SYSTEMATIC REVIEW

The use of eHealth to promote physical activity in people with mental health conditions: a systematic review [version 3; peer review: 3 approved]

Previously titled: The use of eHealth to promote physical activity in patients with mental health conditions: a systematic review

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Abstract

**Background:** Achieving adequate amounts of physical activity (PA) confers important physical and mental health benefits. Despite this, people with mental health conditions often do not meet recommended levels of PA. EHealth, the delivery of health information through internet and mobile technologies, is an emerging concept in healthcare which presents opportunities to improve PA. The aim of this systematic review is to describe the use of eHealth to increase or monitor PA levels in people with mental health conditions.

**Methods:** Databases searched included OVID Medline, EMBASE, PsychInfo and Web of Science using a combination of key-words and medical subject headings. Articles were included if they described an eHealth technology designed to improve or monitor PA in people with mental health conditions. Two reviewers screened articles. Articles included in the qualitative synthesis were screened for risk of bias using the Cochrane Risk of Bias Tool for experimental studies and Downs and Black Checklist for non-experimental studies.

**Results:** Seven studies met the eligibility criteria. A variety of eHealth platforms designed to promote or monitor PA were described in these studies; web-based (n=4), web and mobile application (n=3) and e-mail-based (n=1), one study used both a web-based and mobile application. Three studies reported eHealth interventions significantly increased PA levels, however it is unclear if eHealth interventions are superior at promoting PA compared to conventional interventions. Four studies reported that higher levels of PA, measured using eHealth, were associated with better mental health profiles.

**Conclusion:** eHealth interventions may be an innovative low-cost method to increase PA levels which may have knock-on effects on mental health
outcomes. Although some of the included studies in this review demonstrated promising results, methodological restrictions and potential biases from using subjective measures of PA limit the interpretability of these results. Future research should evaluate this promising technology using well-designed trials.

**Keywords**
eHealth, technology, mental health, physical activity

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Introduction

Physical activity (PA) is associated with a number of health-related benefits such as improved cardiovascular health, bone strength, and a reduced risk of developing chronic conditions such as colorectal and breast cancers, cardiovascular disease, and Type II diabetes. In addition, the benefits of PA among people with mental health conditions extend beyond physical health benefits and include improved mood and sleep, reduced stress, and enhanced self-esteem. Despite the numerous physical and mental benefits of PA, insufficient levels are prevalent among people with mental health conditions. The low levels of PA among this population and potential mental and physical health gains make a strong case to explore innovative and effective ways to improve PA levels.

eHealth is a relatively new concept in healthcare which may present unique opportunities to improve PA levels. eHealth is an umbrella term including ‘the transfer of health resources and health care by electronic means, including, but not limited to the delivery of health information through the internet and mobile technologies’. The implementation of internet technology in health-care provides a number of benefits such as convenience for users, easy storage of large amounts of information, ease of updating information, and ability to provide personalized feedback. eHealth interventions have been extensively studied in a number of populations ranging from cancer survivors to community dwelling adults. Systematic review evidence has consistently supported the effectiveness of eHealth interventions to increase PA levels.

eHealth based interventions may be well suited to improve PA levels among people with mental health conditions. Internet-based interventions have previously addressed several barriers common to traditional PA based interventions including overcoming geographical restrictions and combating a lack of human resources. These advantageous features are some of the reasons the National Institute for Clinical Excellence (NICE) has identified computerised cognitive behavioural therapy as part of an approach to improving standard care of people with depression. In addition, these features may be applicable to help promote PA in people with mental health conditions. Furthermore, people with mental health conditions are reported willing to use eHealth for health-related reasons. A study of 100 people with mental health conditions at a psychiatric outpatient facility reported that 72% of people owned a smartphone and 67% were eager to use a smartphone application to track their condition. Therefore, eHealth interventions may potentially be a useful platform to monitor and increase PA levels in people with mental health conditions.

To our knowledge, no systematic review has synthesised the literature in the field of eHealth and PA for people with mental health conditions. To address this gap, the aim of this systematic review was to describe the use of eHealth to increase or monitor PA levels in people with mental health conditions. Secondary objectives of this review included (i) To investigate the effectiveness of eHealth interventions as a stand-alone or multimodal intervention to promote PA in people with a mental health condition (ii) To explore the extent to which eHealth technologies are used to measure PA among people with mental health conditions (iii) To report associations between PA measured using eHealth devices and mental health outcomes.

Methods

Study design

This systematic review was conducted to identify eHealth technologies with a primary or secondary aim to promote or monitor PA in people with mental health conditions. The “Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)” guidelines and the criteria outlined in “A Measurement Tool to Assess Systematic Reviews (AMSTAR) checklist” guidelines were followed in drafting this review (PRISMA checklist in Supplementary File 1). The protocol outlining the planned search strategy and method of analysis for this review was registered online and is available on PROSPERO, a registry of systematic reviews (CRD42017068834). It was originally planned to include intervention based studies only, however due to the relative paucity of available trials due to the emerging nature of this research field, a pragmatic decision was taken to broaden the objectives of the review. Therefore, studies that used eHealth technology to monitor PA among people with mental health conditions were also included.

Eligibility criteria

Experimental studies and observational studies, with or without controls, were eligible for inclusion if they evaluated an eHealth-based technology to promote or monitor PA, (internet and mobile technologies) delivered to participants with mental health conditions which included PA as a primary or secondary outcome measure. As per Ritterband et al. (2006)2 we included eHealth research into the use of web-based and mobile health technologies to measure, track or encourage increases in PA levels among people with mental health conditions. Mental health conditions were characterized as some combination of abnormal thoughts, emotions and relationships with others, which included but was not limited to; depression, bipolar disorder, anxiety disorders and schizophrenia, spectrum disorders. Single eHealth interventions or multi-modal interventions in conjunction with eHealth were included. Studies were excluded if only telephone calls, short message service (SMS) or conference calls were used. Authors of relevant abstracts or conference presentations were contacted to obtain a full-text article or detailed methodology and data set. Abstracts and conference presentations without an accompanying full-text article were excluded due to lack of a detailed methodology.
PA is a complex multi-dimensional construct measured through objective (e.g. indirect calorimetry, accelerometers, pedometers) or self-report methods (e.g. questionnaire, log)\textsuperscript{21}. Domains of PA can be considered on a continuum from light activity (e.g. slow walking) through to moderate level activity (e.g. brisk walking) and vigorous activity (e.g. jogging). Sedentary behaviour consists of low levels of activity, similar to resting (e.g. sitting or lying down)\textsuperscript{22}. There are many different ways of quantifying PA. We included the following methods of quantifying PA, but not limited to the following; MET-minutes/week\textsuperscript{1}, minutes in light, moderate and/or vigorous PA per week, and meeting/not meeting PA guidelines (150 minutes per week of moderate/vigorous activity)\textsuperscript{23}. All methods of measuring PA were included e.g. self-report, objective or direct measures.

**Data sources & search strategy**

An experienced medical librarian was consulted and a comprehensive search strategy was developed with all keywords and subject headings included (DM). The search strategy consisted of a search of four electronic databases: OVID Medline, Embase, Psychinfo, and Web of Science. Search terms included keywords and medical subject headings adapted for each database. These related to three categories: 1) the condition (e.g. ‘mental health’ ‘depression’, ‘bipolar disorder’, ‘schizophrenia’ and ‘anxiety disorder’), 2) technology (e.g. ‘teleHealth’, ‘telerehabilitation’, ‘mobile health’, ‘Mhealth’, ‘eHealth’, ‘e-health’, ‘mobile technology’, ‘smartphone’), and 3) PA (e.g. ‘exercise’, ‘physical activity’, ‘exercise therapy’, ‘physiotherapy’). There was no limit placed on the year published as it was believed that the search strategy would produce only articles published within the last ten years, due to the relatively novel nature of this technology. Databases were searched until August 2017. The bibliographies of all included studies were examined to identify further studies. The search strategy is available in **Supplementary File 2**.

**Selection of eligible studies**

Two researchers (JM and GK), independently screened titles and abstracts to identify studies that met the eligibility criteria. Any disagreements between researchers were discussed and if a consensus could not be reached a third researcher (JB) intervened. All full-texts were retrieved and examined in detail to assess for inclusion in this review.

**Risk of bias and classification of intervention type within studies**

Two researchers (JM and GK) independently appraised the risk of bias of included studies; any disagreements were resolved through discussion. The Downs and Black checklist was used to assess the risk of bias of all included observational studies\textsuperscript{24}. This checklist contains 27 items, with a maximum possible score of 32 points. The final score is variable as some items of the checklist may not be applicable and can be excluded. In addition, the Cochrane Collaboration’s tool\textsuperscript{25} was used to assess risk of bias for each RCT. Risk of bias was assessed in the following six areas; sequence generation (randomisation); allocation concealment; blinding of participants, personnel and investigator; incomplete data (e.g. losses to follow-up, intention-to-treat analysis); selective outcome reporting; and other possible sources of bias.

**Data extraction & analysis**

Data were extracted by two researchers (JM and GK) independently onto standardised data extraction forms. Any disagreements were discussed, if a consensus could not be reached, a third member of the research team (JB) arbitrated. The standardised data extraction form was piloted on two randomly selected studies and modified accordingly. Data were extracted using the following headings: methods, allocation, blinding, duration, design, setting, participants, diagnosis, age, sex, inclusion criteria, exclusion criteria, intervention, control group, primary outcomes, secondary outcomes, results in PA outcomes, results in secondary outcomes.

**Results**

**Study selection & design**

The PRISMA flow diagram outlines study selection (Figure 1). A total of 2,994 articles were retrieved and 191 duplicates were removed. Following title and abstract screening, 2,728 articles were excluded leaving 75 full-text articles to be screened. Six abstracts were excluded as following contact with abstract authors, no full-texts could be obtained. Ultimately, seven articles were included in this review.

Types of studies were mixed, including RCTs (n=3) and observational studies (n=4). Table 1 describes the methodological features of included studies. Included studies were varied in design, likely reflecting this emerging research field. Three studies compared an eHealth intervention to a control group. The remaining studies (n=4) used an eHealth intervention to measure PA in participants with mental health conditions. Mobile technologies such as smartphones and the Fitbit were used to measure PA levels and predict clinical signs and symptoms of mental health conditions such as mood. The length of interventions ranged from 9 days to 12 months\textsuperscript{26,27}, with the majority of studies not assessing PA post-study completion. Only one study assessed maintenance at 6 months post-baseline\textsuperscript{28}.

A quantitative synthesis of included data were planned, but was deemed inappropriate due to the heterogeneity of study design, participants, interventions and outcomes. Consequently, a qualitative synthesis of study interventions and results was completed. A number of sub-group analyses were planned, including comparing self-report and objectively measured PA and intervention focus such as smart phone applications vs. web-based interventions. Due to insufficient data in included studies these comparisons could not be completed.

**Participant characteristics**

Participant characteristics are also summarised in Table 1. A total of 811 participants were recruited with 102 dropping out. Ultimately, 709 participants were analysed across seven studies.
A total of 101 participants analysed had depression. There were 487 participants with psychological distress, identified with a score of ≥16 using the Kessler-10 screening tool. The remaining mental health conditions included; schizophrenia or schizophrenia spectrum disorders (n=69) and bipolar disorders (n=22). One study did not report the specific diagnoses of mental health conditions included.

**eHealth interventions and control treatments**

A variety of eHealth platforms designed to increase PA were described in these studies; web-based (n=4), web and mobile application (n=3) and e-mail-based (n=1), one study used both a web-based and mobile application. A breakdown of each technological intervention is detailed in Table 2 below.

eHealth interventions included internet delivered cognitive behavioural therapy (CBT). An internet-based PA intervention and an internet-based therapist delivered self-help programme. Control treatments included standard care, waiting list care and an active control group. Participants in the active control group underwent a 12-week online programme that delivers health information on topics including nutrition, stroke, PA, medicines in the home, blood pressure and cholesterol, and heart health.

All experimental studies (n=3) reported eHealth interventions significantly increased PA levels from baseline, however, it is unclear if eHealth interventions are superior to traditional mental health services at increasing PA. Glozier and colleagues reported a greater proportion of participants with psychological distress (n=487) engaging in the recommended levels of PA (≥150 mins a week) who performed internet based cognitive behavioural therapy (ICBT) compared to the online active control group (67% in ICBT vs 61% in control group, Odds Ratio: 1.91, 95% CI: 1.01–3.61). In contrast two studies reported there were no significant differences in PA levels between eHealth interventions and control treatments. Mailey and colleagues noted an increase in PA in both the internet delivered PA intervention and standard care control group. However, there was a larger increase in mean PA in the intervention.
### Table 1. Study methodology & participant characteristics.

<p>| Author, Year | Country   | Design       | Duration | Participants | Age: Mean (SD) years | Gender | Mental Health Conditions | eHealth as a Standalone or Component of Multimodal Intervention | Inclusion Criteria                                                                 | Exclusion Criteria                                                                 |
|--------------|-----------|--------------|----------|--------------|----------------------|--------|--------------------------|---------------------------------------------------------------|----------------------------------------------------------------------------------|
| Beiwinkel et al., 2016&lt;sup&gt;16&lt;/sup&gt; | Germany   | Pilot Observational Cohort Study | 12 months | 13 participants with bipolar disorder | 47.2 (3.8) | Male: 8 Female: 5 | 13 participants with bipolar disorder | N/A | Diagnosis of bipolar I or bipolar II disorder according to the criteria in the DSM-IV ≥18 years of age | The need for inpatient treatment at the time of recruitment Suicidality Diagnosis of schizophrenia or an intellectual disability Alcohol or drug abuse up to 6 months prior to the study |
| Glozier et al., 2013&lt;sup&gt;20&lt;/sup&gt; | Australia | RCT          | 12 weeks | 562 (75 drop-outs) 487 analysed | IG: 57.5 (6.6) CG: 58.4 (6.6) | IG: Female, 173 (61.8%) CG: Female, 172 (61.0%) | 487 participants with psychological distress | Multimodal: Internet delivered cognitive-behavioural therapy designed to address areas including physical activity and symptoms of depression | Self-reported history of CVD, or risk factors for CVD, defined as any one of the following: receiving treatment for heart attack/angina, other heart disease, hypertension or high blood cholesterol in the past month; taking medications for heart disease, hypertension or high blood cholesterol in the past month; previous doctor’s diagnosis of heart disease, stroke or hypertension; previous doctor’s diagnosis of diabetes and report taking glucose lowering therapy in the past month; two or more of the following risk factors: current smoker, obese (BMI&gt;30), aged 65 years or more, family history of heart disease or stroke in two or more first degree relatives, all of which are well established risk factors for CVD Psychological distress at recruitment to the health survey, defined with a high sensitivity as a Kessler-10 (K-10) score of greater than or equal to 16. This screening score reflects distress six months to three years prior to trial recruitment Provided an email address established as previously valid through 45 and Up Study checking processes | N/R |</p>
<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Country</th>
<th>Design</th>
<th>Duration</th>
<th>Participants</th>
<th>Age: Mean (SD) years</th>
<th>Gender</th>
<th>Mental Health Conditions</th>
<th>eHealth as a Standalone or Component of Multimodal Intervention</th>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kerr et al., 2008</td>
<td>USA</td>
<td>Pilot Non-Randomised Study</td>
<td>12 weeks</td>
<td>36 (13 drop-outs)</td>
<td>44.1 (9.8)</td>
<td>Males: 9 (25%) Females: 27 (75%)</td>
<td>36 participants with depression</td>
<td>N/A</td>
<td>English speaking men and women, aged 25–65 years, with newly diagnosed or recurrent mild-to-moderate depression (PHQ-9 score 15 or greater at screening) Doctor approved prescription of escitalopram (Lexapro) Telephone and internet access at home Ability to participate in mild- to moderate-intensity physical activity (PAR-Q) Willingness to participate in all study components</td>
<td></td>
</tr>
<tr>
<td>Mailey et al., 2010</td>
<td>USA</td>
<td>Pilot RCT</td>
<td>10 weeks</td>
<td>47</td>
<td>25 (range 18–52)</td>
<td>Females: 32 (68.1%) Males: 15 (32%)</td>
<td>Participants receiving mental health counselling. No further details supplied.</td>
<td>Standalone: Physical activity website. The website featured four models based on social cognitive theory.</td>
<td>Be registered for and receiving mental health counselling services A student at the university Able to participate in physical activity without exacerbating a pre-existing condition Access to a personal computer with internet connection.</td>
<td>N/R</td>
</tr>
<tr>
<td>Naslund et al., 2016</td>
<td>USA</td>
<td>Observational Cohort Study</td>
<td>6 months</td>
<td>43 recruited (9 drop-outs)</td>
<td>50.2 (11.0)</td>
<td>Female: 21 (61.8%) Male: 13 (38.2%)</td>
<td>Schizophrenia spectrum disorders: 8 (23.5%) Major depressive disorder: 17 (50.0%) Bipolar disorder: 9 (26.5%)</td>
<td>N/A</td>
<td>≥21 years old Serious mental illness defined by an axis I diagnosis of schizophrenia, schizoaffective disorder, major depressive disorder, or bipolar disorder Speaks English On stable pharmacological treatment defined as receiving the same psychiatric medications over the prior 2 months Obesity (BMI ≥30).</td>
<td>Participants were excluded if they had any medical contraindication to weight loss Pregnant or planning to become pregnant within the next 6 months Current diagnosis of an active alcohol-use or substance-use disorder</td>
</tr>
<tr>
<td>Author, Year</td>
<td>Country</td>
<td>Design</td>
<td>Duration</td>
<td>Participants</td>
<td>Age: Mean (SD) years</td>
<td>Gender</td>
<td>Mental Health Conditions</td>
<td>eHealth as a Standalone or Component of Multimodal Intervention</td>
<td>Inclusion Criteria</td>
<td>Exclusion Criteria</td>
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</tr>
<tr>
<td>Shin et al., 2016</td>
<td>South Korea</td>
<td>Observational Cohort Study</td>
<td>9 days</td>
<td>61 analysed</td>
<td>46.59 (8.40)</td>
<td>Males: 35 (52.4%) Women: 26 (42.6%)</td>
<td>61 participants with schizophrenia</td>
<td>N/A</td>
<td>Patient had to be hospitalized with chronic schizophrenia in a closed ward Be involved in ordinary activity in a regular psychiatric treatment program Agree to wear an activity tracker and keep it continuously for a week</td>
<td></td>
</tr>
<tr>
<td>Ström et al., 2013</td>
<td>Sweden</td>
<td>RCT</td>
<td>9 weeks</td>
<td>48 participants</td>
<td>Total: 49.2 (10.7) IG: 48.8 (12.7) CG: 49.6 (8.7)</td>
<td>Total: Female = 40; Male = 8 IG: Female = 20; Male = 4 CG: Female = 20; Male = 4</td>
<td>48 participants with mild to moderate depression</td>
<td>Standalone: Physical activity based self-help programme administered via the Internet</td>
<td>Mild to moderate major depression diagnosis A sedentary lifestyle</td>
<td>Subclinical depressive symptoms, severe depressive symptoms, dysthymia as a primary diagnosis, elevated suicide risk High levels of physical activity prior to treatment Recent changes in medication Somatic illness making physical exercise inappropriate</td>
</tr>
</tbody>
</table>

group (Pre: 243421.81 vs. Post: 299791.57, Cohen’s d=0.68) compared to the control group (Pre: 247753.55 vs. Post: 251625.04, Cohen’s d=0.05) as measured using the Actigraph accelerometer. Furthermore, Ström and colleagues noted PA significantly increased in both the intervention and control groups, however, there was no significant difference between the CBT based eHealth intervention and waiting list control group.

Physical activity assessment
Objective methods of measuring PA included smartphones (GPS, cell tower movement and accelerometer data)\(^{27}\), wearable technologies (Fitbit)\(^{28,32}\), accelerometers\(^{29}\) and pedometers\(^{31}\) as shown in Table 3. The remaining studies (n=2) used the International Physical Activity Questionnaire (IPAQ) to subjectively measure PA\(^{26}\).

Four studies used eHealth technologies to measure PA in participants with mental health conditions\(^{28,29,31,32}\). Higher levels of PA as measured using eHealth are associated with less manic symptoms as measured using the Young Mania Rating Scale (YMRS) in participants with bipolar disorder (YMRS: beta=-.37, p<0.001)\(^{27}\). In addition, a decline in PA participation was reported to be predictive of an increase in depressive symptoms. In participants with schizophrenia, daily PA levels as measured by an eHealth device (Fitbit Flex\(^{®}\)) showed a moderate association\(^{31}\) with positive (steps per day: -0.508, p<0.001), general (steps per day: -0.39, p=0.002) and total (steps per day: -0.459, p<0.001) scores measured using the Positive and Negative Syndrome Scale (PANSS)\(^{26}\).

eHealth technologies were shown to increase PA participation in participants with depression\(^{31}\). Kerr and colleagues reported daily step count significantly increased from baseline (Mean: 6604.1 (SE: 883.6)) to 12 weeks (Mean: 9053.3 (SE: 818.1)) in 36 participants with depression. In addition, sedentary behaviour reduced from baseline to 12 weeks, however, this did not reach statistical significance (Table 5).

Risk of bias of included studies
Risk of bias of all included studies is noted in Table 4 & Table 5. The Cochrane Collaboration’s tool\(^{33}\) was used to evaluate the risk of bias of the three included RCTs. The Downs and Black checklist assessed the risk of bias of the remaining observational studies (n=4). Individual risk of bias for all of the included studies is included as Supplementary File 3.

Discussion
This systematic review comprehensively searched and evaluated the effect of eHealth interventions on PA levels in participants with a range of mental health conditions. Overall, eHealth interventions appear to be beneficial at promoting PA, although consistent increases in PA were not demonstrated across

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**Table 2. Features of E-Health technologies and interventions employed in included studies.**

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Platform for intervention</th>
<th>App/software</th>
<th>Personalisation</th>
<th>Behaviour change theory</th>
<th>PA Reporting by user</th>
<th>Interaction</th>
<th>Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Web app</td>
<td>Mobile app</td>
<td>Email</td>
<td>Web</td>
<td>Yes</td>
<td>No</td>
<td>SCT</td>
</tr>
<tr>
<td>Beiwinkel et al., 2016(^{27})</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>SIMBA</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Glozier et al., 2013(^{29})</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>E-couch and Healthwatch</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Kerr et al., 2008(^{11})</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Mailey et al., 2010(^{39})</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>IPACS</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Naslund et al., 2016(^{22})</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>Fitbit</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Shin et al., 2016(^{26})</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>Fitbit</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Ström et al., 2013(^{38})</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>-</td>
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</tbody>
</table>

CBT; Cognitive Behavioural Therapy, IPACS; Internet Physical Activity for College Students, SIMBA; Social Information Monitoring for Patients with Bipolar Affective Disorder, SCT-Social Cognitive Theory, TTM-Trans Theoretical Model.
### Table 3. Physical activity outcomes.

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Intervention (IG) and control group (CG)</th>
<th>How PA recorded</th>
<th>Method of PA quantification</th>
<th>Baseline and end-intervention PA results: Mean (Standard Deviation) unless otherwise stated.</th>
</tr>
</thead>
</table>
| Beiwinkel et al., 2016[37] | IG: Physical activity recorded over 12 months in 13 participants with bipolar disorder  
CG: N/A | Smartphone. Three smartphone sensors were used to measure physical activity. 
(GPS for the distance travelled per day, cell tower movement as an indicator of location changes, and accelerometer to measure the users’ device activity) | GPS, distance travelled (km)  
Cell tower changes  
Device activity, % of day | Distance travelled as measured by the GPS signal had a significant negative relationship with clinical manic symptoms (YMRS: beta=-.37, P<.001).  
An increase in cell tower movement was negatively related to both manic symptoms (YMRS: beta=-.17, P<.001) and depressive symptoms (HAM-D: beta=-.11, P=.03) |
| Glozier et al., 2013[30] | IG: 12 weeks of internet delivered cognitive behavioural therapy  
CG: 12-week online programme that delivers health information on topics including nutrition, stroke, physical activity, medicines in the home, blood pressure and cholesterol, and heart health | IPAQ | The average time spent walking per day and a composite measure of undertaking enough exercise to provide a health benefit (defined as at least 150 mins of activity over 5 or more occasions each week) | **Post-intervention**  
**Activity sufficient to confer a health benefit post intervention (150 mins over 5 occasions/week)** (N=number of participants)  
IG: N=136 (67%)  
CG: N=165 (61%) (Odds Ratio 1.91, 95%CI: 1.01–3.61),  
Average walking time per day  
0–14 mins per day, IG: N=78 (38%), CG: N=116 (43%)  
15–29 mins per day, IG: N=47 (23%), CG: N=64 (23%)  
30+ mins per day, IG: N=79 (39%), CG: N=92 (34%) (Odds ratio = 1.46, 95% CI: 0.81–2.62) |
| Kerr et al., 2008[31] | IG: A community based physical activity intervention (involving internet, telephone, and pedometer support), integrated with medication and mood management for depressed patients  
CG: N/A | Pedometer | Steps per day  
Units of measurement for sedentary behavior were not reported | All participants (n=36)  
**Daily step count: Mean (SE)**  
Baseline: 6604.1 (883.6)  
6 weeks: 8558.8 (868.8)  
12 weeks: 9053.3 (818.1)  
Significantly different baseline to 12 weeks: p=0.03  
**Sedentary behavior: Mean (SE)**  
Baseline: 62.2 (5.0)  
6 weeks: 58.9 (4.2)  
12 weeks: 57.6 (4.2)  
Not significantly different at any time-point: p=0.15  
Completers only (n=23)  
**Daily step count: Mean (SE)**  
Baseline: 6656.2 (1618.7)  
6 weeks: 8903.2 (1665.2)  
12 weeks: 8550.0 (1374.4)  
Not significantly different at any time-point: p=0.22  
**Sedentary behavior: Mean (SE)**  
Baseline: 63.4 (6.3)  
6 weeks: 58.9 (4.3)  
12 weeks: 56.8 (4.4)  
Not significantly different at any time-point: p=0.09 |
<table>
<thead>
<tr>
<th>Author, year</th>
<th>Intervention (IG) and control group (CG)</th>
<th>Physical activity outcomes and result</th>
<th>Method of PA quantification</th>
<th>Baseline and end-intervention PA results: Mean (Standard Deviation) unless otherwise stated.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailey et al., 2010&lt;sup&gt;29&lt;/sup&gt;</td>
<td>IG: An internet-based physical activity intervention on physical activity, self-efficacy, depression, and anxiety in college students (n=23) receiving mental health counselling CG: Standard mental health care (n=24)</td>
<td>Physical activity pre-intervention</td>
<td>Actigraph accelerometer</td>
<td>Total daily activity score presented as 1-minute epochs Daily totals were averaged across five days of continuous activity</td>
</tr>
<tr>
<td>Naslund et al., 2016&lt;sup&gt;42&lt;/sup&gt;</td>
<td>IG: Daily step count measured using Fitbit wearable devices to improve weight loss and fitness among individuals with serious mental illness enrolled in a 6-month lifestyle programme CG: N/A</td>
<td>Physical activity post-intervention</td>
<td>Fitbit</td>
<td>Steps per day</td>
</tr>
</tbody>
</table>

**Physical activity pre-intervention**
- IG: 243421.81 (62414.56)
- CG: 247753.55 (69613.96)

**Physical activity post-intervention**
- IG: 299791.57 (102800.00)
- CG: 251625.04 (83080.77)

A significant main effect for time with both conditions increasing their physical activity levels across the 10-week period, \( F(1, 40) = 4.20, p=0.04, n^2 = 0.09 \).
<table>
<thead>
<tr>
<th>Author, year</th>
<th>Intervention (IG) and control group (CG)</th>
<th>Physical activity outcomes and result</th>
<th>Method of PA quantification</th>
<th>Baseline and end-intervention PA results: Mean (Standard Deviation) unless otherwise stated.</th>
</tr>
</thead>
</table>
| Shin et al., 2016<sup>26</sup> | IG: Physical activity, measured using an mHealth device, correlations with psychopathology in participants with chronic schizophrenia  
CG: N/A | Fitbit | Steps per day | Mean daily activity: 12,649.21 ± 5883.99 steps/day.  
Range: 3612 – 29,663 steps/day  
Significant correlations were found between daily activity and PANSS positive, general and total subscale.  
**Activity levels (steps per day)**  
PANSS-positive; -0.508 (p<0.001)  
PANSS-negative; -0.356 (p=0.005)  
PANSS-general; -0.39 (p=0.002)  
PANSS-total; -0.459 (p<0.001)  
PANSS 5-factor positive; -0.495 (p<0.001)  
PANSS 5-factor negative; -0.445 (p<0.001)  
PANSS 5-factor disorganisation; -0.362 (p=0.004) |
| Ström et al., 2013<sup>28</sup> | IG: Internet based therapist delivered self-help programme  
CG: Waiting list | IPAQ | Total MET minutes per week | **IPAQ**  
**IG:**  
• Pre: 778 (695)  
• Post: 1331 (990)  
• 6-months: 1282 (1255)  
**CG:**  
• Pre: 953 (670)  
• Post: 1143 (918)  
• 6-months: N/a  
**Between groups effect size: Cohen’s d = 0.20**  
**Within groups effect size:**  
• IG Cohen’s d = 0.66  
• CG Cohen’s d = 0.24  
Physical activity increased in both groups, no significant difference between two groups |

HAMD: Hamilton Depression Scale, IG: Intervention Group, IPAQ: International Physical Activity Questionnaire, CG: Control Group, METS: Metabolic Equivalent of Task, PA: Physical Activity, PANSS: Positive and Negative Syndrome Scale, YMRS: Young Mania Rating Scale. Data is presented as mean (standard deviation) unless otherwise stated.
all studies. Importantly perhaps, higher levels of PA were associated with improvements in clinical signs and symptoms of mental health conditions (e.g. mood) in two studies. Although beneficial in increasing PA levels, it is currently unclear if eHealth interventions are superior to traditional care at increasing PA as results are inconsistent. A summary of objectives and best available evidence is shown in Table 6.

Glozier and colleagues noted a greater proportion of participants achieved the recommended levels of PA (≥150 mins a week) in favour of the e-health intervention compared to the control group (67% in ICBT vs 61% in control group, Odds Ratio: 1.91, 95% CI: 1.01–3.61). The risk of bias for this study as measured using the Cochrane collaboration tool was relatively low in a number of domains. In contrast, two studies comparing eHealth interventions to control treatments reported no significant differences between the intervention and control arms in terms of PA, however both of these studies were rated as unclear risk of bias in a number of domains. In addition, both of these studies had much smaller sample sizes compared to the study by Glozier and colleagues which was notably much larger in size (n=487) compared to other studies included in this review. It should be noted however that Glozier and colleagues employed a subjective measure of PA, the IPAQ, compared to the more reliable objective measure of PA, the Actigraph accelerometer used by Mailey and colleagues.

Table 4. Cochrane risk of bias assessment of intervention studies.

<table>
<thead>
<tr>
<th>Risk of Bias Domain</th>
<th>Glozier et al., 2013</th>
<th>Mailey et al., 2010</th>
<th>Ström et al., 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence generation</td>
<td>Low</td>
<td>Unclear</td>
<td>Low</td>
</tr>
<tr>
<td>Allocation concealment</td>
<td>Low</td>
<td>Unclear</td>
<td>Unclear</td>
</tr>
<tr>
<td>Blinding of participants, personnel and outcome assessors</td>
<td>Low</td>
<td>Unclear</td>
<td>Unclear</td>
</tr>
<tr>
<td>Incomplete outcome data</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Selective outcome reporting</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Unclear</td>
</tr>
<tr>
<td>Other sources of bias</td>
<td>Unclear</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 5. Downs and Black risk of bias assessment of observational studies.

<table>
<thead>
<tr>
<th>Author</th>
<th>Downs and Black Risk of Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beiwinkel et al., 2016²⁷</td>
<td>11/18</td>
</tr>
<tr>
<td>Kerr et al., 2008³¹</td>
<td>17/20</td>
</tr>
<tr>
<td>Naslund et al., 2016³⁵</td>
<td>19/20</td>
</tr>
<tr>
<td>Shin et al., 2016²⁶</td>
<td>16/17</td>
</tr>
</tbody>
</table>

Table 6. Summary of best available evidence for review objectives.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Best available evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>The effectiveness of eHealth technologies as a stand-alone or component of a multimodal intervention to promote PA in people with a mental health condition</td>
<td>Evidence from one high quality RCT supports the use of eHealth technology as part of a multimodal intervention in individuals with psychological distress and concomitant CVD in increasing the likelihood of achieving PA guidelines for adults (Odds Ratio 1.91, 95% CI: 1.01–3.61).</td>
</tr>
<tr>
<td>The effectiveness of eHealth technologies to measure PA among people with mental health conditions</td>
<td>Evidence from three moderate-high quality observational studies reported eHealth technologies offer a feasible, potentially effective method of measuring PA among people with mental health conditions.</td>
</tr>
<tr>
<td>The effectiveness of eHealth technologies, designed to monitor PA, on general or mental health profiles</td>
<td>Evidence from one high quality observational study reported that for participants with schizophrenia, daily PA levels as measured by an eHealth device (Fitbit Flex), showed a significant association with positive (steps per day: -0.508, p&lt;0.001), general (steps per day: -0.39, p=0.002) and total (steps per day: -0.459, p&lt;0.001) scores measured using the Positive and Negative Syndrome Scale (PANSS).</td>
</tr>
</tbody>
</table>
Subjective methods of measuring PA are more prone to error compared to objective measures such as pedometers and accelerometers\(^3\). Subjective measures of PA raise the likelihood of self-report bias influencing results as participants are instructed to think about PA. Furthermore, subjective measures are liable to recall bias, further limiting the interpretability of these results. eHealth technologies such as smartphones and wearable technology (i.e., Fitbit) demonstrate good validity and reliability at measuring PA and have been noted to improve patient motivation to partake in PA\(^{22-24}\). The use of such tools may limit the influence of bias and other factors associated with subjective measures of PA\(^{25}\).

Experimental studies in this review varied in the type of behavior change theory supporting the eHealth intervention. Glozier and colleagues employed an internet-delivered CBT approach in people with psychological distress and was compared to an online active control group. This online programme, Health-Watch, consisted of 12 weeks of information on topics such as PA and nutrition. In addition, Ström and colleagues performed a similar experimental study comparing internet-delivered CBT compared to a wait-list control group. It was not possible to individually assess or estimate whether it was the method of delivery or behavioural change theory supporting the intervention or a combination of these two elements which resulted in any observed changes.

eHealth technologies are rapid and constantly evolving through continuous software and hardware updates that regularly outpace medical research. The RCT is widely regarded the gold-standard of experimental research, however the mean duration from enrolment to publication is 5.5 years\(^{26}\). eHealth technologies are likely to become obsolete within this time-frame. A call has been made for medical research to evolve and adapt to maintain pace with developments in eHealth\(^{27}\). The Continuous Evaluation of Evolving Behavioural Intervention Technologies (CEEBIT) methodological framework has been proposed as an alternative to the conventional RCT design\(^{28}\). It is statistically powered to continuously evaluate eHealth applications throughout the study duration while accounting for updates to the application. Therefore, future eHealth interventions should consider using this novel methodological framework specific to the ever evolving eHealth technologies.

Further research is required to make a judgement of the ability of eHealth interventions to increase PA in people with mental health conditions. A recent systematic review showed that drop-out rates from exercise trials in people with depression are lower when delivered by a health professional with specific training in exercise prescription\(^{29}\). The need for qualified personnel to supervise PA programmes for people with schizophrenia was also echoed in a review by Vancampfort (2016)\(^{30}\). Drop-out rates of the PA arm of randomised controlled trials in people with schizophrenia was reported to be 26.7\%\(^{41}\). Amalgamated drop-out rates for the current review show a lower drop-out rate of 12.5\% but this may be reflective of the mixed mental health population with the majority having mild-moderate depression. It is not known whether the remotely delivered nature of eHealth interventions may result in less or more efficacious outcomes than traditionally delivered programmes. Head-to-head comparisons between these intervention mediums are necessary to elucidate the relative benefits of each.

Previous reviews in other clinical populations such as cancer survivors have reported that the initial results of eHealth technologies to increase PA in the cancer rehabilitation setting are promising\(^{31}\). However, similar to this review, weaknesses in methodological quality and uses of subjective measures of PA limit the interpretability of these findings.

Mental health conditions and CVD are inextricably linked as there is a high prevalence of CVD in people with mental health conditions due to a number of behavioural and lifestyle factors that confer increased CVD risk\(^{32}\), and similarly people with CVD have a high prevalence of mental health disorders\(^{33}\). Therefore, evaluation of the ability of eHealth interventions to ameliorate CVD risk is an important consideration, but this was beyond the scope of this review. Future reviews should explore this topic.

Perhaps due to this nascent field of research, the methodological quality of the included studies is low. This review has a number of suggestions to improve the methodological quality of studies examining eHealth interventions and PA participation among mental health populations. Future studies should use objective measures of PA, including but not limited to pedometers, accelerometers and wearable technology. In addition, eHealth interventions should adhere to improved reporting of interventions, to ensure that such interventions can be repeated. Follow-up times in this review have varied from 9 days–12 months, with the majority of studies not recording PA levels in the maintenance phase. Therefore, the long-term implications of eHealth technologies to increase PA in a mental health population should be explored.

Limitations

There are several notable limitations to this review. Firstly, due to the relatively new nature of eHealth technologies to promote PA among people with mental health conditions, the number of studies included was relatively low (n=7). Secondly, six studies were excluded as only abstract proceedings were available. In each case the authors were contacted to ascertain if further information pertaining to these studies could be supplied however, no further data was supplied and these studies were subsequently excluded from this review. Although this significantly reduced the number of articles a lack of a detailed methodology may have increased bias if these studies were included. Thirdly, eligibility criteria in the study by Mailey and colleagues was unclear it was reported that participants with mental health disorders were recruited, however the criteria used to classify mental health disorders was not specified. Therefore, it is unclear the exact type of mental health disorders in this study population. In addition, Glozier and colleagues reported recruiting participants with mild-moderate depression. They used Kessler-10 screening tool to screen
for depression, however it is a global measure of distress encompassing questions about both anxiety and depression. A possible further limitation is the distinction we have made between observational and interventional studies, as plausibly, if PA is monitored, this may in itself influence PA behaviour blurring the distinction between these two types of studies. The extent of behavioural change as a result of monitoring PA using eHealth is not known at this time and warrants further investigation. Finally, both observational and interventional studies were included in this review which resulted in strong heterogeneity which precluded the ability to quantitatively analyse results.

Conclusion
eHealth interventions appear beneficial at promoting PA and improving mental health symptoms for people with mental health conditions. Even though some of the included studies in this review demonstrated promising results, methodological restrictions and potential biases from using subjective measures of PA limit the interpretability of these results. Currently, it is unclear if eHealth interventions are superior compared to traditional interventions methods to increase PA. Larger well-designed studies are needed to extensively evaluate the true potential of this medium.

Data availability
All data underlying the results are available as part of the article and no additional source data are required.

Competing interests
No competing interests were disclosed.

Grant information
Health Research Board Ireland [CFT-2014-880].

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.
Open Peer Review

Current Peer Review Status: ✔ ✔ ✔

Version 2

Reviewer Report 09 July 2018
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Helen P. French
School of Physiotherapy, Royal College of Surgeons in Ireland, Dublin, Ireland

The authors have made necessary amendments and as a result the manuscript is easier to follow. I have a couple of minor suggested changes.

In relation to the aims, I suggest that they clarify studies were included if Ehealth was ‘a component’ of a multimodal approach. It would also be useful to include in the results, possibly table 1, which studies were ‘stand-alone’ or which were part of a multimodal approach.

Pg 5 – minor grammatical error. A qualitative synthesis ‘was’ planned, rather than ‘were’ planned.

In table 3, the units of measure are not always obvious e.g. Kerr et al- ‘sedentary behaviour’ outcome. Mailey study- were there any units of measure? Can you amend where relevant

Otherwise, I am satisfied with the changes made to the manuscript.

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 11 Jul 2018
Julie Broderick, Trinity College Dublin, University of Dublin, Dublin, Ireland

We would very much like to thank the reviewer for her insightful comments

Competing Interests: No competing interests were disclosed.
Jennifer M. Ryan

1 Department of Epidemiology and Public Health Medicine, Royal College of Surgeons in Ireland, Dublin, Ireland
2 Department of Clinical Sciences, Brunel University London, Uxbridge, UK

I'd like to thank the authors for considering my comments. I believe the amendments made have resulted in an improved review and am satisfied that they have fully addressed my comments.

**Competing Interests:** No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

---

Olive Lennon

School of Public Health, Physiotherapy and Sports Science, University College Dublin, Dublin, Ireland

I am satisfied that this article has been sufficiently revised to warrant full acceptance. The addition of a best evidence table is a welcome and valuable addition and the authors have considered and responded to all recommendations. The final point in the best evidence table may need minor editing.

**Competing Interests:** No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.
Abstract
- Background: change ‘mental conditions’ to ‘mental health conditions’
- In the methods section can you provide some information on the methodological quality evaluation of the review
- In the conclusion section, the word nascent is not very common, so I would suggest changing it to another term that would be more familiar to non-native English readers.

Methods
- In the ‘eligibility criteria’ section, was a full-text version of a study an inclusion criterion?
- Please provide full word for SMS
- In the data analysis section, suggest changing the word ‘abstraction’ to ‘extraction’
- In Figure 1: please add in the box for number of duplicates removed in line with PRISMA flowchart.

Results
- The results section is quite confusing to read, generally because of the way the information is presented in the different tables.
- The presentation of the results in the different tables could be clearer. I suggest merging the content of Tables 1-3 into 2 tables. Please also check the abbreviations in the tables are explained in the legends e.g. CVD, PAR-Q not explained currently.
- Review text in each table thoroughly to ensure information is presented more succinctly
- In table 2, in the column (sex baseline), suggest changing to ‘Gender’. I am unclear why gender is reported for non-missing data and why the word ‘baseline’ is there. In relation to the Mailey study, if the mental health condition was not reported, how did you determine it was eligible for inclusion.
- In relation to Table 3: it would be more useful to provide information on risk of bias for individual items, as overall risk of bias is somewhat meaningless. Issues such as randomisation, baseline comparability, intention-to-treat analysis and drop-out rates are important to report to allow the reader to interpret results in the context of study methodology.
- Table 4:
  - Row on Belwinkel study: results presented in the last column are confusing. I do not think that the between-patient analysis and between-patient analysis is relevant. The results should focus on pre-post intervention results.
  - Row on Naslund study: in the last column, were these results related to post 6-month lifestyle programme?
  - Row on Shin study 2016- please review wording in the first column to ensure clarity.
  - Row on Strom study, please provide the units of measure for IPAQ in the last column.
In the paragraph on ‘Participant Characteristics’ is there a typing error here ‘709 participants 7 were analysed’. Please review this sentence.

Pg 8, 3rd paragraph, please clarify that ‘significance’ relates to ‘statistical significance’

Pg 8, 5th paragraph change ‘there was no significant differences’ to ‘that no significant differences’
In the same paragraph, what does the ‘d’ refer to in relation to the results presented- should this be p?

Discussion

- The discussion section is well written and raises some interesting points.
- Please add a section outlining the limitations of this review

Are the rationale for, and objectives of, the Systematic Review clearly stated?
Yes

Are sufficient details of the methods and analysis provided to allow replication by others?
Yes

Is the statistical analysis and its interpretation appropriate?
Partly

Are the conclusions drawn adequately supported by the results presented in the review?
Partly

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.
benefits of physical activity and describing eHealth. Further information on the benefits of using eHealth for people with mental health conditions, over other modes of service delivery, would strengthen the rationale for this review.

Appropriate methods were used to address the objective of the review. In particular, study eligibility was assessed independently by two reviewers, data were extracted by two reviewers using a standardised data extraction form, and risk of bias was assessed. The methods and results of this review are strengthened by the use of the PRISMA checklist and by registering the protocol in advance of conducting the review.

However, the review would be improved if there was better alignment between the objective, methods and results. There is discrepancy between the objective of the review, the types of study included in the review, and the results. The description of the types of study included in the review could be clearer. Study designs are often considered as “intervention” studies and “observational” studies. An intervention study may be randomised or non-randomised. Critically, the inclusion of studies that include an intervention but are termed observational studies seems contradictory. This may be improved if the use of eHealth is considered an exposure and studies were therefore classified as cohort studies, but if this is the case it could be explained more clearly. The lack of clarity over study design is compounded by the description of study design in Table 1. For example, Beiwinkel et al. is reported as a pilot observational study, but the type of observational design is not reported (e.g. cohort, case-control, cross-sectional), while this detail is provide for Naslund (i.e. “observational cohort study”). Perhaps of more importance is that Kerr et al. is reported as a pilot study but it is not clear if it is an intervention study or observational study.

The authors identify only a small number of studies examining the effect of eHealth on physical activity in people with mental health conditions (n=7), and only three of these are randomised controlled trials (n=3). The results of the randomised controlled trials provide inconsistent evidence that eHealth results in an increase in physical activity. However, it is difficult to determine if the content of the intervention (e.g. CBT) or the fact that it’s delivered electronically is responsible for the change in the PA. It would help the reader to understand the causal pathway if the content of the comparator was described when reporting the results of the study. For example, if the control group received the same intervention (e.g. CBT) as the intervention group but delivered in person rather than electronically it is more plausible than any change in PA is due to eHealth rather than the content of the intervention. If there is no difference in PA between groups eHealth may offer additional benefits such as being more feasible and cost-effective to deliver.

It is not clear, based on the objective and eligibility criteria, why studies that used an eHealth intervention to measure physical activity were included. If monitoring physical activity was considered an intervention, and physical activity was measured pre- and post-introduction of PA monitoring then these studies should be considered intervention studies, and the outcome reported should be change in PA. Monitoring PA is a behaviour-change technique, and as such is very likely an intervention. The authors do report change in PA following PA monitoring for some studies but not all.

The results include findings relating to associations between physical activity/change in physical activity and symptoms and weight loss. While this is of interest it goes beyond the objectives of the review. If an objective of the review is to explore associations between PA and other variables in people with mental health conditions it should be stated under the study objective and the eligibility criteria should be amended accordingly.

Further information on how each domain on the risk of bias tools were assessed and how the overall risk
of bias was determined for RCTs should be provided to allow the reader to understand the quality of the studies and justify areas for future research. It is stated in the discussion that Glozier et al. used a self-report measure of physical activity and this may introduce bias. This should be captured under detection bias when assessing risk of bias. However, despite this, Glozier et al. is rated as low risk of bias. It would be beneficial to understand how the authors determined the study was at low risk of bias despite the outcome assessor not being blinded (as a self-report measure was used).

The authors provide a summary of the findings of the review and discuss a number of pertinent points including the potential to introduce bias by using self-report measure of PA and the need for studies to directly compare eHealth with physical activity interventions delivered in person. The discussion suggests that eHealth is feasible. However, examining the feasibility of eHealth is not a specific objective and the presentation of results do not support this conclusion. If this is of interest, and studies examine feasibility, this should be an objective and results reported accordingly.

The authors reach a sound conclusion based on the findings of the review, acknowledging the limitations with previous studies. However, given that Glozier et al. was a large study (n=562) and it was rated low risk of bias, the statement that larger well designed studies are needed is not justified. Specific information about the limitations of Glozier et al., which a future trial needs to address, should be provided.

Further points for consideration:
To improve consistency throughout the review, the title and objective should align (i.e. the title states to “promote physical activity in patients with mental health conditions” and the objective states “to increase physical activity in individuals with mental health conditions”.

The results section of the abstract is misleading and suggests different conclusions than those presented in the main text. Although three studies reported that eHealth increased PA, the change in PA over time is not of interest when a control group is included, as is the case in these studies. Where a control group is included the effect of interest is whether a larger change in PA is observed in the intervention group in comparison to the control group.

A definition of eHealth could be provided under “eligibility criteria” to further explain decisions regarding exclusion of studies. The description of eHealth in the introduction, as “the transfer of health resources and health care by electronic means, including but not limited to the delivery of health information through the internet and mobile technologies” suggests that interventions that use only telephone calls, SMS or conference calls, are eHealth. These studies were however excluded.

A definition of mental health conditions and/or examples of mental health conditions of interest included in the section on eligibility criteria would be beneficial in order to describe the participants of interest.

Under eligibility criteria it states that “we included the following methods of measuring PA...”. These, however, are ways of quantifying rather than measuring PA. As the sentence after this correctly states, methods of measuring PA are self-report measures e.g. questionnaires, and objective measures, e.g. accelerometers, indirect calorimetry.

For clarity, it would be helpful if the authors stated if data were extracted independently by two researchers.

The authors describe where they were not able to conduct the review as planned e.g. quantitative
synthesis. However, it would be helpful for the reader to have a section summarising the differences between the protocol and review.

It would make the results easier to read if subsections were ordered as follows: results of the search, description of included studies (design, participants, settings, interventions, comparator, physical activity assessment), risk of bias, effect of interventions.

Authors were unable to obtain full text for 6 articles. If full texts were obtained this may nearly double the number of included articles. Further explanation of why these full texts were not found or the potential limitation of not including this data should be provided.

Data are plural (i.e. “data were”).

It would be helpful for the reader if the authors stated the full name of the IPAQ before abbreviating and stated if the short or long form was used.

When reporting studies by author in text and tables e.g. Glozier, it would be helpful to cite the reference number (e.g. 22) to allow cross-referencing with different sections of the text.

It is stated in the discussion that the Actigraph accelerometer is more reliable than the IPAQ; this statement should be supported.

Are the rationale for, and objectives of, the Systematic Review clearly stated?
Yes

Are sufficient details of the methods and analysis provided to allow replication by others?
Partly

Is the statistical analysis and its interpretation appropriate?
Not applicable

Are the conclusions drawn adequately supported by the results presented in the review?
Partly

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 11 Jul 2018
Julie Broderick, Trinity College Dublin, University of Dublin, Dublin, Ireland

We would like to very much thank the reviewer for her insightful comments

Competing Interests: No competing interests were disclosed.
This systematic review explores the available evidence to support ehealth technology (utilising internet and mobile technologies) as a stand-alone intervention or as part of a multimodal intervention to increase physical activity in individuals with mental health conditions. The introduction addresses the importance of Physical Activity (PA) in general and mental health populations and supports the use of eHealth technology, as an interventional means to affect positive change in mental health. It highlights that no systematic review to date has considered the utility of eHealth technology to promote PA for mental health conditions/ in mental health populations and as such this review makes a valuable contribution to the literature in the area. The methodology outlined conforms to best practice guidelines in systematic review (PRISMA) and the review was registered with the international prospective register of systematic reviews (PROSPERO).

As behavioural intervention technologies are a relatively new and evolving area, the authors of the review opted to include both experimental and observational studies in their review and data synthesis. The reviewers believe that this was the correct choice and commend the authors in taking this approach. However this brings its own challenges when reporting and summarising the available evidence in a clear and accessible format for readers of this review. These difficulties are further compounded when the interventions delivered include multi-modal packages underpinned by different theoretical frameworks for behaviour change, different delivery platforms and heterogeneous populations with a variety of mental health conditions.

Greater clarity on how the authors are distinguishing between mobile technologies which monitor activity levels versus those which are utilised as an intervention designed to improve PA. For example the Shin et al., 2016 study included in this review, employs a Fitbit to measure activity levels in individuals with chronic schizophrenia and examines the association between this measure and psychopathological profiles. Table 5 which summarises the included e-health interventions, outlines that feedback of PA levels to participants was not reported in the Shin et al. study, thus ruling out the device as an ehealth intervention for promoting PA. While the results of this study are narratively reported in the review synthesis, it is not clear whether this was a pre stated objective in the methodology.

To address these issues, the reviewers suggest that the title and objectives should reflect broader objectives
e.g. The use of eHealth to promote or monitor physical activity in individuals with mental health conditions: a systematic review

In addition, given the complexity in study types and interventions considered in this review, the reviewers recommend the authors state their objectives as clinically relevant questions and that the results reported
follow this outline and conclude with a best evidence synthesis summary for each question.
e.g. Can eHealth technology as a stand-alone or component of a multimodal intervention improve PA in individuals with a mental health condition?
Do eHealth interventions designed to promote PA improve general or mental health profiles in individuals with a mental health condition?
Are eHealth captured PA levels, of individuals with a mental health condition, associated with severity of clinical signs and symptoms of the mental health condition?

Results of the review can then be narratively synthesised and a best evidence synthesis summary provided. An example of what is suggested as summary is provided below but should be in table format:

**Question:**
Can ehealth technology as a stand-alone or component of a multimodal intervention improve PA in individuals with a mental health condition?

**Best available evidence**
Evidence from one high quality RCT supports the use of ehealth technology as part of a multimodal intervention in individuals with psychological distress and concomitant CVD in increasing the likelihood of achieving PA guidelines for adults (Odds Ratio 1.91, 95%CI: 1.01–3.61)

**Question:**
Do ehealth interventions designed to promote physical activity improve general or mental health profiles in individuals with a mental health condition?

**Best available evidence.....**

Other comments the peer reviews raise for consideration are summarised below:

**Title:**
The reviewers recommend that the authors change the wording *patients with mental health conditions* to *individuals with mental health conditions* and continue this throughout the text.

**Abstract:**
In the results, it is not correct to say that four studies reported that higher levels of PA resulted in improvements in mental health outcomes. We suggest this should read as ... four studies reported that higher levels of PA are associated with better mental or general health profiles.

**Manuscript:**
**Methods:** In the data extraction and analysis section, the authors provide results with reference to heterogeneity in study design, participants etc. These should be reported in the results section. In the methods section only the proposed analysis should be stated.
Similarly with respect to subgroup analyses, only the proposed analyses should be reported in the methodology section. Results of the data presented from the review that prohibited this analysis should not be presented in this section.

**Tables:** The reviewers recommend collapsing a number of the study summary and quality review tables and include the reference number with the study identified to allow the reader to better consider multiple study aspects together and reference back and forth more easily to the narrative summary provided.

In the results section of table 4 the reviewers advise the following:
Beiwinel et al., remove the between patient and within patient analysis labels as these are not relevant to
the analysis and results provided
Kerr et al., please report were within group changes statistically significant and provide p values
Mailey et al., please report the results of the main effect analysis.
Naslund et al., please detail whether within group change scores over the intervention period were reported and their significance
Sin et al., please provide a reference correlation coefficient (r or rho) used in the analysis conducted and comment on the strength of the association identified (moderate to strong) before addressing whether these were significant associations
Strom et al., please provide the results of the within and between group analysis conducted

Table 5: please reconsider the label: Features of eHealth Interventions. Given the inclusion of the Shin et al. study this would be better labelled as Features of eHealth technologies and interventions employed in included studies.

Results:
The peer reviewers request further clarity with respect to the Glozier study in the participant characteristics section of the text. Here the Kessler-10 screening tool for psychological distress was used to identify individuals with CVD and a mental health condition identified as a K-10 >=16. As this tool screens for both symptoms of depression and anxiety, please justify the inclusion of this group under the summary of included participants with a depressive disorder.

In the risk of bias section in the text, please provide a summary of the quality of the observation studies. Results are difficult to interpret from the table provided. Please indicate whether the results generated indicate high or low quality in the included studies. This detail becomes more relevant when readers consider the best available evidence, in the absence of RCTs in the area.

Discussion:
The discussion section considers the findings of this review well and with broad consideration of the contemporary literature. As the primary finding of this review lies in a population of individuals with high psychological distress and concomitant CVD, the discussion would benefit from considering what is known with respect to eHealth technologies for promoting PA in CVD. Similarly where the association between higher levels of PA and clinical signs and symptoms is discussed, it would be worth exploring the broader PA in mental health literature to strengthen discussion in this area. Here the peer reviewers reiterate concerns in stating that increased PA levels are associated with improved clinical signs and symptoms. This is only possible where the studies have looked at the linear association between changes in clinical signs and symptoms and changes in PA levels and we believe the studies cited have not clearly addressed this.

In conclusion this systematic review was conducted with scientific rigour and makes a valuable contribution to the scientific literature in the area. The authors, as a result of this review, provide valuable recommendations for future research with respect to PA measurement and intervention reporting that will enable better standardisation and data synthesis at a future date.

Are the rationale for, and objectives of, the Systematic Review clearly stated?
Partly

Are sufficient details of the methods and analysis provided to allow replication by others?
Yes
Is the statistical analysis and its interpretation appropriate?
Yes

Are the conclusions drawn adequately supported by the results presented in the review?
Partly

**Competing Interests:** No competing interests were disclosed.

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however we have significant reservations, as outlined above.

**Author Response 11 Jul 2018**

**Julie Broderick,** Trinity College Dublin, University of Dublin, Dublin, Ireland

We would very much like to thank the reviewers for their insightful comments

**Competing Interests:** No competing interests were disclosed.