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Smartphone applications and health promotion: Do they work?

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Everyone has a smartphone or so it seems[*]. We use these electronic communication devices to surf the Internet, shop online, send emails, connect to social media, and even manage our day-to-day lives using various business, educational, financial, personal, and home care applications. Smartphone[†] mobile application software or "apps[‡]" have full video graphic capabilities and provide remote control functions as "if" we were sitting behind a personal desktop computer. Currently, Apple (iPhone) offers

2.2 million downloadable apps, second to Google Play (Android) with 2.8 million[§].

Healthcare apps. Apps are proliferating in every facet of our daily lives, including healthcare[1]. There are hundreds of lifestyle change apps now available that work to improve health. These include mobile apps for smoking cessation, apps that monitor blood sugar levels for patients with diabetes, apps that provide EKG readings, check our blood pressure, or using digital WiFi sensors

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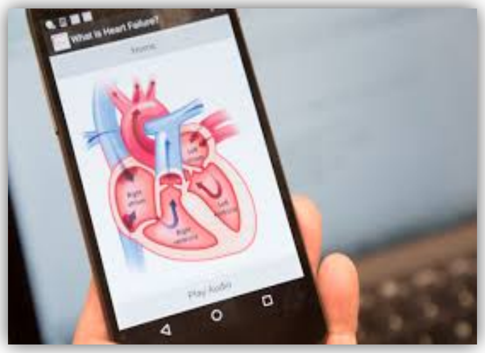
[*] Recent data shows that 222.9 million people (~68% of the population) in the U.S. own at least one smartphone (https://www.statista.com/statistics/201182/forecast-of-smartphone-users-in-the-us/) with the primary operating systems as Google Android and the Apple iOS (smaller market shares go to Symbian, Microsoft Windows, Bada and the PEW Foundation of mobile phone usage (http://www.pewinternet.org/2015/10/29/technology-device-ownership-2015/) also indicates 68% of the U.S. population owns a smartphone.

[†] Smartphones are distinguished from cell phones by their ability to engage in email, Internet access, QWERTY keyboard, PDA functions and a built-in camera. More recent upgrades include high tools, video viewing, text messaging, and high-speed Internet with WiFi capabilities.

[‡] The term introduced in 2008 was so popular that in 2010 "app" was designated word of the year by the American Dialect Society.

[§] Source: https://www.statista.com/statistics/276623/number-of-apps-available-in-leading-app-stores/ not produce an electrocardiogram, all of which can enable cardiologists to remotely monitor patients with heart disease. There are apps that help patients manage chronic pain, and ones that wirelessly measure blood oxygen levels for individuals with sleep apnea. There are also mobile apps that connect individuals with online chat forums for professional medical advice, and apps that send push notifications reminding patients to take their pills and adhere to medication regimens. Ease of use, portability, privacy, tailoring, flexibility, multimedia content, reduced cost, and instant gratification are among the many features that make mobile health[**] apps highly attractive to end users.



Behavioral interventions that use apps. Mobile health apps have now proliferated for teaching self-management, self-monitoring, and coping skills to individuals with chronic diseases including asthma, diabetes, obesity, cardiac or pulmonary problems, HIV, autoimmune and inflammatory disorders, and other medical conditions that require constant monitoring or routine checking. Patient-based medical apps are also used to monitor diet and nutritional servings (calorie counters), determine salt content, and keep daily diaries of food intake, to name a few uses.

Bringing science into the equation. Despite their rapid proliferation and advanced technical achievements, very few of the healthcare apps targeting behavior change have undergone methodologically rigorous program evaluations. One feature of a rigorous evaluation is the use of a truly experimental design complete with randomization. Randomized controlled trials are considered the 'gold standard' of scientific testing because they summarily rule out potential confounders that might bias one experimental condition over another[2]. For instance, if members of the control group have only limited access to smartphones while intervention subjects have owned smartphones for at least three years, their "exposure" to mobile technology can bias findings (there are many other distinguishing features of the population that can bias findings). By randomly assigning individuals to treatment, we can assure "pretest equivalence" or that individuals assigned to the different experimental conditions are not different from each other at the beginning of the study[3]. With randomization any differences in outcomes following the intervention cannot be attributed to preexisting sample selection "biases."[††]

In this issue of the **LARS eNEWS** we explore studies of behavioral interventions that rely on mobile applications using smartphones. In the interest of conserving space, we restrict this review to include use of smartphone apps for intervening with obese and overweight individuals. We discuss the results of several small scale feasibility studies as well as findings from larger program efficacy and evaluation trials, several of which used a RCT design. Put quite simply, there are many unknowns regarding whether apps for behavioral interventions work equally as efficiently as web-based platforms or in–person face-to-face training.

Obesity & physical activity apps. Obesity is a major economic cost-driver and plays a vital role in our national economic debate over healthcare. It is linked with very profound medical and physical complications including cancer, kidney disease, knee and joint osteoarthritic pain, high blood pressure, heart disease, COPD, and digestive ailments[4‡‡]. Extreme obesity has been linked with depression, alcohol and drug use, and among children there is evidence of associations with lower self-esteem[5] and later health problems including continued obesity[6].

Because in many cases, obese individuals require constant monitoring and medical feedback (over decisions on exercise, nutritional value of food, social support, and medical advice), there has been a proliferation of obesity and weight loss mobile phone applications. Unfortunately, although strong on theory (i.e., self-determination and social cognitive theory) the research literature provides very limited support for their efficacy as behavioral "interventions." A recent review article[7] examined 27 trials that met inclusion criteria[§§] and had used a smartphone app for treatment of overweight and obese individuals.

Although all of the trials focused on reducing weight and maintaining weight loss in

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[**] mobile-Health or mHealth is traditionally used to describe the interface of medicine and public health initiatives that use mobile communication technology like smartphones, tablets, and PDAs. Included is the use of mobile technology for the diagnosis and tracking of diseases, home monitoring based on integrated connectivity, formidable ways to provide public health information (alerts), readily collect data for immediate use or collation as part of research studies, and provide medical education or training in remote areas where access can hinder delivery

[††] Rubin (1978) noted that randomization has a prophylactic effect because it "guards against data that might be unbalanced with respect to recorded covariates." By randomizing, these covariates or markers of population behavior should in theory be equally distributed (balanced) between the experimental conditions (i.e., the equal units assumption or what is called "initial probabilistic equivalence"), leading to greater confidence attributing post-intervention differences between groups to the experimental treatment (i.e. any systematic sources of bias are now random).

[‡‡] A good source examining the global obesity epidemic can be found in the 2015 CDC publication, "*What causes overweight and obesity?*" downloadable from http://www.cdc.gov/obesity/adult/causes/index.html.

[§§] Trials had to focus on adults, include a technology component, meet the BMI threshold, weight change outcomes, and include a control group that did not receive a technology (i.e., mobile phone) intervention.

overweight (BMI ≥ 25 kg/m^2), obese (≥ 30kg/m^2), or morbidly obese (≥40 kg/m^2) individuals, the trials varied in research design (most were RCTs), control conditions (usual care, wait list, or minimal intervention) methodology (study protocols), intervention type (single modality or multiple intervention arms), and length of follow-up (varying from 12 weeks to 24 months); with only 13 showing any significant weight loss among study participants. Interestingly, only one trial used a smartphone application as part of the intervention (reviewed below). Most used some combination of a web-based platform, telephone consultation, computerized self-monitoring (diaries), email or text messages, wearable monitoring devices (e.g., Jawbone, Apple Watch, Fitbit), telephone coaching, web podcasts, mailed materials (written instructions outlining dietary guidelines) or some type of face-to-face individual or group counseling. All of the programs that combined multi-modal features produced significant weight loss compared to control conditions.

Smartphone mHealth applications for weight loss are clearly in their infancy. Only a handful of these trials have been reviewed[8] and very few studies prominently featured a mobile application as a core intervention strategy. One other review[9] of mHealth weight loss applications indicated seven weight loss behavioral modification interventions that featured smartphones (most using SMS text messaging in concert with another modality such as face-to-face or telephone counseling) with only two studies actually using a mobile application as the focal intervention component. In these studies, mobile applications recorded daily calorie intake and consumption, logged exercise routines, and produced reports of daily weight loss goals. One app created teams designed around weight loss goals and produced reports, updates on goals, and SMS messages. Only one of the two applications (SmartDiet) showed favorable results in terms of weight loss, fat mass, and BMI when compared to controls.

We now examine in greater detail interventions that utilized a mobile phone app as the principal intervention strategy. This may help to shed light on the different trial features and reasons for the lack of empirical findings supporting mobile apps as effective weight loss instruments. The ATLAS cluster-randomized controlled trial[10] was conducted with 361 male New South Wales youth. The hybrid web-based and smartphone intervention produced some reductions in sugary drink consumption, screen time (use of video gaming and television watching), and improved muscular fitness but no reductions in BMI, body fat, waist circumference or physical activity, all important markers of risk for obesity.

The 20-week multi-component ATLAS intervention include a host of didactic training activities, sports sessions, physical activity mentoring, as well as 2-day teacher professional development workshops, parental strategies to reduce screen-time, and a smartphone application and website. The app was intended to promote autonomous motivation for physical activity and increase users' self-efficacy by providing choices of workouts, techniques, and goals[11]. Students could select "CrossFit" fitness challenges (i.e., push-ups, shuttle runs, squats, lunges) and record date-stamped times that could be matched up against "goals" as "reinforcements" for their activity (with *push notifications*). Although the app provided encouraging news about its "feasibility" and end users enjoyed the different features, the overall study findings did not support benefits (reduced weight or body fat) following exposure to the program.***

Pilot results from a smartphone app for obesity treatment tested with adults provided evidence of more promising results[12]. Called SLIM (smart coach for Lifestyle Management), the weight control app was used in a study of 68 adults who were randomized to one of four conditions. The conditions included exercise counseling, intensive diet and exercise counseling + self-

monitoring smartphone app, a less intensive diet and exercise condition plus the self-monitoring smartphone app, and the self-monitoring smartphone app only. Nutritional counseling sessions were standardized between conditions to last one hour but were offered more frequently to the intensive condition. The 'Lose It!' weight loss application offered self-management and mindful empowerment, real-time feedback, motivational push notifications, networking and support. Vitals that could be entered into the app included weight, height, gender, and age and with the Mifflin equation for calculating a resting metabolic rate, could be used to build a calorie budget. Graphic charts and graphs tracked participants' progress on their energy balance, food intake and exercise regimen.

Six month follow-up data indicated that intervention usage was highest in the heavy dose group (intensive counseling and smartphone condition). However, the groups did not differ significantly in weight loss or anthropometric measures (waist circumference or BMI). All four conditions showed reductions in kilocalorie consumption and reduced calories from fat, and dietary intake of sodium. The small sample size may have precluded finding significant findings, but still the trends were clinically significant and support some

***It is important to keep in mind this was a multi-component intervention in which the smartphone app was one feature of the intervention. It is absence of other components. Some form of componential analysis involving a dismantling strategy is required to "disassemble" the efficacy component is stripped out and the leftover features evaluated).

reductions in BMI and improvements in caloric intake in the intensive counseling and smartphone condition.

An 8-week RCT in Ireland enrolled weight loss patients from three primary care settings[13]. Both groups received an Android smartphone app promoting physical activity and that could record step counts. Baseline data was collected blinded at week 1 at which point all participants in both conditions were given physical activity goals and brochures from the Irish Heart Foundation outlining the benefits of exercise. Only the treatment condition received direct instruction how to use the mobile weight loss application. Physical activity included daily step count and the app provided participants with activity benchmarks (10,000 steps/day), feedback and caloric information, plus graphic displays of their step history and goal achievement. All participants were instructed via SMS how to use a "share data" function in the app to email to the investigators their step-count data at the end of weeks 1, 2 and 8.

Mixed model analyses, adjusted for important covariates (e.g., baseline differences, demographics, BMI, blood pressure, smartphone literacy), showed that intervention subjects significantly improved their step counts (22% increase) compared to controls over the 8 week trial, albeit there were no significant differences in weight, BMI, and blood pressure.

Several other studies used RCT designs to study program effects with weight loss applications. A small 12-week pilot study of the SmartLoss^{SM} weight loss intervention indicated significant weight loss among intervention participants compared to the health education control group[14]. All contact with the participants in this trial was by smartphone including SMS text, email or phone calls. The intervention also include tailoring weight loss programs including regimens for caloric intake, physical activity, and graphical output of weight loss goals. Daily weights were transmitted wirelessly to a secure website accessible by study counselors and used to gauge program adherence. The control group received health education materials on various topics related to excessive weight including stress management, healthy eating, exercise and sleep. In this study, dose and attention effects were controlled by sending equal numbers of text messages and emails to both experimental conditions.

Another RCT of a popular weight loss smartphone app "MyFitnessPal" showed no significant differences between intervention participants compared to usual care (education only) in a sample of overweight individuals drawn from primary care clinics[15]. These differences were assessed at both 3- and 6-months post-intervention (controls actually gained a tiny bit and intervention subjects lost a trivial amount of weight). The app is based on social cognitive theory and includes self-monitoring, goal setting, and personalized feedback. Participants used Apple iPads for the study and a secure data hosting service to upload weekly data to the University host server. Control participants received minimal app instruction and educational handouts. Based on current weight, goal weight, and goal rate of weight loss, the app provides individual calorie goals, produces weight trends, nutritional summaries based on diet, a bar code scanner, and a social networking feature.

Interestingly, although many individuals found the app content thrilling to use and helpful, their actual use declined considerably over time, indicating perhaps that adherence to technology may be a cause for concern. There was also no change in proposed mediators of weight loss (self-efficacy) over time. Thus, the intervention did little to boost an individual's sense of their ability to lose weight, considered an important prognosticator of eventual weight loss. The study also revealed some contamination by control group participants who used the MFP app during the trial, however, this intervention diffusion did not adversely affect the evaluation findings.

Parting thoughts: Weighing the evidence. The few studies we reviewed point to a mixed bag of evidence regarding the efficacy of smartphone mobile health applications for obesity and weight loss interventions. Notwithstanding, it is worth addressing the pressing question, "***What are some of the reasons these programs may not be***

keep pace with technological developments, researchers may have strayed from their theoretical roots. In other words, program content may not adhere closely to the theoretical tenets underlying the logic model driving these programs. In the case of a reasoned action approach (TRA), often used as a foundation for health interventions[16], beliefs, attitudes, perceived control, subjective norms, and self-efficacy all play a central role instigating behavior; however, the last word is with "intentions," a pivotal mediator closely related to behavior. Many individuals may be willing to change their behavior, but as we all know, especially in overweight individuals, behavior is hard to change. Without influencing the full gamut of cognitive predictors inherent in this model, an intervention can fail. In the case of TRA, the full chain of mediators including beliefs, attitudes, control, norms, efficacy, and intentions all must be subject to behavior modification. In this manner, meticulous adherence to the theory[17] is required to explicate precisely the "ways in which overweight individuals initially lose and then maintain their weight loss."

Dose also may be a concern, because even though the apps are "used" they may not be used enough, and few programs collect usage metrics that document how much exposure time was spent on the app (versus other components of an intervention). There is no standard showing how "many" SMS text messages are required to sustain weight loss, nor any reference to how much "dose" of an mHealth application is required to create initial or maintain subsequent weight loss. Process evaluations provide a good means to assess actual usage patterns and potential barriers to usage (i.e., is the app acceptable and easy to use?). Pilot feasibility trials usually provide a means to assess these features through cognitive playtesting[18]. From a measurement point of view, even though they try to assess the inherent strengths of a program, researchers may have inadvertently failed to assess core "active ingredients" only examining target outcomes (e.g., BMI, weight, caloric intake waist circumference, physical activity, sugary drink consumption, diet adherence, screen time, and body fat composition)[7]. Active ingredients (the cognitions the program targets) are what makes the program "work" and are crucial to assess in order to flesh out validity of the program logic model.

Implementation is always a concern, regardless of venue or technology used to deliver a program. Despite claims for consistency in program delivery, smartphone applications can vary in how well program content is adhered (fidelity). Intermittent use, skipping modules or tasks, rushing through a particular section or not adhering to "push notifications" all make it easy for program content to slip below the radar of detection. Furthermore, none of the studies reviewed teased apart the relative efficacy of different intervention approaches, pitting for instance, technology approaches versus usual methods including face-to-face counseling or group meetings.

Furthermore, none of the programs reviewed used "boosters" or refreshers that are delivered after initial exposure. There is considerable evidence from many different health intervention settings showing that boosters work to improve program outcomes[19]. Boosters may be essential for overweight individuals as they struggle to comply with diet/nutrition and physical exercise regimens that are accompanied by transformation of their addictive personality. Race and sample heterogeneity also need to be considered as many of the samples reviewed in the various meta-analyses were predominantly white and female. One factor supporting the utility of mHealth and particularly smartphone applications is the popular use of mobile communication technology even among low SES and racial minority groups. Indeed, there is evidence that the "digital divide" is rapidly decreasing as greater numbers of racial minorities are using mobile phones. Related to this, African-Americans are disproportionately represented in the obesity category. The problem then would appear to be the "reach" of these programs and their uptake as they are disseminated to vulnerable populations. Also worth considering is that content analyses of mHealth apps shows that many programs emphasize "instruction" and "tasks" and also self-monitoring[17]. While these are staple components of behavior change theories they may be insufficient to foster weight loss, which demands greater emphasis on 'psychological' constructs, for instance, mood and motivation (i.e., relapse prevention strategies). Finally, with few exceptions, many of the studies reviewed used relatively small samples and power may be too limited to detect significant program effects. Larger, carefully monitored, multi-site studies may be an effective antidote.

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