Review

Mobile Health Interventions for Self-control of Unhealthy Alcohol Use: A Systematic Review

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Abstract

Background: Unhealthy alcohol use (UAU) is one of the major causes of preventable morbidity, mortality and associated behavioral risks worldwide. Although mobile health (mHealth) interventions can provide consumers with an effective means for self-control of UAU in a timely, ubiquitous, and cost-effective manner, to date, there is a lack of evidence about the health outcomes of these interventions. The components of these interventions are also unclear.

Objective: To systematically review and synthesize the research evidence about the health outcomes of mHealth interventions for self-control of UAU and to explore the common components of these interventions.

Methods: We systematically searched four electronic interdisciplinary databases: Scopus, PubMed (PMC), CINAHL Plus with full text and MEDLINE with full text. Search terms and MeSH headings, “mHealth”, “text message”, “self-control”, “self-regulation”, “alcohol*” were used individually or in combination to identify peer-reviewed publications in English from 2007 to 2017. We screened titles and abstracts, and assessed full-text articles as per inclusion and exclusion criteria. Data were extracted from the included articles according to CONSORT-EHEALTH checklist (V.1.6.1) by two authors independently. Data quality was assessed by the Mixed Methods Appraisal Tool. Data synthesis and analyses were conducted following the procedures for qualitative content analysis. Statistical testing was also conducted to test differences among groups of studies.

Results: Twenty publications were included in the review. In fourteen studies (70%), mHealth interventions brought significant positive outcomes in improving participants’ health as measured by behavioral indicators (n=13), physiological indicators (n=1) and cognitive indicators (n=1). No significant health outcome was reported in the other five studies (25%). Surprisingly, a significant negative outcome was reported for the male participants in the intervention arm in one study (5%), but no change was found for the female participants. Five common components reported in mHealth interventions for consumer self-control of UAU were context, theoretical base, delivery mode, content and implementation procedure. The health outcomes were similar regardless of types of UAU,
deployment setting, with or without non-mobile co-intervention and with or without theory.

**Conclusions:** The major change brought by mHealth interventions for consumer self-control of UAU appeared to be improving behavior. There is still a lack of sound evidence on the effects of these interventions in improving the physiological and cognitive outcomes. More robust trials are needed to validate the short- and long-term health benefits and the contributing factors of mHealth interventions.

**Keywords:** systematic review; unhealthy alcohol use; UAU; self-control; mobile health; mHealth; health outcomes; components
Introduction

Unhealthy alcohol use (UAU) is one of the major causes of preventable morbidity, mortality and related behavioral risks around the world [1-3]. Approximately 3.3 million deaths, accounting for 5.9% of global deaths, were caused by alcohol-related problems annually [4]. Nearly 81% of adults in Australia consumed alcohol and UAU contributed to around 70,000 emergency department presentations in 2014 and 2015 [5, 6]. Unhealthy alcohol use may cause allergic reactions, hormonal disturbances and intoxication [7, 8]. Over time, it may cause physical diseases such as alcoholic hepatitis, diabetes, cardiovascular and cerebrovascular diseases [9], or psychological problems like depression, obsession, mania and suicide [10, 11]. Once the brain and neurons were anesthetized, UAU can cause a person to lose self-control [12], leading to social problems such as conflicts, unprepared sexual activities, drunk driving and violence [13, 14]. Therefore, UAU is not only a profound public health challenge, but also a social concern.

As an umbrella term, UAU covers various degrees of negative effects of alcohol use on people's well-being [15]. According to the severity, there are two major types of UAU: risky drinking and alcohol use disorder (AUD) [15, 16].

Risky drinking refers to alcohol use that leads to the risk of negative health consequences [16]. It can be measured by the number of standard drinks (SDs) consumed. An SD is defined by the amount of pure alcohol contained in a drink and it varies among countries [14, 16, 17]. For example, in Australia, an SD contains 10 grams of pure alcohol, in the UK and Iceland it contains only 8 grams, while in Austria it is 20 grams [17]. It is deemed risky drinking if total weekly alcohol consumption is greater than or equal to 15 SDs for men and 13 for women in the US, or over 14 SDs for men and 9 for women in Sweden [12, 18, 19]. In a single occasion, if alcohol consumption is more than 5 SDs for men and 4 for women, it is also seen as risky drinking, risky single-occasion drinking (RSOD) or heavy episodic drinking (HED) [19-21]. Risky drinking can also be measured by scales such as Alcohol Use Disorders Identification Test (AUDIT), AUDIT for Consumption (AUDIT-C) and Fast Alcohol Screening Test (FAST) by scoring over 8 for men and 6 for women in the AUDIT [18, 21, 22], 4 for men and 3 for women in the AUDIT-C [23, 24] or scoring 3 or higher in the FAST [25].
The other major UAU type is AUD. It is a chronically recurrent brain impairment in which compulsive and maladaptive alcohol use results in behavior dysregulation and negative mood once alcohol is ceased [16, 26]. Alcohol abuse and alcohol dependence are two representatives for moderate and severe degrees of AUD respectively [16, 26, 27]. Consumers with either of them suffer from adverse consequences. Alcohol abuse, i.e. unrestrained alcohol use, can make consumers fail to meet their major obligations and cause or exacerbate health and social problems [16, 28]. More seriously, alcohol dependence, i.e., a constant and strong desire for alcohol causing loss of self-control and consideration of health, may result in physical or mental health problems once a large amount of alcohol is consumed over a long period [29, 30]. Two types of common measurement for AUD are SD and HED. If SD is no less than 21 for men and 14 for women or HED is no less than two within 30 days, it is regarded as AUD [31].

Mobile health (mHealth) refers to the use of mobile devices, such as mobile phones, personal digital assistants or other wireless devices, to deliver medical or public health services [32]. Due to limited human resources available for delivering continuous healthcare services for community-dwelling consumers suffering from chronic diseases, mHealth interventions are increasingly considered by the decision makers as a potential alternative solution in providing same quality, but low cost services to address the challenge [33]. Likewise, there has been a growing interest in using mobile phones to deliver public health interventions to support consumer self-control of UAU [18, 21, 34, 35].

To date, mobile health is mainly delivered solely or in combination of three channels: short message services (SMS) text messaging, apps and interactive voice response (IVR). SMS text messaging has been used to guide consumers to change alcohol use behavior, for example, to reduce alcohol intake, and thus to enable self-control of UAU [12, 20, 35]. App has been used to monitor consumers’ alcohol use and to provide visual feedback about drinking behavior based on statistical analysis of input data. By raising self-awareness, it has ignited consumers’ self-regulation to reduce alcohol use [36]. Interactive voice response has been used to generate audial interactions and to provide automatic answers to consumer queries on UAU [21, 37]. Therefore, evidence suggests that these three delivery channels can all provide effective and efficient intervention for consumer self-control of UAU.
Recent reviews on health interventions for self-control of UAU have either focused on using electronic health (eHealth) interventions [38, 39] or on specific areas of mHealth interventions [40-42]. Two reviews on eHealth interventions recommend that real-time, personalized feedback is beneficial [38, 39]. Keoleian et al. have specifically reviewed SMS-enabled interventions for UAU and find it promising [40]. Two later reviews suggest that interventions delivered via Internet, SMS and apps have high fidelity, anonymity, accessibility and efficacy for reducing alcohol use [41, 42]. However, none of these studies have found sound evidence about clear health outcomes of these mHealth interventions, nor have they identified the components of these interventions. This knowledge gap has hindered the effective adoption and use of mobile technology in public health prevention and intervention programs against UAU. Therefore, this review aims to understand and synthesize the research evidence about the health outcomes of mHealth interventions for consumer self-control of UAU and to identify their components.

**Methods**

A mixed-method systematic review was conducted. Literature search and screening followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [43]. Data extraction was guided by the CONSORT-EHEALTH checklist (V.1.6.1) [44]. The methodological quality of the studies was assessed by the Mixed Method Appraisal Tool (MMAT) [45]. Data synthesis and analysis followed the principle of realist synthesis [46] and qualitative content analysis [47]. Statistical testing was also conducted to test differences among groups of studies.

**Literature Search and Screening**

The literature search was performed from December 2016 to March 2017 in four electronic interdisciplinary databases: Scopus, PubMed (PMC), CINAHL Plus with full text and MEDLINE with full text. The following terms and MeSH headings were used individually or in combination to identify the relevant publications: “mHealth”, “text message”, “self-control”, “self-regulation”, “alcohol*”. To ensure adequate coverage, a manual search was also conducted to identify papers cited by the relevant publications and reviews. The search was restricted to journal articles (1) published in English, (2) from 2007 to 2017, (3) of
which abstracts were available, and which were (4) peer-reviewed. In addition, the following criteria were used in the selection of papers.

**Inclusion criteria**

Included were papers in which (1) the research focused on supporting consumer self-control of UAU, including comorbidities like HIV and depression, or unhealthy behavior such as smoking; (2) health intervention was delivered through mobile technologies; (3) the data were collected from empirical studies.

**Exclusion criteria**

Excluded were papers which (1) reported passive therapy rather than consumer active participation in the daily self-control of UAU; (2) did not report any alcohol-related outcome; (3) did not have comparison group(s); or (4) were review articles, study protocols, conceptual papers, editorials, government reports or guidelines in the topic area.

**Data Extraction**

Data were extracted using a combination of an Endnote X8 and an Excel spreadsheet by two authors independently. These included name(s) of the author(s), year of publication, country of origin, population type, study setting, type of UAU, study type, eligibility, sample size, study arms and grouping, non-mobile co-intervention, mHealth intervention theory, delivery mode, mHealth intervention content, implementation procedure, measurement and outcomes.

**Quality Assessment of the Studies**

Quantitative randomized controlled studies were assessed using the criteria in Section 2 of MMAT, in terms of randomization or sequence generation, allocation concealment, outcome data and attrition. Quantitative non-randomized studies were assessed using the criteria in Section 3 of MMAT, in terms of participants’ recruitment, health outcome measurement, grouping situation and controlled conditions, and completeness of collected data. Responses to each criterion were “yes”, “no”, or “can’t tell”.

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Data Synthesis and Analyses

Data were synthesized and analyzed using an inductive method. We reviewed all data collected and identified similar notions and tagged them with the same code. Then we grouped the codes with similar meaning into an overarching concept. Concepts with similar meaning were grouped into a category that addresses our research question. The coding and data management was iteratively developed through constant comparison of the similarities and differences among codes. Chi-square testing was conducted to assess whether there were significant differences in the health outcomes among groups of studies with different conditions.

Results

Search Outcome

The primary search yielded 349 publications. Eight papers from the reference list and other reviews were added. After removing duplicates, 303 articles remained. Their titles and/or abstracts were manually screened against the inclusion and exclusion criteria. This led to 106 candidate papers. Eighty-six of them were excluded after further scrutinizing the full paper. Finally, 20 papers were included (see Figure 1), of which 55% (11/20) met all four MMAT criteria [12, 20, 21, 31, 35, 37, 48-52] and 35% (7/20) met three criteria [18, 19, 23-25, 30, 36], indicating high methodological quality in 90% of these studies.
Characteristics of Studies

Twenty eligible studies were conducted in six developed countries during 2012-2017 (Table 1) [12, 18-25, 30, 31, 35-37, 48-53]. Eight studies (40%) were published in 2014, accounting for the largest proportion [18, 19, 22, 24, 25, 30, 36, 49]. Eleven studies (55%) were conducted in the US [12, 22-24, 30, 31, 35-37, 49, 50], eight in Europe [18-21, 25, 48, 51, 52] and only one in New Zealand [53].

Eighteen studies were randomized controlled trials (RCTs) [12, 18-25, 35-37, 48-53]. One study was a quasi-experiment [31]. Mason et al. conducted a trial and compared its results with those of a relevant group in a previous RCT that they conducted [30].

The sample size varied from 18 to 1,768 participants. All studies except one [19] reported eligibility criteria. These included the participants: (1) passed a certain threshold for
alcohol use or already in treatment [12, 18, 21-25, 30, 31, 35-37, 48-52]; (2) had a frequently-used mobile phone [12, 18, 20, 25, 31, 35, 36, 48, 50-52]; (3) had the required level of cognitive and language capability [12, 23, 37, 48, 51, 52]; and (4) passed a certain age threshold [12, 25, 30, 31, 35, 36, 50-53].

Study arms ranged from two to six. Thirteen studies (65%) were two-arm trials with an intervention arm and a control arm [19, 20, 22, 25, 30, 31, 35, 36, 48, 50-53]. The control-arm participants received (1) no mHealth intervention [20, 22, 36, 48]; (2) non-mobile intervention with the same content through email [19], booklet [25, 31] or e-booklet [30]; (3) non-alcohol related content through the same mobile devices [35, 51, 52]; (4) only assessment [53], or (5) the same mHealth interventions as those in the intervention-arm but different rewarding mechanisms for their abstinence [50]. Five studies (25%) had three arms [18, 23, 24, 37, 49]. Besides intervention and control arms, three of them added an assessment-only arm in which the participants only received assessment for monitoring purpose [23, 24, 49]. Hasin et al. employed an arm in which the participants only received part of the intervention [37]. Gajecki et al. used two parallel intervention arms delivered by two different mobile apps [18]. In the last two studies (10%), Andersson conducted a five-arm RCT in which mHealth intervention was compared with web-based intervention and non-intervention. Both the mHealth and web-based interventions had two implementation procedures, single and repeated [21]. Muench et al. employed a six-arm design including one non-intervention arm, one assessment-only arm and four intervention arms containing different contents [12].

We identified five common components of mHealth interventions for UAU: context, theoretical base, content, delivery mode and implementation procedure; and three types of health outcome: behavioral, physiological and cognitive outcome (see Figure 2).
Figure 2 Five components of mHealth interventions for self-control of UAU and the health outcome achieved

Five Common Components of mHealth Interventions for Self-control of UAU

**Context**

There are three types of context: participant characteristics, deployment setting and non-mobile co-intervention that was conducted simultaneously to support the mHealth intervention. The participants were 18 years and over except Hung et al.’s study [20] which targeted adolescents between 16 and 19 years of age. They were risky drinkers [12, 18-25, 35, 37, 49, 50, 53] or had AUD [18, 30, 31, 36, 48, 51, 52]. They suffered from comorbidity of HIV [30, 37], depression [51, 52] or smoking [49]. The interventions were deployed in clinical settings [23, 24, 30, 36, 37, 48, 51, 52], educational settings [18-22, 35, 49, 53], and community-based settings [12, 25, 31, 50]. The non-mobile co-intervention included human intervention guided by the theory of motivational interviewing [22, 30, 31, 36, 37, 49], web-based intervention [20] and paper-based intervention [12].
**Theoretical base**

One or more theories were reported to have been used to guide the design and implementation of the mHealth interventions [12, 18-20, 23, 24, 31, 36, 48-50, 53]. These theories can be grouped into two types: behavioral change theories and psychological theories of motivation.

Behavioral change theories included theory of planned behavior [18, 19, 23, 48, 53], social cognitive theory [19, 20, 53], cognitive-behavioral treatment [31, 49], health belief model [12, 24], social learning theory [12], behavioral self-control techniques [48], theory of reasoned action [24], health action process approach [20] and information motivation behavioral model [24]. Psychological theories of motivation included self-determination theory [19, 36, 53], model of action phases [19, 53] and contingency management [50].

**Delivery mode**

Three delivery modes were identified: SMS (13/20, 65%) [12, 19, 20, 22-25, 35, 48, 50-53], app (5/20, 25%) [18, 30, 31, 36, 49] and IVR (2/20, 10%) [21, 37]. Six apps used in the five studies were LBMI-A (Location-Based Monitoring and Intervention for AUD) [31], BASICS-Mobile (Brief Alcohol and Smoking Intervention for College Students via Mobile) [49], HealthCall-S [30], A-CHESS (Alcohol-Comprehensive Health Enhancement Support System) [36], PartyPlanner [18] and Promillekoll [18]. Three studies described the operating system for these apps to work. One app ran on the Android system [18], one on both Android [30] and iOS, and the third on Blackberry, Android and iOS [49].

**Content**

Three types of content were designed to support the participants’ self-control of UAU. They were information [12, 18-25, 30, 31, 35-37, 48, 49, 51-53], motivation [12, 19-25, 35, 36, 48, 49, 51-53] and reminder [12, 20, 23, 24, 50].

Informational content included general and personalized information. The general information facilitated the participants in (1) enriching their knowledge about alcohol-related facts [21, 25, 35, 49], social drinking norms [22, 24], the estimated blood alcohol concentration (eBAC) calculation [20], risks and negative consequences of UAU [12, 20, 21,
24, 25, 35, 53] and benefits of reducing drinking amount according to safety guidelines [12]; (2) acquiring strategies to control alcohol use [18, 20, 22-24, 31, 35, 49], to handle relapse or cravings [25, 31, 49, 51, 52], to manage emotion [25] and to reduce intoxication [37]; (3) getting referrals such as alcohol counseling services available [20, 31], instant library and web-links to further alcohol-related information provided in video clips, pictures and websites [20, 36] and high-risk drinking locations [31]; and (4) conducting recommended actions for self-control of UAU, such as conducting alcohol-related testing [20], registration of alcohol use [18] or simulating a drinking occasion to set personal goal of eBAC and comparing actual eBAC after drinking against this goal [18].

The personalized information helped the participants in (1) tracking and reporting their drinking facts [12, 18, 20-25, 30, 31, 36, 37, 48, 53], eBAC value [18], mood [37], medication adherence [37], wellbeing [37] and reasons for drinking or abstinence [37]; (2) providing the tailored feedback according to their responses [12, 20, 21, 23, 24, 31, 49]; (3) recommending them to set intermittent low-risk drinking goals [25], to replace drinking alcohol by alternative activities [21, 31, 49], to celebrate goal attainment [23-25], to self-reflect on challenges of UAU [19], to improve the drinking plan and to reinforce self-control behavior [21, 23, 24] or to return to counselling service [31]; and (4) addressing their problems identified at various stages [12].

Motivational content included (1) encouragement messages for reducing alcohol use [19-25, 35, 49, 51-53], releasing distress [36] and committing to pre-set drinking goals [12, 23, 24, 48] and medical adherence [51, 52]; (2) peer support through sharing experiences with others in the anonymous discussion groups [36]; and (3) contest for designing motivational SMS messages to control UAU [20].

Reminding content facilitated participants in (1) reminding them to remember and fulfil their promises [20, 23, 24, 50]; (2) warning them about alcohol risks at their risky drinking times [12].
**Implementation procedure**

The duration of the interventions varied, ranging from four days [22], one week [53], two weeks [49], four weeks [19, 21, 30, 50], six weeks [31, 35], seven weeks [18], two months [37], three months [12, 20, 23, 24, 51, 52], six months [25, 48] to eight months [36].

With regard to the message frequency, SMS text messages were sent once [12, 20], twice [19, 23, 24] or four times [35, 53] per week in seven studies and once [22], twice [51, 52] or one to three times [50] per day in four studies. The frequency appeared to reduce when the length of the study increased [25, 48]. Haug et al. sent one message per week in the first eight weeks, then one per fortnight in the remaining 18 weeks [48]. Brendryen et al. sent one message per day for eight weeks, then one per week for four weeks, and finally one per month in the last two months [25]~Brendryen, 2014 #8^.

The participants in Alessi and Petry’s study were given a breathalyzer and the corresponding accessories to self-measure breath alcohol concentration (BrAC) and submit a valid real-time video containing the whole self-measuring process to the organizer via text message one to three times per day at the fixed time interval to prove their abstinence [50]. The intervention-arm participants would be rewarded with more vouchers if their BrAC value was normal. In contrast, the control-arm participants were not rewarded even though their BrAC value was normal [50].

Apps were used by the participants in real time, typically to receive a certain recommendation once a pre-set condition was met. For example, Promillekoll could send real-time notification and the corresponding strategies to control alcohol use if a participant’s eBAC was over 0.06% [18]. A-CHESS and LBMI-A would send an alarm when a participant was near a high-risk alcohol place to be detected by the embedded global positioning system [31, 36]. Similarly, HealthCall-S would suggest a participant to contact with a counsellor for personalized feedback once the occurrence of risky drinking was identified [30].

Andersson divided his intervention arm into two sub-groups, both receiving the same content but through different delivery modes, either delivering single IVR every day for one week or delivering repeated IVR for four weeks [21]. Hasin et al. requested their intervention-arm participants to spend one to three minutes per day to send back their
answers to a series of questions asking their compliance with drinking guidelines on the previous day via a toll-free number [37]. The participants’ phone calls were initially answered by the pre-recorded IVR in the first 30 days. After evaluating a participant’s IVR data, the consultant reset the person’s drinking goal for the next 30 days [37].

All studies conducted the baseline assessments. Two studies conducted an assessment during the intervention period to explore the initial outcome [25, 36]. The post-intervention assessments were conducted in all studies at different time points with different number of repetitive measures. Seventeen studies (85%) only conducted one assessment immediately after the intervention [12, 18, 19, 23-25, 30, 31, 35-37, 48-53]. Six studies conducted the second assessment six weeks [35], one month [30], two months [49], one academic semester [53], three months [23, 51, 52] and four months after the intervention [36]. Only one study conducted the third assessment three months after the intervention [23]. Instead of immediately measuring the outcomes, in two studies, the measures were conducted only after one [22] or three months [20]. One study measured the outcome four weeks after the intervention for the single IVR intervention-arm and one week after the intervention for the repeated IVR intervention-arm [21].

Health Outcomes

Behavioral outcome

Behavioral outcome was measured in 19 studies [12, 18, 20-25, 30, 31, 35-37, 48-53]. Significant positive outcome was found in 13 of them [12, 20, 21, 23-25, 31, 36, 37, 50-53]. These positive outcomes were measured by one or more indicators. These included the decreased number of SDs [12, 23-25, 31, 53], HDDs [12, 23, 24, 31, 36, 37, 50], RSOD/binge drinking prevalence [20, 23], alcohol-related injury prevalence [23], and increased number of abstinence days [12, 31, 50, 51]; or the increased negative affect score in Alcohol Abstinence Self Efficacy Scale (AASE) [52] and the decreased score in the Alcohol Addiction Severity Index (ASI), Drinker Inventory of Consequences (DIC) [50] or AUDIT [21].

No significant change was found in five studies [22, 30, 35, 48, 49]. Two studies reported a gender-related behavioral outcome [18]. Contrary to the initial objective of reducing UAU, the male participants in the intervention arm significantly increased drinking frequency,
whereas no change was found in the female participants and the control arm in one study [18]. Gender-related difference was also found in study [53]. After providing intervention-arm participants with a one-week SMS text messages, the female participants consumed significantly less alcohol one-week and one-semester later than their female counterparts in the control arm. However, no intervention effect was found for the male participants [53].

**Physiological outcome**

Physiological outcome was measured in five studies via eBAC [18, 20, 21, 35] or BrAC [50] and was significantly positive in two of them [21, 50]. Andersson identified a significant peak eBAC reduction for the repeated and the total (single and repeated) IVR group [21]. Alessi and Petry found a significant improvement in the percentage of negative BrAC [50]. No significant change was found in the other three studies [18, 20, 35].

**Cognitive outcome**

Cognitive outcome was measured in three studies [19, 22, 31] and was significantly positive in only one study, in which the participants’ readiness to change UAU behavior in the intervention arm was significantly improved [22]. No significant cognitive change was found in the other two studies [19, 31].

**Comparison of the differences in health outcomes among different groups of studies**

Studies were classified into two groups according to types of UAU, being risky drinking or AUD; with or without non-mobile co-intervention; theory-based or not; or three groups as per the deployment setting, being clinical, educational or community-based. Chi-square test did not find any significant differences in health outcomes among these groups. It suggested that the health outcomes were similar regardless of the types of UAU studied, whether there was non-mobile co-intervention, whether the study was theoretical-based or which setting it was deployed.
Discussion

Principal Results and Comparison with Prior Work

This study aims to synthesize the research evidence about the health outcomes of mHealth interventions for consumer self-control of UAU and to explore their common components. Twenty papers were systematically reviewed to compare the health outcomes and the five components of these interventions: context, theoretical base, delivery mode, contents and implementation procedure.

Health outcomes

The health outcomes of the mHealth interventions for UAU that has been measured included behavioral outcome (n=19) [12, 18, 20-25, 30, 31, 35-37, 48-53], physiological outcome (n=5) [18, 20, 21, 35, 50] and cognitive outcome (n=3) [19, 22, 31]. Significantly positive behavioral outcomes were reported in 13 studies. These included reduction in SDs or HDDs [12, 23-25, 31, 36, 37, 50, 53], reduction in the prevalence of RSOD/binge drinking and alcohol-related injury [20, 23], increased number of abstinence days [12, 31, 50, 51], increased negative affect sub-score in AASE [52], and reduced scores in AUDIT, Alcohol ASI or DIC [21, 50]. Significant physiological outcome was reported in two studies, including improvement in BrAC [50] and peak eBAC [21]. Only one study reported the significantly positive cognitive outcome of increased readiness to change UAU [22]. A relatively small sample size [35, 48] and a short follow-up period [49] may cause a lack of significant health outcomes for the mHealth interventions.

Complementing the traditional interventions such as face-to-face counseling, in which unhealthy alcohol users’ access to treatment was provided in a passive manner within a confined time and location, mHealth interventions open new opportunities for engaging consumers in positive self-control with increased flexibility. The effect of control was improved by continuous tracking and monitoring, interactive communication or personalized feedback from healthcare providers anytime, anywhere [54, 55].
Five components of mHealth interventions for self-control of UAU

We identified three parameters to describe the context for mHealth intervention: participant characteristics, deployment setting and non-mobile co-intervention. Participants in most reviewed studies were risky drinkers without documented pathological conditions. Kazemi et al. suggest that for this population group mHealth intervention might be the most cost effective UAU management strategy [56]. We did not find much difference in the intervention outcome between the types of participants, being risky drinker or AUD. This result is consistent with the finding of Blow et al. that the health outcome of the intervention is not influenced by the level of severity of alcohol addiction [57]. The gender difference in intervention outcome found in two studies [18, 53] may be explained by the observation of Hirschi and Gottfredson that men have lower self-control than women [58]. Similar to the finding of Platt et al. [59], we did not find any significant relationship between the health outcome and deployment setting.

Although not having any significant impact on health outcomes, co-intervention, such as induction or training to enable a participant to confidently use the apps or IVR [60, 61], is an integral, vital component for a successful mHealth intervention. This may explain why more cases of non-mobile co-intervention was reported in interventions delivered via apps (3/5, 60%) and IVR (1/2, 50%). Most likely the participants were more familiar with SMS text messaging than the other two delivery modes; therefore, the co-intervention was less reported in the studies delivered by SMS text messaging (4/13, 31%).

The theoretical base for mHealth interventions includes behavioral change theory and psychological theory of motivation. Behavior change theory provides the foundation for the formation of strategies to incrementally change a consumer’s behavior of UAU [62]. Psychological theory of motivation is used to develop motivational strategies to control UAU against psychological craving for alcohol [63]. Although mHealth interventions based on theory can improve instructional design and the effect of self-control of UAU [59], no significant difference in health outcomes was found in this review for the studies based on theory and those otherwise, which is in accordance with the finding of Garnett et al. [64]. There may be two reasons to explain this phenomenon. First, from what was described in the methods, it appears that theory was implicitly applied to the mHealth interventions
even though a study might not make the claim to be theory based. For example, Bock et al. did not report the use of any theory; however, one of the text messages in their intervention “always have an exit plan” indicated the unconscious application of the Theory of Planned Behavior [35]. Second, it takes time to bring in tangible health outcomes for participant self-control of UAU [51, 52]. As the length of the reviewed studies was not long enough, ranging from four days to eight months, it is no surprise that there was no obvious improvement in tangible health outcomes in many studies.

Mobile health interventions are enabled by three types of technologies: SMS text messaging, mobile phone-based apps and IVR. Almost all SMS- or IVR-enabled interventions are effective in reducing alcohol use or increasing readiness to change except the mobile apps [18, 30, 49]. This may be because the former two types of interventions were delivered proactively, on regular basis, always accessible to the participants regardless of their intention. In contrast, the participants’ access to the app-based interventions was relied on their self-action of opening the apps, which may not always happen.

The content included information, motivation and reminder. Informational content provided the participants with essential knowledge and skill to build their capacity to change their belief and UAU behavior. It also provided necessary feedback to enable self-awareness of UAU status, thus could execute self-regulation of UAU. Motivational content provided continuous encouragement and peer support through experience sharing to raise the participants’ morale in changing UAU behavior. Reminding content overcame provided constant recall to ensure the participants to stay on track in self-control of UAU. Delivery of these three types of content are in line with the model of human practical reasoning developed by Michael Bratman [65].

Implementation procedure was unpacked into intervention duration, frequency, follow-up assessment and practical execution strategies, which had influenced outcomes. Longer duration [25, 36], more frequent intervention [51, 52] and certain techniques such as tangible incentives [50], and assessment during the intervention [25] would facilitate the achievement of positive outcomes.
With the same content and implementation procedure, Andersson et al. found differences in health outcomes measured by peak eBAC and AUDIT scores with different delivery modes, being IVR or the Web [21]. Likewise, with the same delivery mode and implementation procedure but different content, Muench et al. also found differences in health outcomes measured by numbers of SDs, HDDs and days abstinence. The content that highlighted the negative consequences of UAU were significantly more likely to bring in positive health outcomes than the content that emphasized the benefits of UAU abstinence [12]. Furthermore, with the same content and delivery mode, Hung et al. found that the health outcomes as measured by RSOD prevalence were significantly different with different intervals of intervention [20].

Although the first generation of iPhone was released in June 2007, marking the debut of smartphone technology [66], no eligible studies were found before 2012. It appears that using mobile phones to deliver mHealth interventions for UAU was gaining spotlight in 2012.

To date, the evidence to support effectiveness of mHealth interventions for consumer self-control of UAU is modest at best [40-42]. Despite the availability of new apps and their commercial use in this area, this review suggests that research is lagging considerably behind the practice on the effectiveness of these apps in supporting vulnerable consumers to self-control their UAU. This calls for further robust, well-designed studies in how to effectively implement and measure the health outcomes of mHealth to support consumer self-control of UAU.

Limitations

The first limitation of this study was that the coverage of the studies may not be exhaustive due to our search was confined to the four databases. However, the comprehensiveness of these databases can ensure the representativeness of the trend suggested by this study. The heterogeneity of participant characteristics, intervention and health outcome measures makes it difficult to compare rigorously the findings among the studies. A lack of homogenous, quantitative measures in the original studies also deemed it impossible to conduct more rigorous meta-analysis. As only peer-refereed journal articles were included
to ensure the rigor of this study, there could be a potential risk of reporting bias towards positive findings.

**Conclusions**

This systematic review synthesized the research evidence about the health outcomes of mHealth interventions for consumer self-control of UAU. We analyzed the five components of the mHealth interventions, namely context, theoretical base, delivery mode, content and implementation procedure. In comparison with the traditional interventions, mHealth interventions are advantageous in helping unhealthy alcohol users to proactively engaging in self-control of their UAU behavior. Sound evidence is yet to be sought about the effects of these interventions in improving the physiological and cognitive outcomes. More robust trials are needed to validate the short- and long-term health benefits and the contributing factors in using mHealth interventions for consumer self-control of UAU.

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**Conflicts of Interest**

None declared.

**Abbreviations**

AUD: Alcohol use disorder  
AUDIT: Alcohol Use Disorders Identification Test  
AUDIT-C: Alcohol Use Disorders Identification Test for Consumption  
A-CHESS: Alcohol-Comprehensive Health Enhancement Support System  
BrAC: Breath alcohol concentration  
BASICS-Mobile: Brief Alcohol and Smoking Intervention for College Students via Mobile eHealth: Electronic health  
eBAC: Estimated Blood alcohol concentration  
FAST: Fast Alcohol Screening Test  
HED: Heavy episodic drinking
IVR: Interactive voice response
LBMI: Location-Based Monitoring and Intervention for AUD
MMAT: Mixed Method Appraisal Tool
mHealth: Mobile health
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT: Randomized controlled trial
RSOD: Risky single-occasion drinking
SMS: Short message service
SD: Standard drink
UAU: Unhealthy alcohol use

Multimedia Appendix 1: [Data collection tables]

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