REVIEW

Review of Smartphone Applications for the Treatment of Eating Disorders

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Abstract

mHealth tools may be a feasible modality for delivering evidence-based treatments and principles (EBPs), and may enhance treatment for eating disorders (EDs). However, research on the efficacy of mHealth tools for EDs and the extent to which they include EBPs is lacking. The current study sought to (i) review existing apps for EDs, (ii) determine the extent to which available treatment apps utilize EBPs, and (iii) assess the degree to which existing smartphone apps utilize recent advances in smartphone technology. Overall, existing ED intervention apps contained minimal EBPs and failed to incorporate smartphone capabilities. For smartphone apps to be a feasible and effective ED treatment modality, it may be useful for creators to begin taking utilizing the abilities that set smartphones apart from in-person treatment while incorporating EBPs. Before mHealth tools are incorporated into treatments for EDs, it is necessary that the feasibility, acceptability, and efficacy be evaluated. Copyright © 2014 John Wiley & Sons, Ltd and Eating Disorders Association.

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Increases in therapeutic smartphone applications

Recent advances in mobile technology have dramatically enhanced both access to smartphones and the capabilities of smartphone technology. As of 2013, over half of all adults in the United States (56%) own a smartphone and 93% of smartphone users use their phone to access information online (Duggan & Smith, 2013). Smartphone users consist of a variety of ethnic groups with 59% of Caucasian, 74% of African American, and 68% of Hispanic individuals owning smartphones (Duggan & Smith, 2013). Furthermore, current mobile statistics have identified over 40 billion smartphone application (app) downloads for the iPhone alone by the year 2013. The Android app market is growing as well with 50 billion app downloads by the year 2013 and an open-source market that is continually expanding. With the expanding interest and availability of smartphones, a growing number of apps have been designed to provide therapeutic assistance, either as a stand-alone platform (Free et al., 2013; Vandelanotte, Spathonis, Eakin, & Owen, 2007) or in conjunction with conventional therapy (Bauer & Moessner, 2012; Newman, Szkodny, Llera, & Przeworski, 2011). Recent estimates have suggested that there are now more than 20,000 health-related apps available for mobile devices (Sherwin-Smith & Pritchard-Jones, 2012).

Mobile health (mHealth) technologies are designed to leverage the functionality and convenience of mobile devices to promote behavior change. Apps can improve treatment engagement by making treatment more interactive, enhancing learning, and enriching the quantity and quality of data that providers can access to guide treatment. Such tools are ideal for engaging patients in treatment due to several advantages over static programs, such as portability, capacity for real-time, in-the-moment interaction, and multiple built-in sensors for collection and presentation of data (Heron & Smyth, 2010). Web-based mHealth tools may be a feasible modality for delivering or enhancing evidence-based treatments (EBT) given the high and growing rates of accessibility (Duggan & Smith, 2013; Smith, 2013).

Current treatments for eating disorders

Individuals with eating disorders (EDs) might be a patient group that could particularly benefit from smartphone apps as either an adjunct to standard treatment or as a way to receive existing evidence-based treatments. There are a range of existing treatment practices for eating disorders, including anorexia nervosa (AN; excessive food restriction, fear of gaining weight, and low body weight), bulimia nervosa (BN; recurrent episodes of binge eating and purging including self-induced vomiting, laxatives, and excessive exercise), and binge eating disorder (BED; recurrent binge eating episodes in the absence of inappropriate compensatory behavior). The two treatments that have received the most empirical support to date for adults with EDs are Cognitive Behavioral Therapy (CBT), including a transdiagnostic, enhanced version of CBT (CBT-E), and Interpersonal Therapy (IPT) (Wilson & Zandberg, 2012). However, these treatments appear to be primarily effective for BN and BED, resulting in 50–70% remission rates at post-treatment. For adolescents with AN and BN, family-based and individual psychotherapy treatment approaches have modest to moderately strong empirical support (le Grange, Crosby, Rathouz,

& Leventhal, 2007; Lock & le Grange, 2005; Lock et al., 2010). For adults with AN, however, no specific form of treatment has received consistent empirical support to date (Raykos, Watson, Fursland, Byrne, & Nathan, 2013). A growing body of evidence is also beginning to support acceptance-based treatments (e.g. Dialectical Behavioral Therapy (DBT), Acceptance and Commitment Therapy (ACT)) for adults with EDs (Federici & Wisniewski, 2013; Juarascio et al., 2013). Below we will briefly review these treatment approaches. We focus on the empirically supported principles that could be included in a smartphone app for adults with EDs, given that an app designed specifically for adolescents may contain components unique from adult treatment.

Enhanced cognitive behavioral therapy (Fairburn, 2008)

CBT-E is a form of CBT that is based on transdiagnostic theory of EDs and includes both a focused version that addresses only eating pathology and a broad version that also addresses external obstacles to change in addition to core eating-related psychopathology (Cooper & Fairburn, 2011). CBT-E is largely a behavioral intervention, with the main components including self-monitoring, eliminating rigid dieting, and substituting alternative activities in times of urges to engage in disordered eating behavior. Additional modules for mood enhancement and coping with clinical perfectionism (Fairburn, 2008) are included. A recent review suggests that CBT-E results in clinically significant decreases in ED pathology for most forms of EDs and tends to have improved relapse rates compared to other treatments (Bulik, Berkman, Brownley, Sedway, & Lohr, 2007; Fairburn et al., 2009; Raykos et al., 2013). However, recent results for CBT-E show that only 60% of AN patients agree to start treatment, and of those, only 50–60% show clinically significant responses to treatment (Fairburn et al., 2009), demonstrating a particular need to improve treatments for AN. Although BN and BED display overall better treatment outcomes than AN, up to 50% of BN and BED patients are symptomatic after a course of CBT (Fairburn et al., 2009). Thus, although CBT is moderately effective in reducing ED symptomology, especially for BN and BED, significant room for improvement remains.

Interpersonal therapy

IPT primarily focuses on modifying problematic interpersonal relationships that are theorized to maintain disordered eating behavior. IPT theory suggests that interpersonal problems likely predate onset and are also a consequence of the disorder, and that certain hallmarks of EDs (e.g. social withdrawal, low self-esteem) prevent the development of meaningful relationships (Murphy, Straebler, Basden, Cooper, & Fairburn, 2012). IPT has been shown to be efficacious in the treatment of BED and BN specifically (Fairburn, Jones, Peveler, Hope, & O'Connor, 1993; Wilfley et al., 2002), but has yet to be fully evaluated for AN. Further studies have identified IPT as having similar rates of effectiveness as CBT for BN and BED; however, it requires a longer time period to achieve such effects (Wilson, Fairburn, Agras, Walsh, & Kraemer, 2002).

Acceptance-based treatments

Acceptance-based treatments emphasize the acceptance of distressing internal experiences (e.g. negative thoughts, emotions) so that one can pursue a valued life (Forman & Herbert, 2009; Hayes, Masuda, Bissett, Luoma, & Guerrero, 2005). Acceptance-based

treatments are based on an overarching theory that avoiding aversive internal experiences can inhibit an individual's ability to pursue valued behaviors (Hayes et al., 2005). Several pilot studies of acceptance-based therapies such as DBT (Safer, Telch, & Agras, 2001a, 2001b), mindfulness-based cognitive therapy (Kristeller & Wolever, 2010), and ACT (Berman, Boutelle, & Crow, 2009; Heffner, Sperry, Eifert, & Detweiler, 2002; Juarascio, Forman, & Herbert, 2010; Juarascio et al., 2013; Merwin, Zucker, & Timko, 2013) have demonstrated the initial effectiveness of acceptance-based interventions in the treatment of EDs, primarily for binge eating and transdiagnostic eating pathology. However, further research is necessary to determine relative efficacy.

Although the treatments described above produce improvements in ED symptoms for many individuals across diagnoses (though outcomes are significantly poorer for AN compared to BN and BED) and remain the current gold-standards for treating eating pathology, existing treatments leave substantial room for improvement (Hay, 2013). As described below, smartphone apps may be one way to both facilitate access to existing evidence-based treatments and augment current treatments to increase efficacy.

Smartphone apps could increase access to treatment

Many individuals with EDs, especially those with AN, express ambivalence to change (Serpell, Treasure, Teasdale, & Sullivan, 1999; Vitousek, Watson, & Wilson, 1998) as these individuals become extremely attached to and identify with the symptoms of their ED (Fairburn, 2008). This attachment leads to relatively high rates of treatment refusal and low rates of treatment adherence and acceptance (Halmi et al., 2005; Kahn & Pike, 2001; Mahon, 2000; Surgenor, Maguire, & Beumont, 2004). Furthermore, there are a number of practical reasons that prevent those with EDs from receiving the proper treatment including but not limited to cost, hassle and shame, and lack of treatment providers (Clement et al., 2012). For these reasons, the number of individuals seeking face-to-face professional treatment for eating pathology is low compared to the number of individuals who experience these conditions. mHealth technology could be one method for addressing this gap.

Individuals with an ED may be more willing and able to seek treatment through mHealth technology. Apps may serve as a more palatable first step of seeking treatment for those who are ambivalent about entering treatment. Smartphone apps can allow patients to approach treatment at an individualized pace, which may address some concerns about ambivalence towards treatment and help patients feel more in control of their treatment. The accessibility of apps could also address problems of cost and hassle; the confidentiality and privacy of apps could reduce shame experienced by seeking in-person treatment (Boulos, Wheeler, Tavares, & Jones, 2011). Additionally, there is a shortage of specialists in ED treatment and an even greater shortage of those who utilize evidence-based practices for ED. Therefore, even those individuals motivated to receive EBT for eating pathology are unlikely to successfully locate a local EBT-trained provider (Van Den Berg, Shapiro, Bickerstaffe, & Cavanagh, 2004).

Thus, smartphones offer the potential to increase access to EBTs for EDs. However, there are no best practice guidelines for app-based treatments. Ideally apps would include components

of evidence-based principles (EBPs) for EDs with augmentations designed to capitalize on smartphone technology. Even if a smartphone platform is not as effective as face-to-face treatment from a professional, it has the potential to produce improvement in symptoms and could produce recovery in a higher number of participants than would have otherwise been the case in the absence of any intervention.

Smartphone apps may address limitations of current treatments

Several factors that contribute to the lowered effectiveness of ED treatment make smartphone apps an attractive intervention option. Given that EDs, specifically AN, but often BN as well, are largely experienced as ego-syntonic, individuals with EDs tend to present with low motivation for change, and even lower motivation to practice skills outside the therapy office (Vitousek et al., 1998). Thus, adherence to key treatment recommendations (e.g. homework and self-monitoring) suffers. Homework encourages generalization of treatment skills outside of the therapy office by providing a venue for patients to practice, generalize, and maintain therapeutic skills (Kazantzis, Deane, & Ronan, 2000; Kazantzis, Lampropoulos, & Deane, 2005) and poor homework compliance is a robust predictor of treatment retention and outcomes (Bryant, Simons, & Thase, 1999; Burns & Spangler, 2000; Kazantzis et al., 2000; Kazantzis, Whittington, & Dattilio, 2010; Primakoff, Epstein, & Covi, 1986). Smartphone apps are well-suited to improve adherence to treatment recommendations outside the therapeutic office. Reminders and motivational messages to complete homework assignments could also be provided between sessions (Bock et al., 2013; Patrick et al., 2009; Suffoletto, Callaway, Kristan, Kraemer, & Clark, 2012), thus increasing motivation and compliance with treatment.

Self-monitoring, one of the core drivers of behavior change in CBT-E, could be enhanced if completed via smartphone, as entry and storage are simpler than pen-and-paper methods. Real-time self-monitoring could be enhanced through in-the-moment recording via Ecological Momentary Assessment (EMA) (Dölemeyer, Tietjen, Kersting, & Wagner, 2013). EMA is an approach to data collection that uses repeated sampling (usually consisting of a combination of prompted and user-initiated responses) to capture real-time data, in the natural environment (Shiffman, Stone, & Hufford, 2008). This approach to self-monitoring is likely to produce more accurate data collection than self-monitoring by traditional methods. When self-monitoring by traditional methods (without systematic prompting), it is rare that individuals will record their experiences in the exact moment that they are occurring (Shiffman et al., 2008). Thus, traditional methods involve some degree of retrospective recall. Research has shown that these recollections are systematically biased, and that this bias occurs involuntarily (Bradburn, Rips, & Shevell, 1987). EMA utilizes prompting to allow individuals to self-report thoughts, feelings, and behaviors in the context that they occur in order to minimize recall, thus increasing accuracy (Shiffman et al., 2008). The fact that most individuals keep their smartphones with them the vast majority of the day facilitates more real-time monitoring through EMA, which would likely be more accurate than recalling many hours (or even minutes) later. Smartphones also allow for the easy delivery of personalized, and random prompts for users to enter

their data. Thus, not only is self-monitoring enhanced due to the accessibility of smartphones, but the reminders make self-monitoring a more active, in-the-moment process therefore increasing the likelihood that self-monitoring will lead to increased awareness and behavior change. Furthermore, the capabilities of app sensors (e.g. GPS) allow for the automatic recording of information to reduce user-burden. Apps also have the capability to sync information within or between apps and present instant feedback regarding behavior patterns to the app user. The ability to view and analyze patterns over time is another method of facilitating behavior change.

Smartphones could also provide in-the-moment interventions directly during times of need to enhance treatment adherence and skills generalization. Having support in-the-moment can be particularly useful in the context of EDs because episodes of disordered eating behaviors (e.g. restriction and/or binging and purging) can be triggered by numerous internal (e.g. negative affect, hedonic desire) (Berg et al., 2013; Smyth et al., 2007), and external (e.g. exposure to stimuli associated with the behavior) factors (Jansen, 1998). When exposed to these triggers, the urge to engage in disordered eating behavior is high as these behaviors provide temporary pleasure and/or relief from tension (Stice & Agras, 1999). In these moments of high distress, patients may struggle to recall and attempt skills taught in the therapy office or feel unable or unmotivated to implement them (Edelman & Chambless, 1995; Schmidt & Woolaway-Bickel, 2000). Consequently, when faced with strong urges to engage in disordered eating behavior, access to adaptive coping strategies (via smartphone app) may facilitate skill use by providing reminders of the skills taught, as well as step-by-step instructions on how to utilize strategies in moments of high distress.

Heron and Smyth (2010) recently coined the term Ecological Momentary Intervention (EMI) to describe a range of treatments characterized by the delivery of interventions to people as they go about their daily lives, particularly in moments of need. EMI can be provided on smartphones in several different ways. For example, the content of the EMI can be specifically designed based on information individuals provide during pre-intervention assessments or EMA (Forman et al., 2014; Heron & Smyth, 2010; Runyan et al., 2013). A second method of tailoring EMI involves delivering the interventions at specific moments when individuals are especially in need of additional support. Smartphones now have a variety of features that could help identify when individuals might be at high-risk, including user initiated, fixed prompt times, random prompted times, tailored dates/or times, and machine learning algorithms that can predict customized delivery times for each individual user (Forman et al., 2014).

There is a growing body of literature devoted to examining the effectiveness of EMI for a variety of psychological disorders and behavioral health problems. A review by Heron and Smyth (2010) observed that EMI can be an effective intervention tool for smoking cessation, weight loss, anxiety symptoms, diabetes self-management, disordered eating symptoms, alcohol consumption in college students, and physical activity in older adults. Since the publication of that review, several studies have also revealed EMI to be an acceptable, feasible, and potentially efficacious treatment modality for mood disorders (Burns et al., 2011), marijuana cessation for youth (Shrier, Rhoads, Burke, Walls, & Blood, 2014),

bipolar disorder (Depp et al., 2010), and schizophrenia (Depp et al., 2010). However, few investigations have published data regarding user acceptability of such interventions. Heron and Smith's review revealed that all studies that published acceptability data noted that participants perceive EMIs as credible and generally acceptable (Heron & Smyth, 2010). However, others have noted several areas of improvement for of existing EMIs, including the frequency of EMI messages (Weitzel, Bernhardt, Usdan, Mays, & Glanz, 2007) and technical problems (e.g. shortness of battery life, phone freezing, failure to receive prompts (Burns et al., 2011; Depp et al., 2010).

Currently, feasibility and acceptability of EMI for EDs treatment are understudied. To date, only four published studies have examined EMI for EDs, but all four have assessed text-message interventions for patients with BN or EDNOS BN spectrum (Bauer, Percevic, Okon, Meermann, & Kordy, 2003; Bauer, Okon, Meermann, & Kordy, 2012; Robinson et al., 2006; Shapiro et al., 2010). These studies found mixed data regarding feasibility and acceptability, but it is difficult to generalize these results to more technologically advanced EMI platforms. To date, there is no published data available regarding the acceptability of more invasive aspects of EMI, such as geolocation and other context-aware sensors. Furthermore, there is a paucity of research that provides guidance on which EDs are best targeted by smartphone apps. For instance, the research on EMI is relatively restricted to the BN, BED, and subthreshold diagnoses (Smyth et al., 2001). Though some studies have revealed high levels of compliance and acceptability in EMA for AN (De Young et al., 2014; Engel et al., 2005; Lavender et al., 2013; Stein & Corte, 2003), the limited work in this area prevents the abilities to draw conclusions. Overall, there are conflicting opinions within the field regarding whether technology-based treatment alone would be appropriate for AN, given that these patients typically require a higher level of care (Shingleton, Richards, & Thompson-Brenner, 2013).

Risks and challenges of using smartphone apps for the treatments of EDs

Despite the promise of using smartphone apps to address the limitations of current treatments of EDs, several challenges and risks of integrating technology into ED treatment must be acknowledged. First, although apps could increase access to treatment, availability of treatment programs via apps could possibly lead individuals to avoid seeking professional in-person treatment even when it is available and warranted. To counteract this to the extent possible, any available apps should include built-in messages to encourage users to seek treatment (especially when endorsing high levels of symptoms) and links to websites with ED referrals. Second, utilization of apps could detrimentally interfere with concurrent in-person treatment; for example, an individualized treatment plan from an in-person treatment provider could include recommendations (e.g. frequency of eating) that are conflicting with that of app recommendations, perhaps causing confusion and interference with treatment. Another potential problem is the advice or feedback patients may receive via social forums built into apps; patients could receive unhelpful or even detrimental advice from other individuals using the app. Clinicians, before assigning use of apps as part of treatment should thoroughly review the app treatment components, and clearly communicate

to patients any differing treatment recommendations, as well as caution them against taking treatment advice from other users.

Using smartphone apps to deliver EBPs

Overall, despite existing risks and challenges, smartphone apps are a promising venue through which to enhance treatment for EDs because of the widespread availability and the potential to facilitate treatment adherence and skill utilization outside of the therapy office. However, a major weakness of the broad mHealth field is that few existing health-related apps explicitly draw on EBT principles for the problems they purport to address (Istepanian, Laxminarayan, & Pattichis, 2006). Although components of existing apps that are not empirically supported may be useful at enhancing engagement (e.g. positive affirmations, gamification) or at least may not be iatrogenic, these components must be viewed more cautiously as there is minimal available data to support their utility. Recognition of this gap has prompted calls for a more empirically grounded approach to mHealth technology development. One effective approach endorsed by experts is to adapt existing EBTs into technology-based interventions that either take the place of or augment conventional outpatient psychotherapy (Heron & Smyth, 2010). Current research for the treatment of EDs has thus far focused on developing full EBT packages, and limited work has been completed assessing which components are efficacious in and of themselves. Although, some components of treatment packages may not be deliverable via smartphone app (e.g. food exposures, collaborative weighing, building appropriate interpersonal relationships), there are many specific evidence-informed principles that could be included in smartphone-based interventions. Smartphone apps will likely most improve treatment if the apps successfully incorporate both EBPs (see Table 1 for a description of the components of the EBPs in the treatment approaches described above) *and* utilize the recent advances in smartphone technology to enhance gold-standard treatment. Given the potential promise of therapeutic apps for enhancing treatment for EDs, a review of commercially available apps for EDs is warranted.

Current review

The aim of this paper is to (i) review existing apps for EDs, (ii) determine the extent to which available treatment apps utilize components from EBTs as a basis for treatment provision, and (iii) assess the degree to which existing smartphone apps utilize recent advances in smartphone technology (e.g. EMI, EMA, use of mobile sensors to facilitate automatic recording) to enhance treatment.

Methods

We inventoried smartphone apps that directly addressed eating disorders by using the following serial search terms: 'Eating disorders,' 'Anorexia,' 'Bulimia,' 'Binge eating,' and 'Binge Eating Disorder.' We conducted the review in the respective app stores of the iOS (App Store) and Android (GooglePlay) platforms, as these are the most widely used and viable platforms for smartphone apps (Boulos et al., 2011).

Table 1 Evidence-based features present in currently-available ED treatment apps

EBPs	Recovery Record	RiseUp	Before I Eat	iCounselor	Stop Binge Eating	Daytime Affirmations
CBT-E components						
Self-monitoring of eating behavior	X	X		*		
Weekly weighing						
Establishing a regular pattern of eating	X	*		*		
Stopping use of compensatory behavior	X			*		
Substituting alternative activities	X	X	X			
Reducing/restructuring cues	X			*	*	
Eliminating rigid dieting and food avoidance	X					
Reducing shape checking/avoidance, "feeling fat"	X					
Relapse prevention						
IPT components						
Identification of interpersonal problem areas						
Identifying interpersonal goals						
Addressing interpersonal problems	X					
ABT components						
DBT coping strategies	X		X	*		
Emotion regulation skills	X					
Psychological acceptance	X					
Mindfulness	X	X	X	*		
Values clarification						
Cognitive defusion						

X = feature or component present
*= Feature present, but guidance or functionality is limited

Coding and categorization

Apps were reviewed by two independent coders and were categorized based on thematic analysis. Apps were included if they directly focused on treatment, psychoeducation, assessment, or provided general information about eating disorders or disordered eating behavior. Apps were excluded if they did not specifically address disordered eating or focused solely on tracking food intake or weight loss. Coding and thematic analysis yielded three main categories of apps for eating disorders: 'Treatment,' 'Psychoeducation,' and 'Other.' Only treatment-focused apps were considered for the purposes of this review.

Critique and review of empirically-based principles in treatment-focused apps

We reviewed treatment-based apps to determine whether the app used components of empirically-supported interventions for EDs (see Table 1 for a complete list of the EBPs evaluated). The criteria we used for these components was based on a review of the current literature for what treatments are effective for adults with EDs from the website of the Society of Clinical Psychology from Division 12 of the American Psychological Association 'Website on Research Supported Psychological Treatments'. Specifically, we examined apps for features that taught or facilitated the major components of CBT/CBT-E and IPT. Additionally, we reviewed the apps for components of acceptance-based interventions, which are beginning to show empirical support for treating EDs. Lastly, we examined whether apps contained information regarding nutrition management, a common component of EBTs for EDs; however, no apps contained such components.

Utilization of smartphone technological capability

We additionally reviewed each app for use of smartphone technology to enhance treatment, such as EMA, EMI, or sensors (e.g. GPS to facilitate automatic recording; see Table 2). Apps were coded for the presence of each of these features, as well as any additional functions that utilized features unique to smartphone (e.g. connections to other applications or phone functions).

Results

Of over 350 000 apps in the iTunes apple store and 850 000 in the Android app store, we found a total of 20 apps that fell into the categories of ED treatment apps, self-diagnosis tools, referral sources, recovery support, assessment, or clinician tools. Apps were listed in Health and Fitness ($n = 12$), Medical ($n = 5$), or Books ($n = 3$). Of the 20 apps, six were aimed at treatment of EDs, five for ED psychoeducation, and nine in 'Other' (including a self-diagnosis tool, a tool for finding referrals, a pro-recovery/support app, assessment tools, and a reference tool for ED clinicians).

The six ED intervention apps included *Recovery Record, RiseUp: Overcoming Your Eating Disorder, Before I Eat, iCounselor: Eating Disorder, Stop Binge Eating: Lose Weight,* and *Daytime Affirmations.* For each app, any notable features, EPB utilization, and technology utilization were reviewed.

Recovery record

Recovery Record (see Table 1) is the most comprehensive ED treatment app that exists to date, and contains features such as self-monitoring, personalized coping strategies, social connection, and a portal to connect with the user's clinician.

Table 2 Technology utilization in currently available ED treatment apps

Technology component	Recovery Record	RiseUp	Before I Eat	iCounselor	Stop Binge Eating	Daytime Affirmations
Self-monitoring of eating behavior	X	X				
EMA, user-specified, or automatic reminders	X	X				
EMI						
Use of sensors or other technology to automatically enter data						
Visualization of user data	X					
Use of multimedia				X		X
Reinforcement for use of the app (e.g. badges, rewards, and levels)	X					
Ability to connect with clinician	X					
Ability to connect with other app users	X					
Other features (e.g. ability to sync with other apps or send app data via e-mail)	X	X				

X = feature or component present

EBP utilization

Many of these features contain components of evidence-based interventions for EDs, including cognitive-behavioral-based interventions. *Recovery Record* has the capability for the user to log food/meal intake (including specific food items eaten), thoughts (through an open text field), and emotions/feelings (through a Likert-type scales of overall energy level, overall feelings, and specific emotions such as guilt and anxiety), representing a comprehensive self-monitoring system. For each meal, snack or binge entry, *Recovery Record* allows for the user to enter energy level, overall affect, specific emotions, the context of the eating episode, as well as urges to binge and/or use compensatory behavior. The components of self-monitoring allowed for in the app are consistent with the self-monitoring components in CBT-E. Users are able to request coping strategies for in-the-moment problems (e.g. negative emotions), which are derived from CBT (e.g. delaying/distraction from an urge) and acceptance-based techniques (e.g. defusion from distressing thoughts, urge surfing). Users are also able to write their own personalized coping techniques.

Recovery Record allows users to set clinical goals, many of which are based on cognitive-behavioral strategies. Clinical goals includes the categories of Appointment Planning, Meal Management, Prevention, and Intervention. Within each category, users can set goals based on CBT strategies such as stimulus control, meal planning, and introducing fear foods. Strategy provision consists of a one-sentence description of how to implement the strategy.

Notable features

Other features of *Recovery Record* include 'pairing up' with another *Recovery Record* user to share recovery experiences (e.g. send encouragement, sharing feelings), posting of app activity to a *Recovery Record* community feed, and positive affirmations. These components are not specifically derived from empirically supported interventions for EDs; however, they are features that likely facilitate user engagement.

There is additionally a clinician version of *Recovery Record* (*Recovery Record Clinician*), which allows clinicians to view user data, with the user's permission. The clinician is able to view patients' food and thought records, view the user's goals and coping strategies used, and communicate with the user, and make private notes.

Technology utilization

Recovery Record is the only ED treatment app to utilize automatic prompting to encourage users to record meals and to remind users of meal plans and goals for the day, a form of EMA that is aimed to facilitate self-monitoring. *Recovery Record* does not include EMI or utilization of sensor-initiated automatic recording. Users are able sync goal-setting with an online calendar system (Google Calendar), and set reminders to complete specific goals.

RiseUp: overcoming your eating disorder

RiseUp allows for self-monitoring of eating behaviors and emotions and provision of coping strategies.

EBP utilization

The self-monitoring features allow for logging of daily meals/snacks, emotions, and 'target behaviors' (e.g. binging and purging), which is consistent with the core self-monitoring component of CBT. Coping skills, such as teaching users to call a friend, are meant to be accessed in moments of distress, which is also consistent with CBT-E. *RiseUp* contains additional modules that include topics such as cultivating positive body image, building strong relationships with others, journaling, and mindfulness practice. While some small components of each of these modules (e.g. mindful eating, cultivating body image) may be loosely based on empirically-supported interventions (e.g. Mindfulness-Based Eating Awareness Training) (Kristeller, Baer, & Quillian-Wolever, 2006; Kristeller & Wolever, 2010), much of the content of these particular modules is not based on CBT-E or other empirically-based principles (e.g. journaling activities).

Technology utilization

Rise Up does not utilize EMA, EMI, or automatic recordings.

Before I Eat

Before I Eat is aimed at providing strategies for in-the-moment urges to overeat, engage in emotional eating, and binge eating.

EBP utilization

Before I Eat provides in-the-moment strategies for dealing with urges through audio clips explaining strategies such as urge-surfing,

cognitive defusion, distraction, and self-soothing, which are broadly based on CBT and acceptance-based strategies. Additional audio modules describe strategies for handling specific situations (e.g. nighttime eating) and learning to relax and eating mindfully.

Notable features

Before I Eat has the capability to track daily progress, set eating-related goals, and make general notes; however, it does not facilitate daily recording of eating behavior.

Technology utilization

Before I Eat utilizes multimedia (audio-based interventions), however, does not utilize EMA, EMI, or automatic monitoring.

iCounselor: eating disorder (Android: *Eating D*)

iCounselor contains short modules/coping skills that include psychoeducational, supportive, stress management, and behavioral and cognitive strategies.

EBP utilization

Several short behavioral and lifestyle suggestions, such as eating regularly, keeping a daily food record, and strategies for delaying the urge to binge/purge, are consistent with some components of CBT-E. Other strategies are additionally based on cognitive therapy more broadly, such as challenging thinking errors and core negative beliefs. Acceptance-based principles, such as urge surfing and distress tolerance (e.g. tolerating the feeling of fullness) are also included in *iCounselor*. However, many strategies provided by the app are not based on CBT-E or empirically based principles (e.g. 'be a cheerleader for yourself'). Although including several types of short strategies, functionality of the app is limited.

Technology utilization

iCounselor does not utilize EMA, EMI, or automatic recording.

Stop binge eating: lose weight

Stop Binge Eating consists of three short modules, including 'Is it Binge Eating…?' (psychoeducation), 'I feel like I am going to binge eat soon' (a short description of tips to avoid binge eating), and 'I have already binged on food today' (helps evaluate the cause of a binge that already occurred).

EBP utilization

The intervention components of 'I feel like I am going to binge eat soon' are not based on principles known to help resist an urge, e.g. 'eat something healthy…' The 'I have already binged module' advises users to examine the causes of a binge, e.g. negative affect, and long periods without eating, which are based on research evidence; however, *Stop Binge Eating* provides little guidance outside of the advice to examine a binge's cause.

Technology utilization

Stop Binge Eating does not utilize EMA, EMI, or automatic monitoring.

Daytime affirmations

Daytime Affirmations consists of a 30-min audio clip of a guided imagery/hypnosis intervention for binge eating.

EBP utilization

Guided imagery is not an empirically supported intervention for EDs, and no other components of CBT are included.

Technology utilization

Daytime Affirmations does not utilize EMA, EMI, or automatic recording.

Discussion

The current review sought to examine existing smartphone apps that delivered eating disorder interventions. After an exhaustive search, 20 apps were identified that directly targeted EDs. Only six of these 20 were designed to provide intervention. The primary goals of this systematic review were to assess the extent to which current apps are (i) utilizing empirically supported treatment principles; and (ii) harnessing the capabilities of smartphone technology.

Overall, most existing ED intervention apps incorporate few empirically supported treatments components. Although it would be impossible (and likely ineffective) for any app to include all of the empirically support treatment components we assessed for, most apps reviewed in this study contained few if any evidence-based principles. Additionally, many of the apps reviewed contained primarily non-empirically supported treatments. For example, *Daytime Affirmations* solely offers guided imagery. *Stop Binge Eating* offers coping strategies that are inconsistent with empirically supported treatments for binge eating such as 'eat something healthy.' Although the non-empirically supported components included in these apps are not necessarily ineffective or iatrogenic, it may be particularly important to view these components with more caution as there is minimal or no data to support their inclusion.

Recovery Record stood out as delivering the most empirically supported content. Many of the coping strategies are cognitive, cognitive behavioral, or acceptance-based in nature. *Recovery Record* also offers a method of setting clinical goals, which is also consistent with cognitive-behavioral practice. Additionally, *Recovery Record* offers extensive self-monitoring functionality (e.g. meals, thoughts, and emotions) and has the ability to be shared with a clinician via a clinician version of the app. Though the app is relatively comprehensive and evidence-based, there remains room for improvement. For instance, the empirically supported interventions and coping strategies that are offered in *Recovery Record*, as well other most other apps, are extremely brief (i.e. one to three sentences). There are notable limitations of smartphones in their ability to deliver print material such as the amount of space on the screen, size of the font, differing user interfaces on varying devices, and scrolling abilities. For apps to become an effective method of delivering ED treatment, it is essential that coping skills and interventions (i) closely follow EBPs that have already been empirically tested, and (ii) are tested in app format to examine whether such a mode of intervention delivery leads to skill utilization.

Our systematic review indicated that ED intervention apps are not fully utilizing the advanced capabilities of smartphone apps. Smartphones are extremely well-suited to the creation of highly customized, personalized, and engaging interventions due to

advances in smartphone technology (Aldhaban, 2012; Bauer & Moessner, 2012, 2013; Oulasvirta, Rattenbury, Ma, & Raita, 2012). However, these capabilities were largely neglected across the six apps reviewed. Self-monitoring via user-initiated recordings was the most common, as it was in place in three of the current apps (*Recovery Record, RiseUp,* and *iCounselor*). *Recovery Record* also makes use of EMA-type prompting to provide automatic reminders to record when it detects that participants have not been recording frequently, and customizable settings so that users can set reminders for goal completion that are synced with their electronic calendars. These reminder features have the potential to increase compliance to self-monitoring, one of the most important components of cognitive behavioral interventions for EDs. *RiseUp* also allows for users to set reminders to log meals. However, none of the other apps utilized a similar feature. Without substantial reminders and prompts, it is difficult to guarantee the frequent, accurate, and in-the-moment documentation of emotions, meals, and urges.

Overall, app functionality in ED intervention apps appears to be very limited. No app supplemented manual data entry with automated data entry (e.g. geolocation, time). Additionally, none of the apps featured personalized EMIs or automatically-delivered EMIs during identified times of high risk. Existing interventions appear to be fairly brief and lack personalization. In future ED recovery apps, EMI could be utilized to suggest coping strategies drawn from EBTs that the patient reports are most helpful, feedback based on concurrent EMA, individual counseling, or messages based on pre-intervention behavior patterns. Furthermore, future apps should incorporate the capability of smartphones to execute programmed machine learning, such that an app can become acquainted with a particular user's behavior patterns, predicting times of need and deliver a customized coping strategy (Burns et al., 2012). The high-risk situations could be identified by data drawn from the numerous smartphone sensors (e.g. global positioning systems, ability to detect patterns in recent calls or messages). The information obtained from these sensors could be used to develop context-aware systems to automatically detect when patients require assistance by utilizing machine learning models, which can predict patients' mood, emotions, cognitive/motivational states, activities, and environmental and social contexts (Forman et al., 2014; Runyan et al., 2013). The utilization of EMIs in future apps would be could be incredibly useful and efficient, as they could potentially enhance recovery for the user, and also require little ongoing involvement by researchers or clinicians as EMI is delivered.

Last, only two apps (*Recovery Record* and *Before I Eat*) allowed customization of the treatment experience. For example, users can set individual goals for treatment and use the app to track progress. Another useful customization tool is the use of a dashboard or toolbox where users can save particular strategies that are most effective. Though app development is certainly progressing, there is room for improvement. For instance, more advanced technology is capable of generating automatic, but personalized feedback on treatment progress on both assigned goals/homework and self-monitoring records (Burns et al., 2012). This feature may be able to reduce clinician burden, increase user adherence, and potentially counteract the potential downside of apps offering contradicting recommendations to clinicians; however, it is not utilized by any available apps for consumers.

Future research

The field of therapeutic smartphone apps is rich with areas that require further research. Given that technology-based treatments for EDs are particularly understudied in comparison to other disorders, a particular area of concern is how to best deliver EBPs via smartphone app to enhance treatment outcome. First, there should be extensive efforts made to formally evaluate the effectiveness of the existing apps on the market either as standalone entities or adjuncts to ED treatments. There is a strong need for empirical studies that directly assess whether smartphone apps can enhance treatment of eating disorders. None of the apps included in this review have been subject to rigorous research to date and there is no empirical evidence showing that any of these programs may facilitate access to treatment or improve treatment efficacy. Even apps that include all of the evidence-based components described in our review need to establish their feasibility, acceptability, and efficacy before their implementation and large-scale dissemination should be recommended. These types of formal evaluations may prove challenging as the quickly moving mHealth field and the long-term nature of treatment outcomes studies are incompatible in many ways. For example, a smartphone app that is created and evaluated over the period of several years would then likely be outdated by the time it is ready for release to the public. Researchers in the mHealth field have noted this concern and called for the development of novel systems to evaluate technology-based treatments, yet there is little consensus at this point as to what may be the ideal method through which to evaluate smartphone app interventions (Kaplan & Stone, 2013).

In addition to the overall need for more research described above, future research should also attempt to compare the effect of shortened smartphone app interventions with the effects of the traditional self-help text that they were drawn from. Work in this area should be aiming to objectively evaluate how much effectiveness is being sacrificed for enhanced disseminability. Furthermore, within the field of EDs, published studies on smartphone apps for patients with BN and BED far out-number studies of smartphone apps for patients with AN. However, given the specific treatment recommendations for AN (e.g. weight regain), it is possible that apps may not serve as a viable stand-alone intervention for this specific diagnosis. An area for future investigation is whether specific diagnoses, severity levels, or ED behaviors (e.g. binge eating), are more well-suited for smartphone-enhanced or smartphone-only treatment compared to others.

As the above review has identified, smartphone apps currently on the market do not make use of recent technological advancements that could enhance effectiveness of treatment. There is a call within the field of health behavior change for developers to begin utilizing varying methods of both input and output functionalities to personalize therapeutic apps and increase the likelihood of behavior change (Riley et al., 2011). Future research should continue to identify methods of applying such technologies to ED-related smartphone apps specifically (e.g. EMI, sensor systems, and machine learning). For example, our team is currently developing a smartphone app, *TakeControl*, that provides both self-help CBT content and utilized several of the advanced app-related technologies described above. For example, *TakeControl* contains the following functions: (i) automatic (location and time) and EMA-style collection of data on binge eating episodes and

triggers; (ii) graphic presentation of changes in these variables over time and modeling of patterns between triggers and binge episodes; (iii) machine-learning-powered algorithm to continuously establish an individual's current level of risk for a binge eating episode that relies on data collected by the target user; (iv) a 'risk alert' to the user when the algorithm detects elevated risk of a binge eating episode; (v) an in-the-moment intervention tailored to the individuals' current risk factor/s; (vi) a library of short coping strategies that are focused on specific problem areas, e.g. managing urges, modifying erratic eating patterns; and (vii) a full CBT self-help program adapted from other sources (e.g. Fairburn's *Overcoming Binge Eating*, Mitchell's *Binge Eating Disorder: Clinical Foundation and Treatment*). Although the app is still in active development, initial testing has ($n = 7$) supported the preliminary acceptability and feasibility of *TakeControl*. However, additional research is needed to test the efficacy of these app components once *TakeControl* is complete.

Last, there is a paucity of data on the feasibility and acceptability of therapeutic smartphone apps among ED users. For instance, there are little empirical data that are available regarding patient perceptions on levels of intrusion, such as message frequency, geolocation, and other context-aware systems. Users may be unlikely to report revealing and stigmatized medical information using smartphone applications given concerns about potential interceptions of digital data from third parties. Future apps will need to address privacy and HIPPA concerns to ensure these treatments are acceptable to patient users. Additionally, further research should assess the potential risk apps pose to individuals pursuing in-person treatment, as well as ways in which apps could interfere with in-person treatment (e.g. conflicting recommendations, harmful advice from other apps users) via social media portals or forums. Further feasibility and acceptability testing is essential before recommending app use to individuals with EDs, and should be taken into account with further development of apps that harness current technological advancements and employ EBPs.

Conclusion

In conclusion, current ED intervention apps vary tremendously in terms of their empirical basis and their usage of smartphone technology, both of which are likely to increase the efficacy of smartphone-delivered ED intervention. Currently, there are few ED intervention apps that are commercially available on iOS or Android platforms. However, existing apps do not contain many components of evidence-based treatment packages for EDs. It should also be noted that, in addition to evidence-based components, all apps contained strategies that have not yet been empirically tested (e.g. affirmations). In addition, apps for ED have so far largely failed to take advantage of the abilities that set smartphones apart from in-person treatment (e.g. EMA, EMI, and machine learning) and would improve engagement and feasibility of intervention. Given the limited efficacy of extant treatments for EDs, there is a great potential for smartphone apps to increase access to treatment, enhance treatment by provision of extra support outside of the therapy office, and utilize technical capabilities to enhance treatment compliance and skill utilization. However, despite the promise of smartphone apps as an adjunct to existing treatment, the literature base on the use of smartphone apps in treatments for EDs is sparse. The lack of research assessing the efficacy of this treatment modality limits our ability to assess the value of smartphone apps and indicates a strong need for empirical studies in this field. Future research should examine ways to deliver EBPs and utilize growing technological capabilities of smartphones to enhance treatment outcome for EDs.

Conflicts of interest

The authors do not have any conflicts of interest.

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