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Mobile Health as a Viable Strategy to Enhance Stroke Risk Factor Control: A Systematic Review and Meta-analysis

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Abstract

Background—With the rapid growth worldwide in cell-phone use, Internet connectivity, and digital health technology, mobile health (mHealth) technology may offer a promising approach to bridge evidence-treatment gaps in stroke prevention. We aimed to evaluate the effectiveness of mHealth for stroke risk factor control through a systematic review and meta-analysis.

Methods—We searched PubMed from January 1, 2000 to May 17, 2016 using the following keywords: mobile health, mHealth, short message, cellular phone, mobile phone, stroke prevention and control, diabetes mellitus, hypertension, hyperlipidemia and smoking cessation. We performed a meta-analysis of all eligible randomized control clinical trials that assessed a sustained (at least 6 months) effect of mHealth.

Results—Of 78 articles identified, 13 met eligibility criteria (6 for glycemic control and 7 for smoking cessation) and were included for the final meta-analysis. There were no eligible studies for dyslipidemia or hypertension. mHealth resulted in greater Hemoglobin A1c reduction at 6 months (6 studies; 663 subjects; SMD: -0.44 ; 95% CI: $[-0.82, -0.06]$, $P=0.02$; Mean difference of decrease in HbA1c: -0.39% ; 95% CI: $[-0.74, -0.04]$, $P=0.03$). mHealth also lead to relatively higher smoking abstinence rates at 6 months (7 studies; 9,514 subjects; OR: 1.54; 95% CI: $[1.24, 1.90]$, $P<0.0001$).

Conclusions—Our meta-analysis supports that use of mHealth improves glycemic control and smoking abstinence rates.

Keywords

mobile health (mHealth); stroke prevention; diabetes; smoking cessation; hyperlipidemia and hypertension

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1. Introduction

Each year nearly 795,000 new or recurrent strokes (ischemic or hemorrhagic) occurred in the US[1]. The data projects that an additional 3.4 million adult people will have a stroke by 2030[2]. The overwhelming majority of strokes can be prevented via optimal vascular risk factor control. Diabetes mellitus, hypertension, hyperlipidemia, and smoking are all major modifiable risk factors to prevent first-ever strokes as well as recurrent strokes[3, 4]. Overall, risk factor control has been improving over the years. However, there is still room for improvement, for example, only 30% recent stroke survivors have blood pressure (BP) controlled 75% of the time[5]. Lack of medication adherence is a major risk factor for poorly-controlled hypertension[6]. Mobile health (mHealth) involves the use of mobile and wireless devices to improve health outcomes, health care service, and health research. Generally mHealth comprises three categories: Short-Message-Service (SMS) based interventions, smartphone application interventions and social media interventions[7, 8]. mHealth has the potential to reach broad populations, including the six billion mobile phone users worldwide[9]. Therefore, mHealth may provide a direct avenue to support recommended therapeutic lifestyle changes and foster improved medication adherence. In this study, we aim to examine the potential role of mHealth on vascular risk factor control, including diabetes mellitus, hypertension, hyperlipidemia, and smoking, by systematic review and meta-analysis of published randomized-controlled clinical trials on these topics.

2. Methods

This systematic review and meta-analysis is in accordance with the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis: The PRISMA Statement[10].

2.1 Study search

We searched PubMed from January 1, 2000 to May 17, 2016 using keywords: “mobile health,” “mHealth,” “short message,” “cellular phone,” “mobile phone” and “stroke prevention and control” to investigate the role of mobile in stroke prevention. Next, we used keywords: “mobile health,” “mHealth,” “short message,” “cellular phone,” “mobile phone,” “diabetes mellitus,” “hypertension,” “hyperlipidemia” and “smoking cessation.” Then we screened for clinical trials published in English, which investigated the effects of mHealth on vascular risk factor control.

2.2 Study selection

We assessed full-text articles for eligible studies. Inclusion criteria were: (1) adults (≥ 18 years old) being treated for diabetes, hypertension, and hyperlipidemia; age ≥ 16 years old in smoking cessation; (2) a minimum of 6-month follow-up; (3) randomized controlled clinical trials. We expanded the inclusion criteria to age ≥ 16 years old for smoking cessation studies because there have been several large-scale studies including older adolescents. Exclusion criteria were: (1) studies not related to studying the direct effects of mHealth on vascular risk factor control (e.g. Studies carried to improve depression management in diabetes patients

instead of improving glycemic control); (2) study protocols without data; (3) review articles; (4) non-English articles; (5) studies that did not provide mean and standard deviation of change in Hemoglobin(Hb)A1c/BP/low-density lipoprotein cholesterol (LDL-c) or studies that did not provide smoking abstinence rate at 6-month interval.

2.3 Data extraction and quality assessment

We extracted data based on the studies' objectives to test the effects of mHealth on diabetes control, hypertension control, hyperlipidemia control or smoking cessation individually. The extraction form is shown in Fig. A. Changes in Hb1Ac/BP/LDL-c as primary or secondary outcomes in the studies were sought. Smoking abstinence rate was also extracted. Study quality assessment included adequate sequence generation, allocation concealment, blinding of outcomes assessors, use of intention-to-treat analysis and description of losses[11].

2.4 Data analyses

We used Review Manager 5.3 (Cochrane IKMD – Copenhagen, Denmark; Freiburg, Germany; London, UK; USA). We used random effect model for meta-analysis. We performed an inverse-variance weighted linear meta-analysis of standardized mean difference (Hedge's g) to measure the effect size of mHealth on the change in Hb1Ac/BP/LDL-c (after and before mHealth interventions). Briefly, Hedge's g value of <0.2 is considered as mild effect, ~ 0.5 and >0.8 is considered as moderate and strong effect, respectively. Odds ratio was used to assess smoking abstinence rate. I^2 was calculated to test heterogeneity of included studies in the meta-analysis, and we consider I^2 value of $>25\%$ as a presence of heterogeneity in the data. Effect sizes were compared by using z-tests. A P value of <0.05 is considered as statistically significant.

3. Results

3.1 Description of studies

No original papers about clinical trials of the role of mHealth on either primary or secondary stroke prevention were found. The data flow diagram of study search and selection in vascular risk factors control is shown in Fig. A.

Studies included for meta-analysis are described in Table A, B, C and D: 6 randomized controlled clinical trials investigated the effect of mHealth on the HbA1c control (Table A), 7 studies tested the effect of mHealth on smoking cessation (Table B), 2 studies provided the results of the change in BP as the secondary outcomes (studies focused on diabetes control with BP change as the secondary outcome)(Table C), and only 2 studies provided the change in LDL-c as the secondary outcomes in the studies, which focused on diabetes control (Table D). Due to insufficient data on LDL-c control or BP control, we did not conduct meta-analysis regarding hyperlipidemia or hypertension control. In the end, thirteen studies were selected for final meta-analysis for glycemic control and smoking cessation.

3.2 Risk of Bias Assessment

Among the studies included, 9/13 presented adequate sequence generation, 8/13 reported allocation concealment, 5/13 had blinded assessment of outcomes, 12/13 applied the

intention-to-treat principle in analysis and all described the losses (Table E). We found no concern about publication bias in across studies regarding HbA1c or smoking cessation rate.

3.3 Glycemic Control

We included 6 studies with a total of 663 patients diagnosed with Type 1 or Type 2 diabetes mellitus in the meta-analysis. Two studies used smart phone applications to improve medication compliance or self-monitoring, the other four studies used short text or video message to facilitate the communication between health care providers and patients. Inverse-variance weighted linear meta-analysis of standardized mean difference (SMD, Hedge's g) on these studies revealed a medium effect size of -0.44 favoring mHealth (95% CI: $[-0.82, -0.06]$, $P=0.02$) (Fig. B). Mean difference of decrease in HbA1 was -0.39% between mHealth group and control group (95% CI: $[-0.74, -0.04]$, $P=0.03$).

3.4 Smoking Abstinence Rate

Seven studies with a total sample size of 9,514 subjects were included in meta-analysis to assess the effect of mHealth on smoking cessation. Five studies used short text/video message and two studies used the Internet and cell-phone based smoking cessation programs as an adjunctive care approach to encourage smoking cessation. mHealth led to a relatively higher smoking abstinence rates at 6 months (OR: 1.54; 95% CI: $[1.24, 1.90]$, $P<0.0001$) (Fig.C).

4. Discussion

Prior published data suggests that mHealth is a potentially effective adjunctive tool in the managing key stroke risk factors. It would seem that the effectiveness of mHealth for diabetes control and smoking cessation are the most studied vascular risk modification strategies to date. Specifically, our meta-analysis (6 studies, 663 patients) indicated that mHealth use was associated with a modest decrease in HbA1c vs. usual care group in patients with diabetes. These mHealth methods comprised provision of self-monitoring services, education by health service providers, and interval prompts/reminders. Meanwhile, mHealth (7 studies, 9,514 patients) increased smoking abstinence rate by facilitating communication between health care provider and smokers, providing smoking cessation education, improving adherence to smoking cessation care, and adopting healthy behaviors. However, we did not find appropriately eligible studies of mHealth focusing on either hypertension or hyperlipidemia control. Moreover, there have not been published mHealth studies with stroke as an endpoint. Major reasons for the lack of interventions for stroke may because stroke largely affects elderly (vs. younger) individuals who may currently not have as much ability or interest in using mobile phone applications or Internet, and the cognitive and physical deficits from stroke may also limit participation in mHealth related activities.

This systematic review and meta-analysis is rigorous since we only included randomized controlled clinical trials with 6-month follow-up visits in older adolescents or adults. We consider the studies as having low risks of bias in quality assessment. Although 4/6 studies did not describe allocation concealment in diabetes patients, the interventions were non-blinded, and the primary outcomes were objective; 5/6 studies did not provide evidence of

blindness in outcome assessment in diabetes management, but the outcomes-HbA1c were objective.

Our results are in accord with other systematic review and meta-analysis, which found that health education via mobile text message decreased HbA1c in Type 2 diabetes patients[12]. The International Diabetes Federation (IDF) believes that mHealth use can play a supportive role and have a considerable impact on diabetes control, especially in coaching or educating patients about healthy lifestyles, improving online support in managing disease condition and monitoring serum glucose level[13]. Cigarette smoking cessation is strongly advised for both primary and secondary stroke prevention[14, 15]. mHealth showed a profound effect in improving smoking cessation in this meta-analysis. It is reasonable to apply mHealth in stroke prevention through enhance smoking cessation.

This study has several limitations. First, there is heterogeneity among the included studies ($I^2=82\%$, and 62% in glycemic control and smoking cessation, respectively). The types of mHealth interventions across the studies were diverse. Due to the relative small number of included studies, it was challenging to stratify the studies by baseline HbA1c or smoking status. Second, the number of included studies are small, with only six studies for diabetes control and seven studies for smoking cessation. Our inclusion criteria to only include studies with at least 6-month follow-up visits excluded quite a few studies. Third, we cannot exclude the possibility of false positive results. Since studies of health interventions cannot achieve true blinding of subjects, placebo effects are not impossible. Fourth, since self-reported abstinence rates are subjective outcomes, we cannot completely rule out the possible reporting bias from the study participants.

5. Conclusions

Our meta-analysis demonstrates encouraging results that mHealth use can moderately improve stroke risk factors control, such as glycemic control and smoking cessation. The next logic step would be conducting clinical trials to investigate the role of mHealth in the control of other traditional stroke risk factors especially hypertension and dyslipidemia. A robust and consistently positive effect of mHealth in improving the control of these two factors, should lead to the future conduct of studies sufficiently powered to test the efficacy of mHealth on preventing cerebrovascular events. The premier contributory role of hypertension to overall stroke risk and occurrence of both major types of stroke (ischemic and hemorrhagic) makes the conduct of mHealth-based blood pressure control strategy a priority.

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Highlights

- Use of mobile health was associated with a significant improvement in glycemic control at 6 months
- Use of mobile health was associated with significantly higher rates of smoking cessation at 6 months
- There is a paucity of published studies examining longer term (> 6 months) impact of mobile health on control of hypertension and hyperlipidemia

Figure A

Fig A.
Data Flow of Study Selection.

Figure B

Fig B. Change in Hemoglobin A1c at 6 Months

T1D, type 1 diabetes; T2D, type 2 diabetes. Inverse-variance weighted linear meta-analysis of standardized mean difference (Hedge's g) on 6 studies revealed a moderate effect (Hedge's $g = -0.44$, 95% CI: $[-0.82, -0.06]$, $P = 0.02$) with HbA1c change at 6 months (comparable to mean difference of 0.39% decrease in HbA1c, 95% CI: $[-0.74, -0.04]$, $P = 0.03$), which favored the mHealth group.

Figure C

Fig C. Smoking Abstinence Rate at 6 Months

Relatively higher number of subjects in the mHealth group did not smoke in the recent past at 6 months follow-up (OR: 1.54, 95% CI: [1.24, 1.90], $P < 0.0001$).

Table A

List of studies provided the changes in HemoglobinA1c at 6 months.

Author, Study	Participants	Sample size	Follow-up Duration	Baseline HbA1c, (SD) (%)	Intervention descriptors	Mean Change in HbA1c, (SD) (%)
1. Rossi et al., 2013	Type 1 diabetes	M: n= 63 C: n= 64	6 months	M: 8.4 (0.1) C: 8.5 (0.1)	M: mobile phone-based carbohydrate/bolus calculator installed in the mobile phone, promoting the patient-physician communication via SMS C: traditional education	M: -0.49 (0.11) C: -0.48 (0.11)
2. Bell et al., 2012	Poorly controlled type 1 or type 2 diabetes	M: n= 32 C: n= 33	12 months	M: 9.6 (1.5) C: 9.0 (0.9)	M: mobile phone-based daily self-care video messages C: usual care	M: -1.1 (2.3) C: -1.1 (1.6)
3.1. Charpentier et al., 2011	Poorly controlled type 1 diabetes	M: n =60 C: n =61	6 months	M: 9.19 (1.14) C: 8.91(0.90)	M: home use of a smartphone application recommending insulin doses C: paper logbook	M: -0.5 (0.9) C: 0.2 (0.8)
3.2 Charpentier et al., 2011	Poorly controlled type 1 diabetes	M: n= 59 C: n = 61	6 months	M: 9.11 (1.14) C: 8.91 (0.90)	M: home use of the smartphone application recommending insulin doses with teleconsultations C: paper logbook	M: -0.7 (0.8) C: 0.2 (0.8)
4. Rossi et al., 2010	Type 1 diabetes	M: n= 67 C: n= 63	6 months	M: 8.2 (0.8) C: 8.4 (0.7)	M: self-monitoring of blood glucose and insulin dose, communication between health professionals C: standard education	M: -0.4(0.9) C: -0.5 (1)
5. Noh et al., 2010	Type 2 diabetes	M: n= 20 C: n= 20	6 months	M: 9.0 (2.3) C: 8.6 (1.2)	M: a web-based for cell phone user information system and provide diabetes education C: diabetes educational books	M: -1.53 (1.42) C: -0.49 (1.07)
6. Benhamou et al., 2007	Poor controlled type 1 diabetes	M: n= 30 C: n= 30	12 months	M: 8.31 (0.65) C: 8.22 (0.72)	M: weekly medical support through SMS based upon review of glucose values C: self-monitored blood glucose values without receiving SMS	M= -0.14 (0.53) C=0.12 (0.65)

SD: standard deviation; HbA1c: Hemoglobin A1c; M: mobile health group; C: control group; SMS: short message service.

Table B

List of Studies provided smoking abstinence rate at 6 months.

Author, Study	Participants	Sample size	Follow-up Duration	Baseline	Intervention descriptors	Abstinence Rate
1. Naughton et al., 2014	Smokers	M: n = 299 C: n = 303	6 months	Smoke at least 1 cigarette a day	M: tailored advice report and SMS to advise smokers to quit +usual care C: usual care	Self-reported prolonged abstinence M: 15.1% C: 8.9%
2. Abrams et al., 2014	Smokers	M: n = 262 C: n = 241	6 months	Smoke 5 or more cigarettes a day	M: an automated bidirectional text messaging program C: a web link with quitting smoking information or guidebook on quitting smoking	Self-reported 1-week abstinence M: 31.7% C: 20.8%
3. Whittaker et al., 2011	Smokers	M: n = 110 C: n = 116	6 months	Smoke daily	M: an automated package of video and text messages about reasons to stop smoking C: general health video message and reminders	Self-reported 1-week abstinence M: 22.7 % C: 22.4%
4. Free et al., 2011	Smokers	M: n= 2911 C: n= 2881	6 months	Willing to make an attempt to quit smoking in the next month	M: SMS smoking cessation program, comprising motivational messages and behavioral-change support C: SMS unrelated to smoke quitting	Self-reported 1-week abstinence M: 24.2% C: 18.3%
5. Brendryen et al., 2008	Smokers	M: n= 144 C: n=146	12 months	Smoke 5 cigarettes or more daily	M: a daily intense smoking cessation program delivered via the Internet and cell phone C: a self-help booklet	Self-reported 1-week abstinence M: 29% C: 14%
6. Brendryen et al., 2008	Smokers	M: n= 197 C: n= 199	12 months	Smoke 10 or more cigarettes daily	M: a daily intense smoking cessation program delivered via the Internet and cell phone + nicotine replacement therapy C: a self-help booklet + nicotine replacement therapy	Self-reported 1-week abstinence M: 37.1% C: 21.6%
7. Rodgers et al., 2005	Smokers	M: n= 852 C: n= 853	6 months	Smoke daily	M: regular, personalized text messages providing smoking cessation advice, support, and distraction C: regular text messages not related with smoking cessation	Self-reported current abstinence M: 25.4% C: 23.7 %

M: mobile health group; C: control group; SMS: short message service.

Table C

List of Studies provided blood pressure control results by mobile health at 6 months.

Author, Study	Participants	Sample Size	Follow-up Duration	Baseline BP (SD)(mmHg)	Intervention descriptors	Mean Change in BP (SD) (mmHg)
1. Rossi et al., 2013	Type 1 diabetes	M: n= 63D C: n= 64	6 months	SBP: M: 119.0 (1.4) C: 120.0 (1.3) DBP: M: 72.9 (1.0) C: 71.5 (1.0)	M: mobile phone-based carbohydrate/bolus calculator installed in the mobile phone, promoting the patient-physician communication via SMS C: traditional education	SBP: M: -0.72 (1.51) C: -2.00 (1.45) DBP: M: -2.00 (0.94) C: 0.16 (0.91)
2. Rossi et al., 2010	Type 1 diabetes	M: n= 67 C: n= 63	6 months	SBP: M: 122 (17) C: 120 (11) DBP: M: 74 (7) C: 74 (8)	M: a web-based for cell phone user information system and provide diabetes education C: diabetes educational books	SBP: M: -0.8 (8.6) C: 0.7 (11.5) DBP: M: -1.3 (6.5) C: -1.1 (7.6)

BP: blood pressure; SD: standard deviation; M: mobile health; C: control; SBP: systolic blood pressure; DBP: diastolic blood pressure; SMS: short message service.

Table D
List of studies provided low-density lipoprotein cholesterol control results by mobile health at 6 months.

Author, Study	Participants	Sample size	Follow-up Duration	Baseline LDL-c (SD)(mg/dl)	Intervention descriptors	Mean Change in LDL-c (SD) (mg/dl)
1. Rossi et al., 2013	Type 1 diabetes	M: n= 63 C: n= 64	6 months	M: 109.4 (3.7) C: 109.1 (3.6)	M: mobile phone-based carbohydrate/bolus calculator installed in the mobile phone, promoting the patient-physician communication via SMS C: traditional education	M: 8.27 (4.39) C: 5.08 (4.37)
2. Rossi et al., 2010	Type 1 diabetes	M: n= 67 C: n= 63	6 months	M: 102 (28) C: 106 (27)	M: a web-based for cell phone user information system and provide diabetes education C: diabetes educational books	M: -3.4 (29.1) C: 0.3 (27.6)

LDL-c: low-density lipoprotein cholesterol; SD: standard deviation; M: mobile health; C: control; SMS: short message service.

Table E

Risk of bias of included studies for final meta-analysis (n=13).

	Adequate sequence generation	Allocation concealment	Blinding of outcomes assessors	Use of intention-to-treat analysis	Description of losses
1. Rossi et al., 2013	Yes	Yes	Unclear	Yes	Yes
2. Bell et al., 2012	Yes	Unclear	Unclear	Yes	Yes
3. Charpentier et al., 2011	Yes	Unclear	Unclear	Yes	Yes
4. Rossi et al., 2010	Yes	Yes	Unclear	Yes	Yes
5. Noh et al., 2010	Unclear	Unclear	Unclear	Yes	Yes
6. Benhamou et al., * 2007	Unclear	Unclear	No	No	Yes
7. Naughton et al., 2014	Yes	Yes	Yes	Yes	Yes
8. Abroms et al., 2014	Unclear	Unclear	Unclear	Yes	Yes
9. Whittaker et al., 2011	Yes	Yes	Yes	Yes	Yes
10. Free et al., 2011	Yes	Yes	Yes	Yes	Yes
11. Brendryen et al., 2008	Yes	Yes	Yes	Yes	Yes
12. Brendryen et al., 2008	Unclear	Yes	Unclear	Yes	Yes
13. Rodgers et al., 2005	Yes	Yes	Yes	Yes	Yes

* A randomized, controlled, cross-sectional study, which used per-protocol analysis.