marcelino MS, Oliveira JAQ, D’Agostino M, Ribeiro AL, Alkmin MBM, Novillo-Ortiz D. The impact of mhealth interventions: systematic review of systematic reviews. JMIR Mhealth Uhealth. 2018;6(1):e23.
Tall group had significantly lower rates of “any” falls or a health education program. Although no significant differences of fall rates were observed at year 1, the Standing-Tall group had significantly lower rates of “any” falls or “injurious” falls at 24 months. Strengths of the intervention included individual-level onboarding to the program; an evidence-based program; attention to scalability; and enrollment of an older population.

Paes H, Plum BM, Kilic O, Verhagen E, Gouttebarge V, Holman R, et al. Effectiveness of an e-health tennis-specific injury prevention programme: randomised controlled trial in adult recreational tennis players. Br J Sports Med. 2020;54(17):1036–41.

Castro MYR, Orriols L, Contrand B, Dupuy M, Szal-Kutas C, Avalos M, et al. Cohort profile: MAVIE—a web-based prospective cohort study of home, leisure, and sports injuries in France. PLoS ONE. 2021;16(3):e0248162.

Wieneke J, Storey EP, Orchinik JE, Grady MF, Leddy JJ, Willer BS, et al. Measuring recovery with ecological momentary assessment in a randomized trial of exercise after sport-related concussion. Clin J Sport Med. 2022;32:345–53.

Corwin MD, Orchinik J, D’Alonzo B, Master C, Agarwal AK, Wiebe D. A randomized trial of incentivization to maximize retention for real-time symptom and activity monitoring using ecological momentary assessment in pediatric concussion. Neurology. 2022;98(1 Supplement 1):S7–S.

Reneker JC, Babi R, Pannell WC, Adah F, Flowers MM, Curbow-Wilcox K, et al. Sensorimotor training for injury prevention in collegiate soccer players: an experimental study. Phys Ther Sport. 2019;40:184–92.

Belanger HG, Toyinbo P, Barrett B, King E, Sayer NA. Concussion coach for postconcussive symptoms: a randomized, controlled trial of a smartphone application with Afghanistan and Iraq war veterans. Clin Neuropsychol. 2021;1–27.

Niegu P, Cheng P, Schwebel DC, Yang Y, Yu R, Deng J, et al. An app-based intervention for caregivers to prevent unintentional injury among preschoolers: cluster randomized controlled trial. JMIR Mhealth Uhealth. 2020;8(6):e15752.

Corinne A, Hernán M A, Reeves B C, Savović J, Berkman N, Uram J, Mehta R, Sasangohar F. Technologies for opioid use disorder management: mobile app search and scoping review. JMIR Mhealth Uhealth. 2020;8(6):e15752.

Kazemi, Donna M PhD, FIAAN; Li, Shaoyu PhD; Levine, Maureen J PhD, ABPP; Auten, Beth MLS, MA, AHIP; Granson, Matthew BS. Systematic review of smartphone apps as a mHealth intervention to address substance abuse in adolescents and adults. Journal of Addictions Nursing: 7/9 2021 - Volume 32 - Issue 3 - p 180–187

Kraaijikamp J, van Dam van Isselt EF, Persoon A, Versluis A, Chavannes NH, Achterberg WP, eHealth in geriatric rehabilitation: systematic review of effectiveness, feasibility, and usability. Journal of medical internet research. 2021;23(8):e24015.

Edwards D, Williams J, Carrier J, Davies J. Technologies used to facilitate remote rehabilitation of adults with deconditioning, musculoskeletal conditions, stroke, or traumatic brain injury: an umbrella review. JBI evidence synthesis. 2022;20(8):1927–68.

Wickersham A, Petrides PM, Williamson V, Leightley D. Efficacy of mobile application interventions for the treatment of post-traumatic stress disorder: a systematic review. DIGITAL HEALTH. 2019;5.

Sterne JA, Hernán M A, Reeves B C, Savović J, Berkman N D, Viswanathan M et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions BMJ 2016; 355 i4919.

Struyss DH, Davoodi NM, Healy M, Metts CL, Merchant RC, Banksota S, et al. The geriatric acute and post-acute fall prevention intervention (GAPcare) II to assess the use of the apple watch in older emergency department patients with falls: protocol for a mixed methods study. JMIR Res Protoc. 2021;10(4):e24455.

Olson M, Lockhart T. Predicting fall risk through automatic wearable: a systematic review. International Journal of Prognostics and Health Management 2021;12(Special Issue on PHM for Human Health and Performance II).

Delbaere K, Valenzuela T, Woodbury A, Davies T, Yeong J, Steffens D, Miles L, Pickett L, Zijlstra GA, Clemson L, Close JC, Howard K, Lord SR. Evaluating the effectiveness of a home-based exercise programme delivered through a tablet computer for preventing falls in older community-dwelling people over 2 years: study protocol for the Standing Tall randomised controlled trial. BMJ Open. 2015;5(10):e009173. https://doi.org/10.1136/bmjopen-2015-009173 This trial enrolled 503 Australians age 70 +, currently living independently, and block randomized them to an app-based balance exercise program (“Standing Tall”): two hours weekly of balance exercises or a health education program. Although no significant differences in fall rates were observed at year 1, the Standing-Tall group had significantly lower rates of “any” falls or “injurious” falls at 24 months. Strengths of the intervention included individual-level onboarding to the program; an evidence-based program; attention to scalability; and enrollment of an older population.

Pas H, Plum BM, Kilic O, Verhagen E, Gouttebarge V, Holman R, et al. Effectiveness of an e-health tennis-specific injury prevention programme: randomised controlled trial in adult recreational tennis players. Br J Sports Med. 2020;54(17):1036–41.

Castro MYR, Orriols L, Contrand B, Dupuy M, Szal-Kutas C, Avalos M, et al. Cohort profile: MAVIE—a web-based prospective cohort study of home, leisure, and sports injuries in France. PLoS ONE. 2021;16(3):e0248162.

Wieneke J, Storey EP, Orchinik JE, Grady MF, Leddy JJ, Willer BS, et al. Measuring recovery with ecological momentary assessment in a randomized trial of exercise after sport-related concussion. Clin J Sport Med. 2022;32:345–53.

Corwin MD, Orchinik J, D’Alonzo B, Master C, Agarwal AK, Wiebe D. A randomized trial of incentivization to maximize retention for real-time symptom and activity monitoring using ecological momentary assessment in pediatric concussion. Neurology. 2022;98(1 Supplement 1):S7–S.

Reneker JC, Babi R, Pannell WC, Adah F, Flowers MM, Curbow-Wilcox K, et al. Sensorimotor training for injury prevention in collegiate soccer players: an experimental study. Phys Ther Sport. 2019;40:184–92.

Belanger HG, Toyinbo P, Barrett B, King E, Sayer NA. Concussion coach for postconcussive symptoms: a randomized, controlled trial of a smartphone application with Afghanistan and Iraq war veterans. Clin Neuropsychol. 2021;1–27.

Niegu P, Cheng P, Schwebel DC, Yang Y, Yu R, Deng J, et al. An app-based intervention for caregivers to prevent unintentional injury among preschoolers: cluster randomized controlled trial. JMIR Mhealth Uhealth. 2019;7(8):e13519.

McKenzie LB, Roberts KJ, McAdams RJ, Abdal-Rasoul M, Kristel O, Szymbanski A, et al. Efficacy of a mobile technology-based intervention for increasing parents’ safety knowledge and actions: a randomized controlled trial. Inj Epidemiol. 2021;8(1):56.

Dixon CA, Ammerman RT, Johnson BL, Lampe C, Hart KW, Lindsell CJ, et al. A randomized controlled field trial of iBSafe-a novel child safety game app. Mhealth. 2019;5:3.

Tselentis DI, Yannis G, Vlahogianni EI. Innovative motor insurance schemes: a review of current practices and emerging challenges. Accid Anal Prev. 2017;98:139–48.

Winlaw M, Steiner SH, MacKay RJ, Hilal AR. Using telematics data to find risky driver behaviour. Accid Anal Prev. 2019;131:131–6.

Arumugam S, Bhargavi R. A survey on driving behavior analysis in usage based insurance using big data. Journal of Big Data. 2019;6(1):86.


demographic, age, and driving differences in cellphone usage using an add-on application to drivers’ phones.

31. Peer S, Muermann A, Sallinger K. App-based feedback on safety to novice drivers: Learning and monetary incentives. Transportation Research Part F: Traffic Psychology and Behaviour. Transp Res. 2020;71:198–219.

32. Stevenson M, Harris A, Wijnands JS, Mortimer D. The effect of telematic based feedback and financial incentives on driving behaviour: a randomised trial. Accid Anal Prev. 2021;159:106278.

33. Choudhary V, Shunko M, Netessine S. Does immediate feedback make you not try as hard? A study on automotive telematics. Manufacturing & Service Operations Management. 2020;23.

34. •• Suffoletto B, Pacella-LaBarbara ML, Huber J, Delgado MK, McDonald C. Effectiveness of a Text Message Intervention Promoting Seat Belt Use Among Young Adults: A Randomized Clinical Trial. JAMA Netw Open. 2022;5(9):e2231616. https://doi.org/10.1001/jamanetworkopen.2022.31616 This pilot randomized controlled study evaluated the efficacy of a 6-week text message program to reduce texting while driving (TWD) among a sample of 112 young adults (age 18–25) recruited from emergency departments. The intervention was more effective at reducing self-reported TWD among young adults than the assessment control at 12 weeks, but not at assessment 6 weeks. Strengths of the study include recruitment from an emergency department and the use of theory-based interventions.

35. Kit Delgado M. 167 Randomized trial of social comparison feedback and financial incentive strategies for reducing handheld phone use while driving in a national usage-based auto insurance program. Injury Prevention. 2020;26(Suppl 1):A27-A.

36. Ebert J, Xiong R, Abdel-Rahman D, Kahn N, Leitner A, Everett W, et al. 103 A randomized controlled trial of habit formation interventions for reducing distracted driving in a diverse national sample of auto-insurance customers. Inj Prev. 2022;28(Suppl 1):A36–7.

37. Bettis AH, Burke TA, Nesi J, Liu RT. Digital technologies for emotion-regulation assessment and intervention: a conceptual review. Clin Psychol Sci. 2022;10(1):3–26.

38. Brown LA, Taylor DJ, Bryan C, Wiley JF, Pruiksma K, Khazem L, et al. Digital phenotyping to improve prediction of suicidal urges in treatment: study protocol. Aggression and Violent Behavior. 2022;101733.

39. Torous J, Bucci S, Bell IH, Kessing LV, Faurholt-Jepsen M, Whelan P, et al. The growing field of digital psychiatry: current evidence and the future of apps, social media, chatbots, and virtual reality. World Psychiatry. 2021;20(3):318–35.

40. Larsen ME, Nicholas J, Christensen H. A systematic assessment of smartphone tools for suicide prevention. PLoS ONE. 2016;11(4):e0152285.

41. Martinengo L, Van Galen L, Lum E, Kowalski M, Subramaniam M, Car J. Suicide prevention and depression apps’ suicide risk and management: a systematic assessment of adherence to clinical guidelines. BMC Med. 2019;17(1):231.

42. Sander LB, Lemor ML, Van der Sloot RJ, De Jaegere E, Buscher R, Messner EM, et al. A Systematic evaluation of mobile health applications for the prevention of suicidal behavior or non-suicidal self-injury. Front Digit Health. 2021;3:689692.

43. Melia R, Francis K, Hickey E, Bogue J, Duggan J, O’Sullivan M, et al. Mobile health technology interventions for suicide prevention: systematic review. JMIR MHealth Uhealth. 2020;8(1):e12516.

44. Bush NE, Smolenski DJ, Denneson LM, Williams HB, Thomas EK, Dobsha SK. A virtual hope box: randomized controlled trial of a smartphone app for emotional regulation and coping with distress. Psychiatr Serv. 2017;68(4):330–6.

45. Tighe J, Shand F, Ridani R, Mackinnon A, De La Mata N, Christensen H. Ibobby mobile health intervention for suicide prevention in Australian Indigenous youth: a pilot randomised controlled trial. BMJ Open. 2017;7(1):e013518.

46. Kruzan KP, Mohr DC, Reddy M. How Technologies can support self-injury self-management: perspectives of young adults with lived experience of nonsuicidal self-injury. Front Digit Health. 2022;4:913599.

47. Franklin JC, Fox KR, Franklin CR, Kleiman EM, Ribeiro JD, Jaroszewski AC, et al. A brief mobile app reduces nonsuicidal and suicidal self-injury: evidence from three randomized controlled trials. J Consult Clin Psychol. 2016;84(4):544–57.

48. •• Torok M, Han J, McGillivray L, Wong Q, Werner-Seidler A, O’Dea B, Calear A, Christensen H. The effect of a therapeutic smartphone application on suicidal ideation in young adults: Findings from a randomized controlled trial in Australia. PLoS Med. 2022;19(5):e1003978. https://doi.org/10.1371/journal.pmed.1003978 This double-blind RCT recruited 455 young Australian adults (age 18–25) through social media and randomized them to a 6-week dialectical behavior therapy-based app (LifeBuoy) vs a sham application. Based on self-report measures, intervention participations had significant decreases in suicidal ideation immediately post-intervention and at 3 months, compared to control; however, nearly half of participants were lost to follow-up. Strengths of the study include social media-based recruitment, use of a multi-modal intervention, and well-validated self-report measures.

49. Pagoto S, Nebeker C. How scientists can take the lead in establishing ethical practices for social media research. J Am Med Inform Assoc. 2019;26(4):311–3.

50. Shaw JA, Donia J. The sociotechnical ethics of digital health: a critique and extension of approaches from bioethics. Front Digit Health. 2021;3:725088.

51. Ruiz R. Crisis text line ends controversial relationship with for-profit AI company 2022 July 26, 2022. Available from: https://mashable.com/article/crisis-text-line-loris-ai.

52. Tangari G, Ikrarn M, Ijaz K, Kaafar MA, Berkovsky S. Mobile health and privacy: cross sectional study. BMJ. 2021;373:n1248.

53. Anderson EJ, Krause KC, Meyer Krause C, Welter A, McClelland DJ, Garcia DO, et al. Web-based and mHealth interventions for intimate partner violence victimization prevention: a systematic review. Trauma Violence Abuse. 2021;22(4):670–84.

54. Draugham Moret J, Todd A, Rose L, Pollitt E, Anderson J. Mobile phone apps for intimate partner and sexual violence prevention and response: systematic search on app stores. JMI Res. 2022;6(2):e28959.

55. El Morr C, Laval M. ICT-based interventions for women experiencing intimate partner violence: research needs in usability and mental health. Stud Health Technol Inform. 2019;257:103–9.

56. Linde DS, Bakiewicz A, Normann AK, Hansen NB, Lundh A, Rasch V. Intimate partner violence and electronic health interventions: systematic review and meta-analysis of randomized trials. J Med Internet Res. 2020;22(12):e22361.

57. Rempel E, Donelle L, Hall J, Rodger S. Intimate partner violence: a review of online interventions. Inform Health Soc Care. 2019;44(2):204–19.

58. Gilbert L, Shaw SA, Goddard-Eckrich D, Chang M, Rowe J, McCrimmon T, et al. Project WINGS (Women Initiating New Goals of Safety): a randomised controlled trial of a screening, brief intervention and referral to treatment (SBIRT) service to identify and address intimate partner violence victimisation among substance-using women receiving community supervision. Crim Behav Ment Health. 2015;25(4):314–29.

59. Ford-Gilboe M, Varcoe C, Scott-Storey K, Perrin N, Wuest J, Wathen CN, et al. Longitudinal impacts of an online safety and health intervention for women experiencing intimate partner violence.
violence: randomized controlled trial. BMC Public Health. 2020;20(1):260.
60. Koziol-McLain J, Vandal AC, Wilson D, Nada-Raja S, Dobbs T, McLean C, et al. Efficacy of a web-based safety decision aid for women experiencing intimate partner violence: randomized controlled trial. J Med Internet Res. 2018;19(12):e426.
61. O’Campo P, Velonis A, Buharwala P, Kamalathan J, Hassan MA, Metheny N. Design and development of a suite of intimate partner violence screening and safety planning web apps: user-centered approach. J Med Internet Res. 2021;23(12):e24114.
62. Tarzia L, Murray E, Humphreys C, Glass N, Taft A, Valpied J, et al. I-DECIDE: an online intervention drawing on the psychological readiness model for women experiencing domestic violence. Womens Health Issues. 2016;26(2):208–16.
63. Andersson G, Olsson E, Ringsgard E, Sandgren T, Viklund I, Andersson C, et al. Individually tailored Internet-delivered cognitive-behavioral therapy for survivors of intimate partner violence: a randomized controlled pilot trial. Internet Interv. 2021;26:100453.
64. Emeucze C. Digital or digitally delivered responses to domestic and intimate partner violence during COVID-19. JMR Public Health Surveill. 2020;6(3):e19831.
65. Brignone L, Edleson JL. The dating and domestic violence app rubric: synthesizing clinical best practices and digital health app standards for relationship violence prevention smartphone apps. International Journal of Human-Computer Interaction. 2019;35(19):1859–69.
66. Peskin MF, Markham CM, Shegog R, Baumler ER, Addy RC, Temple JR, et al. Adolescent dating violence prevention program for early adolescents: the me & you randomized controlled Trial, 2014–2015. Am J Public Health. 2019;109(10):1419–28.
67. Murta SG, Parada PDO, da Silva MS, Medeiros JVV, Balbino A, Rodrigues MC, et al. Dating SOS: a systematic and theory-based development of a web-based tailored intervention to prevent dating violence among Brazilian youth. BMC Public Health. 2022;22(1):391.
68. Choo EK, Zlotnick C, Strong DR, Squires DD, Tapé C, Mello MJ. BSAFER: a web-based intervention for drug use and intimate partner violence demonstrates feasibility and acceptability among women in the emergency department. Substance Abuse. 2016;37(3):441–9.
69. van Gelder N, Lighart S, Ten Elzen J, Prins J, van Rosmalen-Noorjens K, Oeretk-Prigione S. “If I’d had something like safe at the time, maybe i would’ve left him sooner.” -Essential features of eHealth interventions for women exposed to intimate partner violence: a qualitative study. J Interpers Violence. 2021;8862605211036108.
70. Levesque DA, Ciavatta MM, Castle PH, Prochaska JM, Prochaska JO. Evaluation of a stage-based, computer-tailored adjunct to usual care for domestic violence offenders. Psychol Violence. 2012;2(4):368–64.
71. Easton CJ, Berbary CM, Crane CA. Avatar and technology assisted platforms in the treatment of co-occurring addiction and IPV among male offenders. Adv Dual Diagn. 2018;11:126–34.
72. Diaz-Ramos N, Alvarez C, Debnam K. Teen dating violence and the acceptability of a safety decision aid: perspectives of Puerto Rican youth. Hisp Health Care Int. 2021;19(3):146–54.
73. Jewkes R, Dartnall E. More research is needed on digital technologies in violence against women. Lancet Public Health. 2019;4(6):e270–1.
74. Bacchus LJ, Bullock L, Sharps P, Burnett C, Schminkey DL, Buller AM, et al. Infusing technology into perinatal home visitation in the United States for women experiencing intimate partner violence: exploring the interpretive flexibility of an mHealth intervention. J Med Internet Res. 2016;18(11):e302.
75. Patel D, Sarlati S, Martin-Tuite P, Feler J, Chehab L, Texada M, et al. Designing an information and communications technology tool with and for victims of violence and their case managers in San Francisco: human-centered design study. JMRirt Mhealth Uealth. 2020;8(8):e1566.
76. Oesterle DW, Schipani-McLaughlin AM, Salazar LF, Gilmore AK. Chapter 14 - Using technology to engage boys and men in the prevention of sexual assault. In: Orchowski LM, Berkowitz AD, editors. Engaging boys and men in sexual assault prevention: Academic Press; 2022. p. 341–63.
77. Gilmore AK, Davidson TM, Leone RM, Wray LB, Oesterle DW, Hahn CK, et al. Usability testing of a mobile health intervention to address acute care needs after sexual assault. Int J Environ Res Public Health. 2019;16(17).
78. Downing NR, Bogue RJ, Terrill P, Tucker S. Development and test of a text-messaging follow-up program after sexual assault. Violence Against Women. 2021;27(11):2111–28.
79. Lee MR, Cha C. A Mobile healing program using virtual reality for sexual violence survivors: a randomized controlled pilot study. Worldviews Evid Based Nurs. 2021;18(1):50–9.
80. Loucks L, Yasinski C, Northolm SD, Maples-Keller J, Post L, Zwiebach L, et al. You can do that??! feasibility of virtual reality exposure therapy in the treatment of PTSD due to military sexual trauma. J Anxiety Disord. 2019;61:55–63.
81. Creech SK, Pulverman CS, Kahler CW, Orchowski LM, Shea MT, Wernette GT, et al. Computerized intervention in primary care for women veterans with sexual assault histories and psychosocial health risks: a randomized clinical trial. J Gen Intern Med. 2022;37(5):1097–107.
82. Cronin C, Sood S, Thomas D. From innovation to transcreation: adapting digital technologies to address violence against children. Child Abuse Rev. 2017;26(3):215–29.
83. Ferreira RC, Frota MA, de Vasconcelos Filho JE, Bastos APF, Luna GLM, Rolim KMC. Comparison of features of a mobile application to report school violence through benchmarking. J Sch Health. 2020;90(4):295–300.
84. Ford K, Bellis MA, Judd N, Griffith N, Hughes K. The use of mobile phone applications to enhance personal safety from interpersonal violence - an overview of available smartphone applications in the United Kingdom. BMC Public Health. 2022;22(1):1158.
85. Kutok ER, Dunsiger S, Patena JV, Nugent NR, Riese A, Rosen RK, Ranney ML. A Cyberbullying Media-Based Prevention Intervention for Adolescents on Instagram: Pilot Randomized Controlled Trial. JMIR Ment Health. 2021;8(9):e26029. https://doi.org/10.2196/26029. A sample of 80 adolescents (age 13–17) reporting a past-year history of cybervictimization were recruited through social media for a pilot RCT of an 8-week cognitive behavioral theory and bystander-intervention-informed remote brief intervention + app-based program, compared to web-based resources. Almost all participants (96%) were retained through 12-week follow-up; disproportionate recruitment of low socioeconomic status and self-identified LGBTQ + youth was observed. The intervention group had higher well-being and lower stress at both 8-weeks and 16-weeks and had higher rates of bystander intervention at 8 weeks. Strengths of the study included social media–based recruitment, user-centered design of the intervention, and high rates of follow-up.
86. Ranney ML, Patena JV, Dunsiger S, Spirito A, Cunningham RM, Boyer E, et al. A technology-augmented intervention to prevent peer violence and depressive symptoms among at-risk emergency department adolescents: protocol for a randomized control trial. Contemp Clin Trials. 2019;82:106–14. Ranney ML, Pittman SK, Dunsiger S, Guthrie KM, Spirito A, Boyer EW, et al. Emergency department text messaging for adolescent violence and depression prevention: a pilot randomized controlled trial. Psychol Serv. 2018;15(4):419–28.
88. Jacoby SF, Robinson AJ, Webster JL, Morrison CN, Richmond TS. The feasibility and acceptability of mobile health monitoring for real-time assessment of traumatic injury outcomes. Mhealth. 2021;7:5.

89. Morrison LG. Theory-based strategies for enhancing the impact and usage of digital health behaviour change interventions: a review. Digit Health. 2015;1:2055207615595335.

90. Birnbaum F, Lewis D, Rosen RK, Ranney ML. Patient engagement and the design of digital health. Acad Emerg Med. 2015;22(6):754–6.

91. Patel MS, Asch DA, Volpp KG. Wearable devices as facilitators, not drivers, of health behavior change. JAMA. 2015;313(5):459–60.

92. Al Knawy B, McKillop MM, Abduljawad J, Tarkoma S, Adil M, Schaper L, et al. Successfully implementing digital health to ensure future global health security during pandemics: a consensus statement. JAMA Netw Open. 2022;5(2):e220214.

93. Mason C, Lazenby S, Stuhldreher R, Kimball M, Bartein R. Lessons learned from implementing digital health tools to address COVID-19 in LMICs. Front Public Health. 2022;10:859941.

94. Makri A. Bridging the digital divide in health care. The Lancet Digital Health. 2019;1(5):204–5.

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