Text messages to reduce depressive symptoms. Do they work and what makes them effective? A systematic review.

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Keywords:	Text message, Depression, SMS, Depressive symptoms, Mobile phone
Abstract:	Objective In this systematic review and meta-analysis, we aim to quantify the effects of text messaging interventions to reduce depressive symptoms and identify variables that may influence the effectiveness of the intervention. Design Electronic databases including EMBASE, CENTRAL, MEDLINE, CINAHL, PsycINFO and SCOPUS as well as Clinicaltrials.gov and WHO International Clinical Trials Registry Platform (ICTRP) were searched for randomized controlled trials that sent one or more text messages with health-related content to adults who had been identified by a health care provider. Results Seven trials (9 comparisons), with 1918 participants were included in the review, the pooled analysis revealed a borderline statistically significant reduction in depressive symptom scores between the text messaging intervention and control groups (Standardised Mean Difference, SMD -0.27; 95% CI -0.54 to 0.00; P 0.05) favouring intervention at the end of intervention. Statistically significant reductions were shown in important subgroups e.g. where the primary aim of the messages was to reduce depressive symptoms; in those using the BDI or PHQ-9 questionnaires; text message content was targeted at mental well-being, mood improvement and cognitive behavioural therapy information; and the message frequency was ≥2 times per week. Conclusions Text messaging has potential as an intervention to reduce depressive symptoms. The results of this review should be interpreted with caution due to the methodological limitations of included trials. More research is

	required before recommendations can be made about the routine use of text messaging interventions.

Text messages to reduce depressive symptoms. Do they work and what makes them effective? A systematic review

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ABSTRACT

Objective: In this systematic review and meta-analysis, we aimed to quantify the effects of text messaging interventions to reduce depressive symptoms and identify variables that might influence the effectiveness of the intervention.

Design: Electronic databases including EMBASE, CENTRAL, MEDLINE, CINAHL, PsycINFO and SCOPUS as well as Clinicaltrials.gov and the WHO International Clinical Trials Registry Platform (ICTRP) were searched for randomised controlled trials that sent one or more text messages with health-related content to adults who had been identified by a health care provider.

Results: Seven trials (9 comparisons), with 1918 participants were included in the review, the pooled analysis revealed a borderline statistically significant reduction in depressive symptom scores between the text messaging intervention and control groups (Standardised Mean Difference, SMD -0.27; 95% CI -0.54 to 0.00; P 0.05) favouring intervention at the end of intervention. Statistically significant reductions were shown in important subgroups, e.g. where the primary aim of the messages was to reduce depressive symptoms; in those using the BDI or PHQ-9 questionnaires; where text message content was targeted at mental well-being, mood improvement and cognitive behavioural therapy information; and when the message frequency was ≥2 times per week.

Conclusions: Text messaging has potential to reduce depressive symptoms. The results of this review should be interpreted with caution however due to the methodological limitations of included trials. More research is required before recommendations can be made about the routine use of text messaging for the management of depressive symptoms.

Keywords: Text message, depression, SMS, Depressive symptoms, Mobile phone

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Introduction

Depression can vary in aetiology, presentation and duration. However, common symptoms include sadness, irritability or emptiness, with somatic or cognitive changes that disrupt functioning (American Psychiatric Association, 2018). Depression affects 322 million people globally and depressive disorders are now the largest contributor to non-fatal health loss accounting for over 50 million Years Lived with Disability (World Health Organisation, 2017).

Global estimates suggest up to two thirds of people suffering with a mental disorder never seek treatment from a health professional (The World Health Organization, 2001). This may be partially explained by the lack of safe, effective, low-cost treatments for depressive symptoms in many countries. The primary treatments, psychological therapy and pharmacotherapy, can be resource-intensive, costly and have side effects (Allida et al., 2020). In high income countries where treatments are more readily available, the relatively low rates of seeking treatment (46%) is likely caused in part by the stigma associated with having a diagnosis and seeking or requiring treatment (The Black Dog Institute, 2015). Stigma is also a barrier in lower resource countries where the highest burden of mental illness lies, compounded by a lack of funding and workforce shortages preventing many from accessing treatment (Bruckner et al., 2011). Confounding these barriers is the intrinsic nature of depressive symptoms which may include a lack of motivation to seek treatment or comply with lengthy courses of drugs or therapy.

In the last twenty years, mobile phones have almost universally integrated into humans' daily lives. To date, there are 7 billion people who live in an area covered by a mobile telephone network (Sood et al., 2016). Ninety percent of adults own a mobile phone in the USA (Hughes and Granger, 2014). Mobile phone ownership in low- and middle-income countries has increased exponentially, faster than any other health, transport or communication infrastructure (Abaza and Marschollek, 2017), positioning mobile phones as accessible devices, quite literally at our fingertips, that offer a highly adaptable (personalisation, frequency, content) communication channel between healthcare professionals and consumers.

Community attitudes to health-related mobile phone delivered interventions have been positive regardless of sex, education level or employment status of participants, including those with symptoms of anxiety or depression. Perceived benefits included convenience and the potential to reduce isolation (Proudfoot et al., 2010). Qualitative interviews with HIV positive participants in an antiretroviral adherence text messaging intervention revealed they derived ~~derision of~~ greater emotional meanings from simple reminder messages, for example recurring themes of feeling 'cared about' and 'seen' providing a theoretical mechanism of action (Ware et al., 2016). Pearson et al found mobile phone ownership (after adjustments for wealth and education) increased mental wellbeing among rural Ugandans; suggesting that mobile phone interventions that increase social connectedness may also have value in mental health treatment in lower resource countries, remote locations and isolated communities, where such approaches may be more applicable. Other potential mechanisms of text-message intervention efficacy (Dallery et al., 2015) include altering normative beliefs, promoting acceptance of feelings, changing awareness, increasing knowledge and motivation.

In this systematic review and meta-analysis, we aim to summarise the evidence and quantify the effects of using text messaging as an intervention to reduce depressive symptoms for people presenting to healthcare professionals. We also seek to identify what

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variables (content, frequency and personalisation) may influence the effectiveness of text messaging as a health intervention for reducing symptoms of depression.

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Methods

The full systematic review protocol was registered prospectively in PROSPERO: https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=110027

Types of included trials

Randomised controlled trials (RCTs).

Types of participants

We included trials of adults aged ≥ 18 years. Participants were identified for the trial by a healthcare provider, so as to minimise volunteer bias. No exclusions were made on the basis of any reported medical condition among the participants.

Types of interventions

Text messaging interventions, defined as one or more text messages with health-related content sent to a personal mobile device. The comparator had to be usual care or ~~an~~ attention control ~~,~~ (a small amount of interpersonal interaction without the main intervention). One way (reply not permissible, or participants informed system was one way) and two-way text messaging trials were included, however trials of smartphone applications were excluded.

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Commented [KC14R14]: I have explained in brackets what attention control means – it is the equivalent of placebo.

Types of outcome measures

The primary outcome was depressive symptoms (mean depression scores) measured using a validated questionnaire at the end of the intervention. Secondary outcomes included depression present/absent: proportion of people not meeting the authors' criteria for depression (not depressed) and adverse events if recorded and reported.

Search methods for identification of trials

A search strategy was designed with a librarian using terms including (but not limited to) "depress" OR "depression" AND "SMS" OR "text message" OR "short message service". Electronic databases including EMBASE, CENTRAL, MEDLINE, CINAHL, PsycINFO and SCOPUS were searched from 1992 to 18/09/2018. Other sources such as clinicaltrials.gov and WHO International Clinical Trials Registry Platform (ICTRP) registries were also searched. We sought to include all trials since the inception of text messaging (1992). No language restrictions were imposed. The reference lists of relevant trials and reviews were also screened, and further trials were identified for assessment.

Study selection, data extraction and management

The titles and abstracts identified through the search were screened by two independent reviewers (KC and SA) for eligibility for inclusion. Any disagreements were resolved by a third reviewer (MH). Eligible trials were assessed, and the following data were extracted for included trials using a standardised data extraction form:

- Publication details: authors, year and source
- Sample Characteristics: socio-demographics, descriptions of text messages, usual care and depression criteria, country, attrition
- Participants: age, sex/gender, ethnicity, history of depression, co-morbidities, prior and current treatments for depression
- Trial design: randomisation method, sampling mechanism, adherence, follow up length, trial setting.
- Intervention features: type and content of messages, frequency, timing, duration and total number of messages sent
- Effect size: sample size, estimate, standard error, power
- Measurement tools: outcome scales or measurements
- Comparison group details
- Outcome: depression present/absent and mean depression scores at end of treatment (and follow-up data if available) and adverse events (if recorded and reported)

Trials that met all the inclusion criteria with no available outcome data (from the trial report or the authors) could not contribute meaningfully to a pooled estimate of effect. These were regarded as 'dropouts' rather than ineligible, to indicate that they have not been overlooked. Trials with insufficient information to assess whether they met our inclusion criteria were labelled as 'awaiting assessment' and the authors were contacted for further information. Any trials that met our criteria but had not been completed were regarded as 'ongoing'.

Risk of bias and GRADE assessments

The risk of bias was assessed by two independent reviewers (KC and SA) using the Cochrane risk of bias tool for randomised controlled trials (Higgins et al., 2019). A judgement of low, high or unclear risk was allocated based on the domains of random sequence generation, allocation concealment, selective reporting, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data and any other potential sources of bias such as unbalanced variables at baseline. Any disagreement between judgements was discussed and referred to a third reviewer (MH).

Quality of evidence was assessed and adjusted using the five GRADE considerations: trial limitations, consistency of effect, indirectness, imprecision and publication bias (Brożek et al., 2009). An overall rating was given to reflect the level of confidence we have in the strength of evidence collated in this review.

Statistical analysis

Trial results were pooled and analysed using Review Manager software (Review Manager, 2014). ~~If there were two or more trials t~~The pooled reduction in depressive symptoms was

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calculated using the random-effects approach (DerSimonian and Kacker, 2007). The standardised mean difference (SMD) was calculated for continuous endpoints as different outcome measures were used. Trials with three arms were included as two separate trials with the numbers in the intervention group compared to half the number in the control group. Heterogeneity of the estimates between trial populations was calculated using I^2 statistics. Inconsistency in results was categorised as low (I^2 0-29), moderate (I^2 30-49), substantial (I^2 50-89) and considerable (I^2 90-100) (Higgins et al., 2003). Subgroups included analysis by depression questionnaire used, and content and frequency of messages. A sensitivity analysis was run for all trials with depression (yes/no) as the primary outcome and for trials that assessed depression symptoms using validated rating scales.

Results

Results of the search

We screened 3,762 titles and abstracts and excluded 3,704 irrelevant records. We retrieved 58 articles for full-text review. After reading the full-texts, the primary reasons for excluding 32 studies were the interventions being mHealth smartphone apps, Internet-based or part of a package of intervention which included text-messages as an adjunct to other components rather than the primary intervention being tested (See Figure 1).

Figure 1 about here

We included 7 trials (9 comparisons, n=1,918 participants). Suffoletto et al (2013) and Schlicker et al (2018) were parallel, three armed RCTs (see Table 1 for characteristics of the included trials).

Eight trials are ongoing (Berrouiguet et al., 2014, Chow et al., 2018, Clark et al., 2018, Hartnett et al., 2017, Jiskoot et al., 2017, McCarter et al., 2018, Tandon, 2018, Husain, 2015) and eight awaiting classification (Haas et al., 2017, Boeschoten et al., 2012, Fletcher et al., 2018, Moore et al., 2015, Ohora, 2016, Taleban et al., 2016, Ben-Zeev, 2017, Schueller, 2018). These study authors were contacted to clarify the recruitment methods. Three trials were considered 'dropouts', two studies ~~Wolf et al and Spoelstra et al~~ did not report depression scores at the end of the intervention, and one study ~~Pijnenborg et al~~ did not report results by allocation arm (Wolf et al., 2016, Pijnenborg et al., 2010, Spoelstra et al., 2016).

Participants

Five trials (6 comparisons) recruited participants prior to discharge from hospital and one trial recruited from community mental health clinics. Four trials (5 comparisons) required participants to have depression at entry (Agyapong et al., 2017, Agyapong et al., 2012, Hart and Vaccaro, 2017, Schlicker et al., 2018). Participants in t~~T~~wo of the trials (3 comparisons) had received an~~received an~~ inpatient treatment programme consisting of psychotherapy prior to recruitment in the trial (Agyapong et al., 2012, Schlicker et al., 2018). In one trial, people with a variety of diagnosed mood disorders (e.g. depression and anxiety) were included (van den Berg et al., 2015). The conditions of interest in other trials were coronary

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Commented [PA21]: do you mean Participants in two trials had participated in an inpatient treatment programme ???

Commented [KC22R22]: Correct, now clarified.

heart disease (Islam et al., 2019), and hazardous drinking (Suffoletto et al., 2013). Participants' mean age ranged from 22 to 58 years and the ratio of women to men was unbalanced in all but two trials (Hart and Vaccaro, 2017, Agyapong et al., 2012). The trials were conducted in the USA (2), Germany (2), Ireland (1), Canada (1) and Australia (1).

Interventions and comparators

Two comparisons ~~Van den Berg et al and Suffoleto et al (group A)~~ sent one message a week (van den Berg et al., 2015, Suffoletto et al., 2013) while the other seven comparis~~intervent~~ions sent two or more. Six interventions had depression as the primary outcome (Schlicker et al., 2018, Agyapong et al., 2017, Agyapong et al., 2012, Hart and Vaccaro, 2017, van den Berg et al., 2015, Suffoletto et al., 2013). Five interventions had usual care as the comparator (Islam et al., 2019, Schlicker et al., 2018, Suffoletto et al., 2013). Two trials sent fortnightly thank-you messages as the attention control (Agyapong et al., 2012, Agyapong et al., 2017) One trial administered telephone calls to both groups and also sent tailored SMS messages to the intervention group with therapy themes (van den Berg et al., 2015). Four comparisons had mental health content in the messages (Agyapong et al., 2017, Agyapong et al., 2012, Schlicker et al., 2018).

Suffoleto et al had two intervention groups, group A received a weekly text-message about alcohol drinking intentions and group B participated in two-way messaging, both compared with usual care (Suffoletto et al., 2013). Schlicker et al group A received standard messages and group B received personalised self-written text-message reminders from inpatient cognitive behaviour therapy (CBT) work, both compared with usual care (Schlicker et al., 2018).

Table 1 about here

Risk of bias assessment

A graphical summary of risk of bias assessments as determined by review authors for the included trials is provided in Figure 2.

Allocation. One trial used a systematic method of allocation (alternating week by week) and was assessed as high risk of bias (Schlicker et al., 2018). ~~Neither van den Berg et al (2015) or Hart and Vaccaro (2017)~~ Two studies did not described their method of randomisation and therefore were judged as unclear risk (van den Berg et al., 2015, Hart and Vaccaro, 2017). Only one study~~Islam et al (2019)~~ gave sufficient detail of their allocation concealment and were rated low risk of bias (Islam et al., 2019). Risk of bias for the remaining trials was unclear.

Blinding. Blinding of participants was not possible due to the nature of the intervention therefore all studies received a high risk of bias judgement for performance bias. One study~~Agyapong et al (2012)~~ blinded the outcome assessors, however they reported the blinding was broken in many instances by the participants divulging their allocation group, t~~.~~ ~~T~~hus it ~~, this study~~ was rated as high risk for detection bias (Agyapong et al., 2012). ~~Suffoletto et al A and B~~One study had a self-reported outcome which was ~~were~~ rated as high risk due to potential~~for~~ detection bias ~~as the outcome assessment was self-reported~~

(Suffoletto et al., 2013). ~~Shlicker et al, and van den Berg et al~~Two studies did not report blinding of outcome assessment and therefore received an unclear assessment (van den Berg et al., 2015, Schlicker et al., 2018)

Incomplete outcome data. Three trials conducted per-protocol analysis (where only the participants that completed the study are included in the results) potentially leading to bias (Islam et al., 2019, van den Berg et al., 2015, Suffoletto et al., 2013). ~~Schlicker et al~~One trial had high attrition across the groups (19.4% in group A, 24.6% in group B and 22.3% in the control group), with the number of imputed values potentially contributing to measurement bias (Schlicker et al., 2018). All were rated as at high risk for incomplete outcome data.

Selective reporting. The frequency of medical contacts and acceptability of the intervention were mentioned in one trial's ~~van den Berg et al's~~ protocol, however neither outcome was reported in the publication, as such a high risk of bias was awarded for reporting bias (van den Berg et al., 2015). Only one other trial had a published protocol (Islam et al., 2019), as such all others were awarded unclear risk.

Other bias. There were concerns regarding other sources of bias in six studies due to unbalanced variables at baseline (Agyapong et al., 2017, Schlicker et al., 2018, van den Berg et al., 2015, Islam et al., 2019, Hart and Vaccaro, 2017, Suffoletto et al., 2013)

Figure 2 about here

Outcomes

Primary outcome

The pooled analysis of seven trials (9 comparisons) (Figure 1) revealed a borderline statistically significant reduction in depressive symptom scores between the text messaging intervention and control groups (Standardised Mean Difference, SMD -0.27; 95% CI -0.54 to 0.00; P 0.05) 1,918 participants) at the end of treatment. Substantial heterogeneity was observed (I^2 = 82%).

Secondary outcomes

Only one trial reported depressed (defined as a PHQ-9 score of 5-27) and not depressed at the end of treatment (Islam et al., 2019). There was a significant difference (p <0.001) in the proportions with depression in the intervention (6.3%) and control (24.6%) groups at six months (end of treatment). No trials reported adverse events.

Figure 3 about here

Subgroup analysis

Content of the messages.
The subgroup analysis of the three trials (4 comparisons) with messages that contained a mental health component demonstrated a statistically significant reduction in depression

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symptom scores compared with the control group (SMD -0.39, 95% CI -0.63 to -0.14, n= 353 participants, I^2= 22%). The four trials (5 comparisons) without a mental health component in their text messaging intervention found no reduction in depression symptom scores in comparison with controls (SMD -0.15, 95% CI -0.59 to 0.29, n= 1,515 participants, I^2= 92%). The considerable heterogeneity observed may be due to variations in the intervention and population groups enrolled in the latter trials.

Figure 4 about here

Frequency of the messages.

The subgroup analysis of 7 comparisons where ≥2 messages were sent per week showed a statistically significant reduction in depressive symptoms (SMD -0.39, 95% CI -0.65 to -0.14, n= 1,409 participants, I^2= 69%). The 2 comparisons that delivered <2 messages per week showed no statistically significant difference (SMD 0.14, 95% CI -0.05 to 0.32, n= 459 participants).

Figure 5 about here

Sensitivity analysis- Trials with depression as primary outcome

Sensitivity analysis was performed using 5 trials (6 comparisons) with depression as the primary outcome (van den Berg et al., 2015, Agyapong et al., 2017, Hart and Vaccaro, 2017, Schlicker et al., 2018, Agyapong et al., 2012). A statistically significant reduction in mean depression symptom scores was found in the intervention compared to the control groups (SMD -0.30; 95% CI -0.52 to -0.08; 439 participants) at the end of treatment. There was low heterogeneity (I^2 = 19%) but very wide confidence intervals.

Figure 6 about here

Sensitivity analysis- Trials using standard depression rating scales

Sensitivity analysis was performed in the four comparisons using the Beck Depression Inventory BDI (Beck et al., 1961, Schlicker et al., 2018, Agyapong et al., 2012, Agyapong et al., 2017) and statistically significant lower depressive symptom scores were found in those in the text messaging intervention group compared to control (SMD -0.39; 95% CI -0.63 to -0.14; n= 353 participants) at the end of treatment. There was low heterogeneity (I^2 = 22%) but wide confidence intervals.

The pooled result of the four comparisons using the BDI (Beck et al., 1961, Agyapong et al., 2017, Agyapong et al., 2012, Schlicker et al., 2018) combined with one trial~~Islam~~ who used the PHQ-9 (Kroenke et al., 2001, Islam et al., 2019) was statistically significant for lowering symptoms of depression (p <0.0001) SMD of -0.49 (95% CI -0.73 to -0.25, n= 1063 participants) favouring text messaging over control.

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Figure 7 about here

Summary of findings

The overall rating of the quality of evidence of the effectiveness of text-messaging was very-low, as presented in the Summary of Findings (Ttable 2). The evidence from the trials was downgraded in quality due to a high risk of selection and performance bias, heterogeneity, and very wide confidence intervals. We did not assess publication bias due to the small number of included trials (Brożek et al., 2009).

Table 2 about here

Discussion

Text messages are often included in health research as part of an intervention package. This review assessed text messaging as a standalone intervention to reduce depressive symptoms. It is useful to understand the value of the individual components of an intervention package for optimum programme design, and this information will be of particular importance in lower resource settings where funding for complex packages of care may not be available.

Data from 7 trials (9 comparisons, n=1,918 participants) showed text messages on their own were not associated with a reduction in did not reduce depressive symptom scores at the end of the intervention. However statistically significant reductions in depressive symptoms were shown in important subgroups specified *a priori* e.g. where the primary aim of the messages was to reduce depressive symptoms; in those using the BDI (Agyapong et al., 2017, Agyapong et al., 2012, Schlicker et al., 2018) or PHQ-9 scales (Kroenke et al., 2001, Islam et al., 2019); where text message content was targeted at mental well-being, mood improvement and cognitive behavioural therapy information; and when the message frequency was ≥2 times per week. We found no data on the long-term effects of text messaging interventions or the length of time required to show maximal or sustained response to the receipt of text messages.

Due to the paucity of trials assessing text messaging as a standalone intervention, we also included trials that used other mood rating scales to measure depressive symptoms such as the BSI-18 (Derogatis, 1993) and PHQ-4 (Kroenke et al., 2009). The BSI-18 tool (Derogatis, 1993) is a general mood rating scale that measures psychological distress broadly with only six questions focused on depression while the PHQ-4 (Kroenke et al., 2009) is a brief screening tool with two questions on depression and two on anxiety. While we acknowledge that the use of different scales makes comparisons across trials difficult, the sensitivity analysis showed significant results in trials using the BDI or PHQ-9. Thus, we recommend future trials use depression-specific scales when measuring depressive symptoms.

Any indication of benefit must be considered alongside methodological limitations in the included trials e.g. si.e. short duration of the text messaging intervention (from 6 weeks to 6 months), variation in the types of trial participants, the content and frequency of the text messages, and the inadequate reporting of methods in many of the included trials (particularly in the domain of allocation concealment). The overall quality of the evidence was rated as very low due to these limitations and considerable heterogeneity (I^2= 80%) within and between the trials.

A recently published systematic review evaluating the effectiveness of text messaging, found marginal evidence to support its use as a treatment modality for people with clinical depression (SMD -0.27, 95% CI -0.48 to 0.02, p< 0.07; 7 trials, n= 845 participants) (Senanayake et al., 2019). In contrast to our review which included adults (≥18 years)

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regardless of their baseline depression score, that review included adolescents (≥13 years) diagnosed with ~~with~~ depression at baseline (with any accepted tool). In addition, whilst our review was registered prospectively in PROSPERO, their review was retrospectively registered: https://www.crd.york.ac.uk/PROSPERO/RecordID=141100. Most importantly, our review performed sensitivity and subgroup analyses to identify factors in the design of the text messaging interventions that might influence the reduction of depressive symptoms. A~~Hall et al also undertook a~~ review of systematic reviews into text- messaging for health (no mental health trials were included) ~~and although the results~~ supported the integration of text-messaging into public health practice, however it was ~~they were~~ unable to recommend optimum intervention characteristics or comment upon longer term effects and called for further research into potential risks and unintended consequences (Hall et al., 2015). ~~A number of the authors of these reviews also called for further research into potential risks and unintended consequences (Hall et al., 2015).~~

One theory for a potential mechanism of action is the impression of 'connection' between the sender and the recipient of the messages. Social isolation or lack of connectedness, participation and infrequent social contact has been linked to poorer mental health and is a predictor for increased risk of mortality, compared with less socially isolated individuals (Pantell et al., 2013). The feeling of connection established during a text messaging intervention may help reduce social isolation. Based on our findings, a minimum threshold for the frequency of messages is indicative of 2 or more per week.

The stigma associated with mental illness is also a barrier to treatment access for many people. Although not explored in the included studies, anonymity and confidentiality of text messaging interventions are positive characteristics reported in the area of sexual health where stigma is also often a barrier to care (Willoughby and L'Engle, 2015). Qualitative research focusing on the experiences and perceptions of text messaging programmes would further add to the evidence base.

In addition, the smaller group of trials where the primary focus was to reduce depressive symptoms showed benefit. This points to the importance of close alignment between messages received and the outcome being targeted. However, it is important to note that in two trials, participants had undergone ~~underwent~~ an inpatient treatment programme which involved psychotherapy before commencing the text messaging intervention. Thus, the reduction in depressive symptoms may be the result of the combined effect including reinforced learnings from the therapy received during the inpatient treatment programme.

~~As such, it is possible that the reduction in depressive symptoms observed in these trials was the result of the care received before the intervention or that the text messaging intervention reinforced the learnings from therapy. However, it is difficult to ascertain this.~~

While we acknowledge that text messaging is not a suitable substitute for mental health service support, it has the potential to augment the current gold standard of care. It is a practical and cost-effective approach, one that is able to reach remote locations and isolated communities. Furthermore, it has the potential to be used in low income countries as a standalone intervention to reduce symptoms of depression as complex packages of interventions come at a higher cost per capita which may be prohibitive in some settings (Hall et al., 2015).

It is important to note that most of the trials were conducted in high-income countries, and text messaging applicability and acceptability in lower resource countries has not been extensively studied. Since text messaging is simple and cost-effective, more research should

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be conducted in lower resource countries where the highest burden lies in order to bridge this knowledge gap. Nevertheless, factors such as low literacy levels may present a barrier to the use of this mode of treatment.

Further research measuring fidelity to and compliance with the text messaging programme is crucial to ascertain the true effect of the intervention and whether the impact of text messaging remains after a messaging programme has ceased. Adverse event data should be systematically recorded and reported. Interviews with participants could explore other neglected topics to date such as intrusiveness of messaging and participant burden (Berrouiguet et al., 2016).

Limitations

The inadequate reporting of some trials precluded classification of risk of bias as either low or high risk. This led us to rate some of the trials across the categories at unclear risk of bias. Another limitation is the small number of included trials and participants which contributed to the wide confidence intervals observed in the meta-analysis. These limitations resulted in an overall rating of 'very low' quality of evidence in the summary of findings.

Conclusion

Statistically significant reductions in depressive symptoms were identified ~~shown w~~where the primary aim of the messages was to reduce depressive symptoms; in those trials using the BDI or PHQ-9 questionnaires; where text message content was targeted at mental well-being, mood improvement and cognitive behavioural therapy information; and when the message frequency was ≥2 times per week. These results should be interpreted with caution due to methodological limitations associated with the included trials. More research is required before recommendations can be made about the routine use of text messaging interventions in this area.

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Declaration of interest

MLH is a co-author of one of the included studies.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. MLH is funded by a National Health and Medical Research Foundation Career Development Fellowship (Level 2), APP1141328

References

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Note - all journal titles should appear in full and the first letter of each word in the title should be capitalised

Commented [KC45]: Thank you all corrected as requested. The Trial registries NCT references are not full publications in journals however I have now added their URL's.

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Table 1 Characteristics of the trials included in 'text messaging interventions for reducing symptoms of depression review'

First author, year, country	Target condition, study duration	Sample size, mean age, percent male	Experimental and control	Depression tool (primary/secondary outcome measure)	Outcomes, Endpoint timing, Mean (SD)
Agyapong et al 2012 Ireland	DSM IV diagnosis of unipolar depression and AUD. Completed an in-patient dual diagnosis treatment programme 3 months	54 participants 49 years 46%	*Intervention group:* twice daily supportive text messages (n=26) *Control group:* a fortnightly thank you text message (n=28)	BDI-II (primary)	**End of intervention** Intervention 8.5 (±8.0) (n=196) Control 16.7 (±10.3)
Agyapong et al 2017 Canada	MDD 3 months	73 participants Not reported 32%	*Intervention group:* twice-daily supportive text messages (n=35). *Control group:* single text message every fortnight thanking them for participating in the study (n=38)	BDI-II (primary)	**End of intervention** Intervention 20.8 (±11.7) Control 24.9 (±11.5)
Hart and Vaccaro 2017 USA	TBI sustained at least 6 months prior and at least mild depression and/or anxiety 8 weeks	8 participants 29 years 50%	*Intervention group:* individualised reminder messages that were relevant to ongoing goals, framed as implementation intentions	BSI-18 (primary)	**End of intervention** Intervention 53.2 (±7.9) Control 52.5 (±11.9)

			sent daily by text message (n=4) *Control group:* daily SMS messages with self-selected motivational statements (motivation group, n=4)		
Islam et al 2019 Australia	CHD 6 months	710 participants 58 years 82%	*Intervention group:* four text messages per week that provided education, motivation and support on diet, physical activity, general cardiac education and smoking, if relevant (n=352) *Control group:* usual care (n=358)	PHQ-9 (secondary)	**End of Intervention** Intervention 1.0 (±2.2) Control 2.9 (±3.3)
Schlicker et al A 2018 Germany	Completed inpatient treatment for MDD 10 weeks	226 participants 44 years 35%	*Intervention group:* 81 text messages over 10 weeks (n=77) *Control group:* usual care (n=38)	BDI-II (primary)	**End of intervention (6w)** Intervention 15.08 (±11.35) Control 18.93 (±13.50) **Follow up (10w)** Intervention 13.06 (±10.18) Control 18.29 (±13.93)

Schlicker et al B 2018 **Germany**	Completed inpatient treatment for MDD 10 weeks	226 participants 44 years 37%	*Intervention group:* 81 self-written text messages over 10 weeks, consisting of reminders of what they learned in inpatient CBT (n=73) *Control group: usual care* (n=38)	BDI-II (primary)	**End of intervention (6w)** Intervention 16.32 (±12.02) Control 18.93 (±13.50) **Follow up (10w)** Intervention 16.30 (±11.63) Control 18.29 (±13.93)
Suffoletto et al A 2013 **USA**	Aged 18-25 years presenting to emergency departments who reported hazardous drinking 9 months	289 participants 22 years 35%	*Intervention group*: SMS drinking queries (assessing whether the individual had a weekend drinking plan). If a plan to drink was reported, SMS queried whether the person was willing to set a goal to limit drinking below the threshold of 4 drinks for women (5 for men) per drinking occasion over that weekend) (n=196) *Control group*: usual care (n=93)	PHQ-4 (secondary)	**End of Intervention (3m)** Intervention 2.87 (±3.10) Control 2.38 (±2.69) **Follow up (6m)** Intervention 2.95 (±3.21) Control2.44 (±2.76) **Follow up (9m)** Intervention 2.59 (±2.09) Control 2.69 (±3.15)
Suffoletto et al B 2013	Aged 18-25 years presenting to	476 participants 22 years	*Intervention group*: SMS plus feedback including: intention	PHQ-4 (secondary)	**End of Intervention (3m)** Intervention 2.09 (±2.70)

USA	emergency departments who reported hazardous drinking 9 months	35%	formation, barrier identification, general encouragement, goal setting, self-monitoring, positive feedback on performance, these two-way messages were based on motivational interviewing styles. A sequence of messages sent on Thursday and another sequence on Sunday (n=384) *Control group*: usual care (n=92)		Control 2.38 (±2.69) **Follow up (6m)** Intervention 2.19 (±2.65) Control 2.44 (±2.76) **Follow up (9m)** Intervention 2.11 (±2.75) Control 2.69 (±3.15)
Van den Berg et al 2015 Germany	Preparing for discharge with diagnosed depression, anxiety disorder, adjustment disorder or somatoform disorder 6 months	123 participants 44 years 22%	*Intervention group*: telephone calls and tailored once a week short text messages (n=40) *Control group* telephone calls only (n=42)	BSI-18 (primary)	**End of treatment** Intervention 6.22 (±5.59) Control 6.27 (±5.75)

Abbreviations AUD: alcohol use disorder; DSM IV: Diagnostic and Statistical Manual of Mental Disorders, 4th edition; BDI-II: Beck Depression Inventory, second revision; BSI: Brief symptom index; CBT: Cognitive Behavioural Therapy; CHD: coronary heart disease; m: months; MDD: major depressive disorder; PHQ-4: 4-item Patient Health Questionnaire; PHQ-9: 9-item Patient Health Questionnaire; PROMIS: Patient Reported Outcomes Measurement Information System; RCT: randomised controlled trial; SMS: short message service; TBI: traumatic brain injury; w: weeks.

Table 2. Summary of findings table

Text messages compared to control for Depression

Patient or population: People with depression

Setting: Inpatient

Intervention: Text messages

Comparison: Control

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with control	Risk with Text messages				
Depression: mean scores at end of treatment		SMD **0.27 SD lower** (0.54 lower to 0.00 lower)	-	1918 (9 RCTs)	⨁◯◯◯ VERY LOW [a,b]	
Depression: mean scores at end of treatment - Beck Depression Inventory, BDI (high score = more depressed)		SMD **0.39 SD lower** (0.63 lower to 0.14 lower)	-	353 (4 RCTs)	⨁◯◯◯ VERY LOW [c,d]	
Depression: mean scores at end of treatment - Brief Symptom Inventory, BSI-18		SMD **0 lower** (0.42 lower to 0.41 higher)	-	90 (2 RCTs)	⨁◯◯◯ VERY LOW [a,d]	
Depression: mean scores at end of treatment - Patient Health Questionnaire, PHQ-4 (high score = more depressed)		SMD **0.02 higher** (0.24 lower to 0.29 higher)	-	765 (2 RCTs)	⨁◯◯◯ VERY LOW [d,e]	
Depression: mean scores at end of treatment - Patient Health Questionnaire, PHQ-9 (higher score = more depressed)		SMD **0.68 SD lower** (0.83 lower to 0.52 lower)	-	710 (1 RCT)	⨁◯◯◯ VERY LOW [d,e]	

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval; **SMD:** Standardised mean difference

GRADE Working Group grades of evidence
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Explanations

a. We downgraded the quality of evidence as the studies were rated as high risk for multiple risk of bias domains.

b. We downgraded the quality of evidence as there is considerable heterogeneity (I= 75% to 100%) observed.
c. We downgraded the quality of evidence as the confidence intervals were wide.
d. We downgraded the quality of evidence as the confidence intervals were very wide.
e. We downgraded the quality of evidence as there are only 2 studies with <100 participants contributing to the analysis.

Figure 1. PRISMA flow diagram.

Please can we have editable figures, we cannot reproduce the figures in the format currently provided?

Commented [KC46]: Thank you please find editable (Word) Prisma

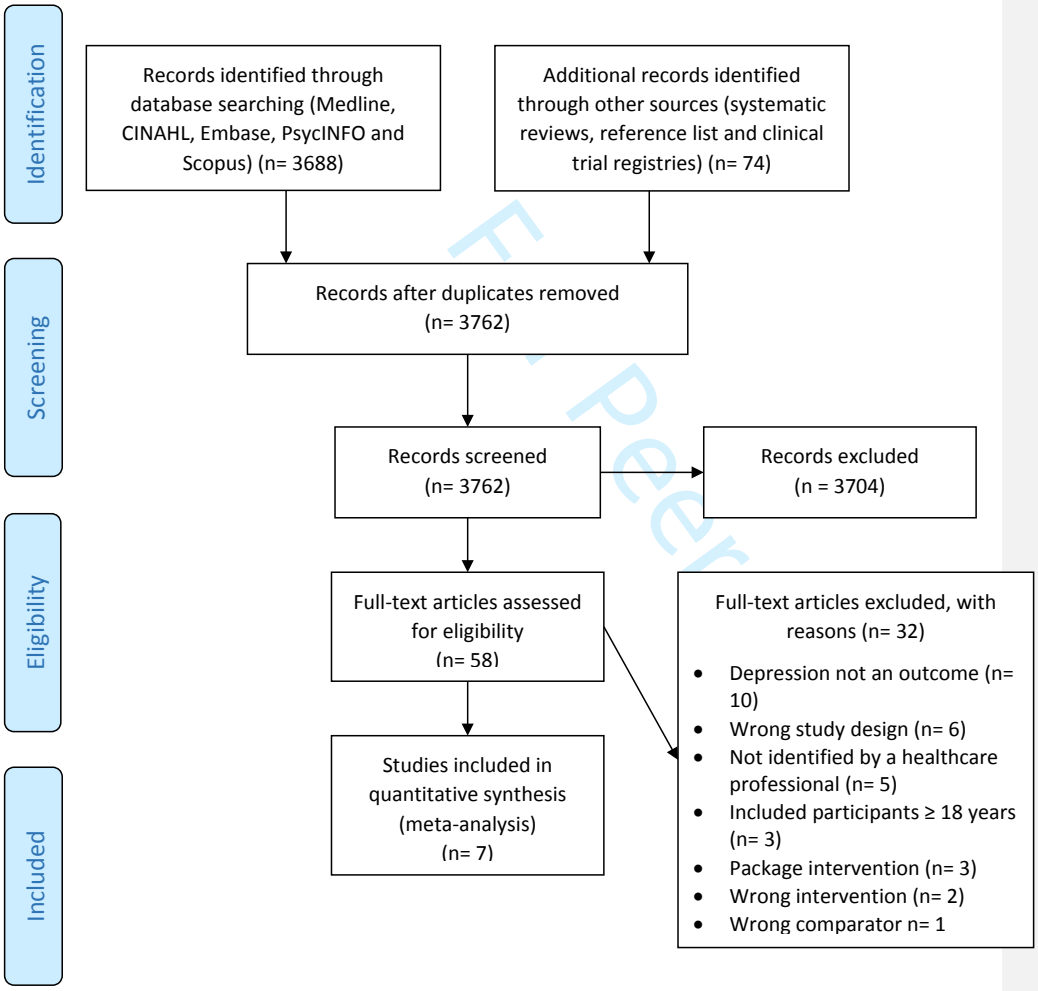
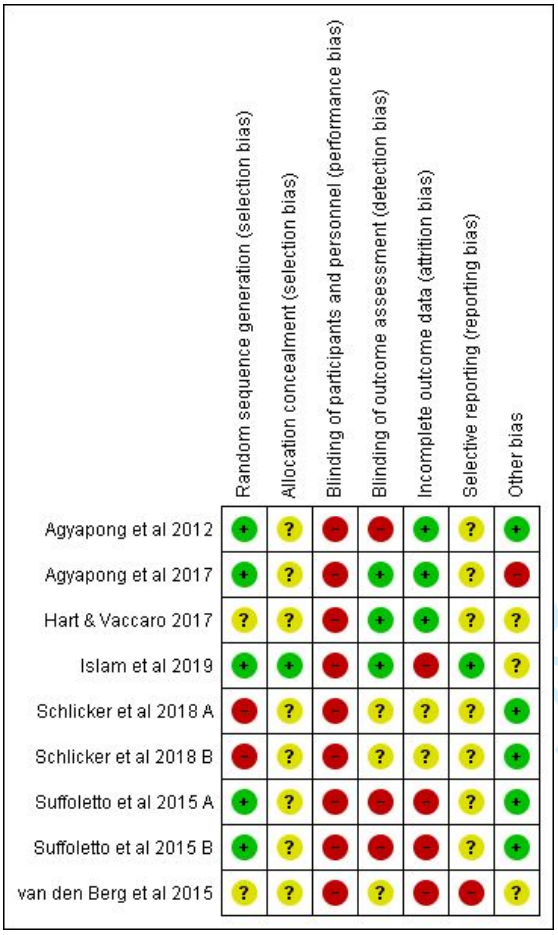


Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.



Legend: Green + represents low risk; yellow? represents unclear risk; red – represents high risk.

Other bias relates to whether a published trial protocol was available.

Figure 3. Forest plot of comparison: Text messages vs. control, Depression: mean scores at end of treatment.

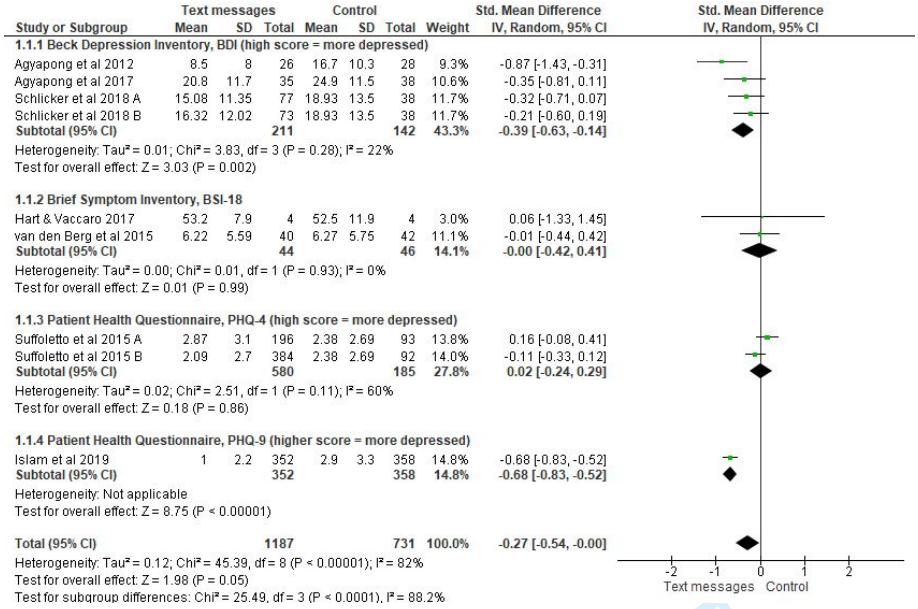


Figure 4. Forest plot of comparison: Text messages vs. control, content of the messages, Depression: mean scores at end of treatment.

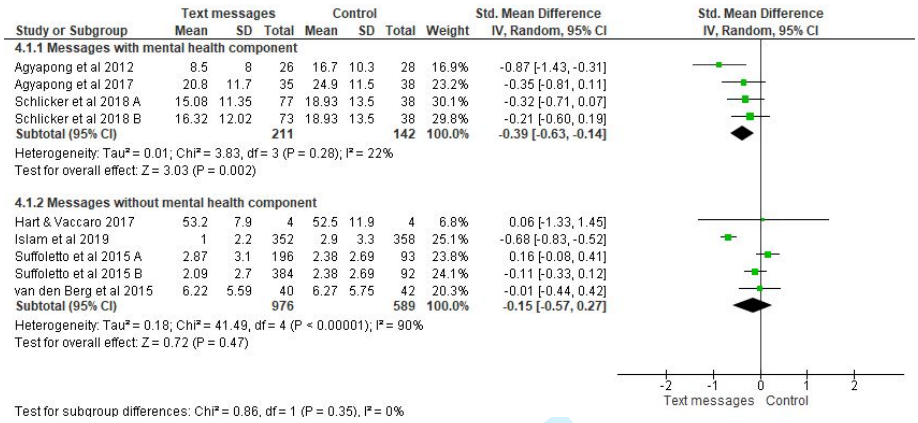


Figure 5. Forest plot of comparison: Text messages vs. control, frequency of messages, Depression: mean scores at end of treatment.

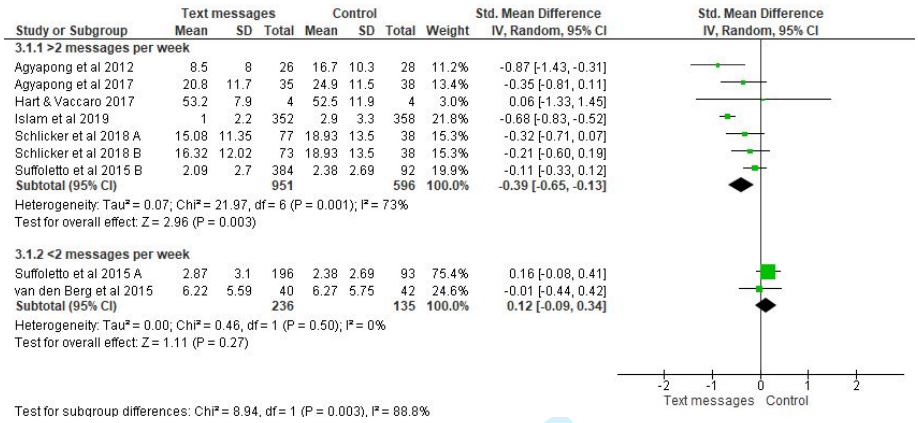


Figure 6. Forest plot of comparison: 2 Text messages vs. control, studies with depression as primary outcome, outcome: 2.1 Depression: mean scores at end of treatment.

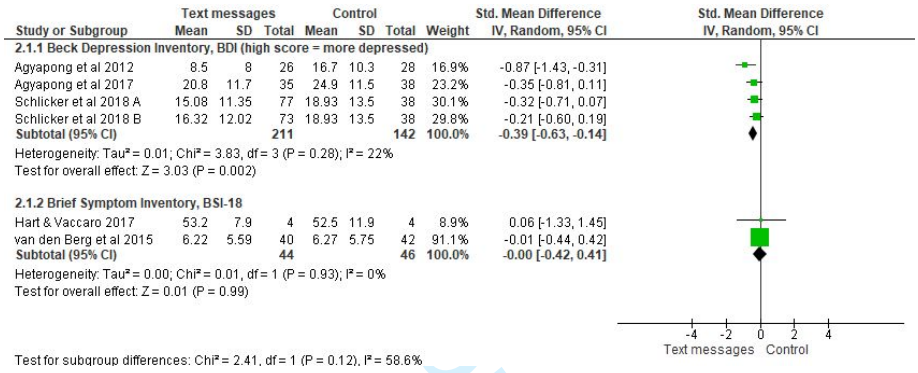
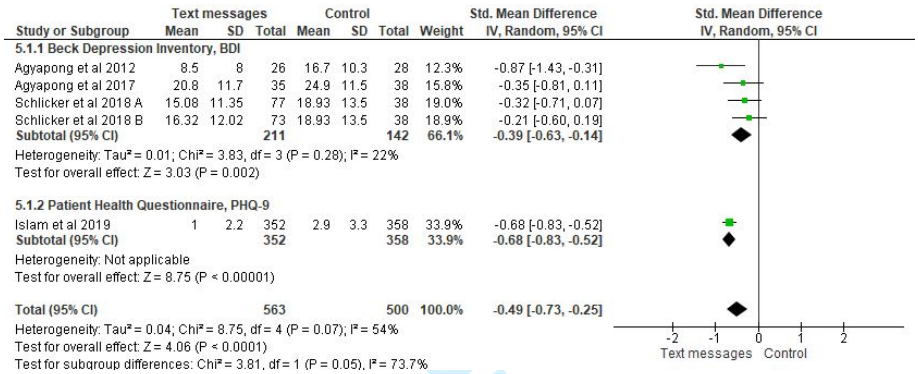


Figure 7. Forest plot of comparison: 2 Text messages vs. control, studies with standard depression rating scales, outcome: 2.1 Depression: mean scores at end of treatment.



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			Control group: daily SMS messages with self-selected motivational statements (motivation group, n=4)		
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Depression: mean scores at end of treatment - Patient Health Questionnaire, PHQ-4 (high score = more depressed)		SMD **0.02 higher** (0.24 lower to 0.29 higher)	-	765 (2 RCTs)	⨁◯◯◯ VERY LOW [d,e]	
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GRADE Working Group grades of evidence
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Explanations

a. We downgraded the quality of evidence as the studies were rated as high risk for multiple risk of bias domains.

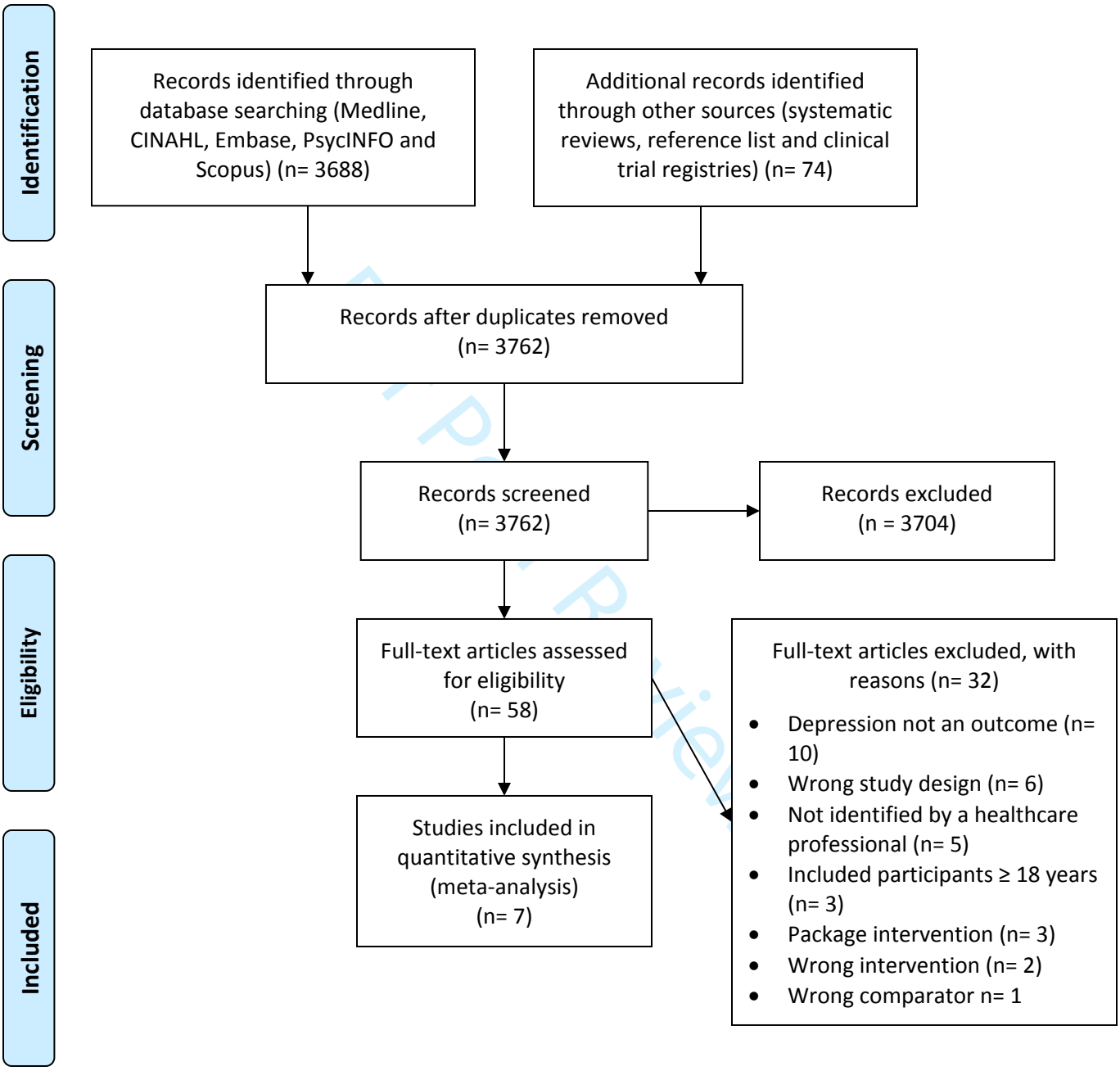
b. We downgraded the quality of evidence as there is considerable heterogeneity (I= 75% to 100%) observed.

c. We downgraded the quality of evidence as the confidence intervals were wide.

d. We downgraded the quality of evidence as the confidence intervals were very wide.

e. We downgraded the quality of evidence as there are only 2 studies with <100 participants contributing to the analysis.

PRISMA 2009 Flow Diagram



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit www.prisma-statement.org.

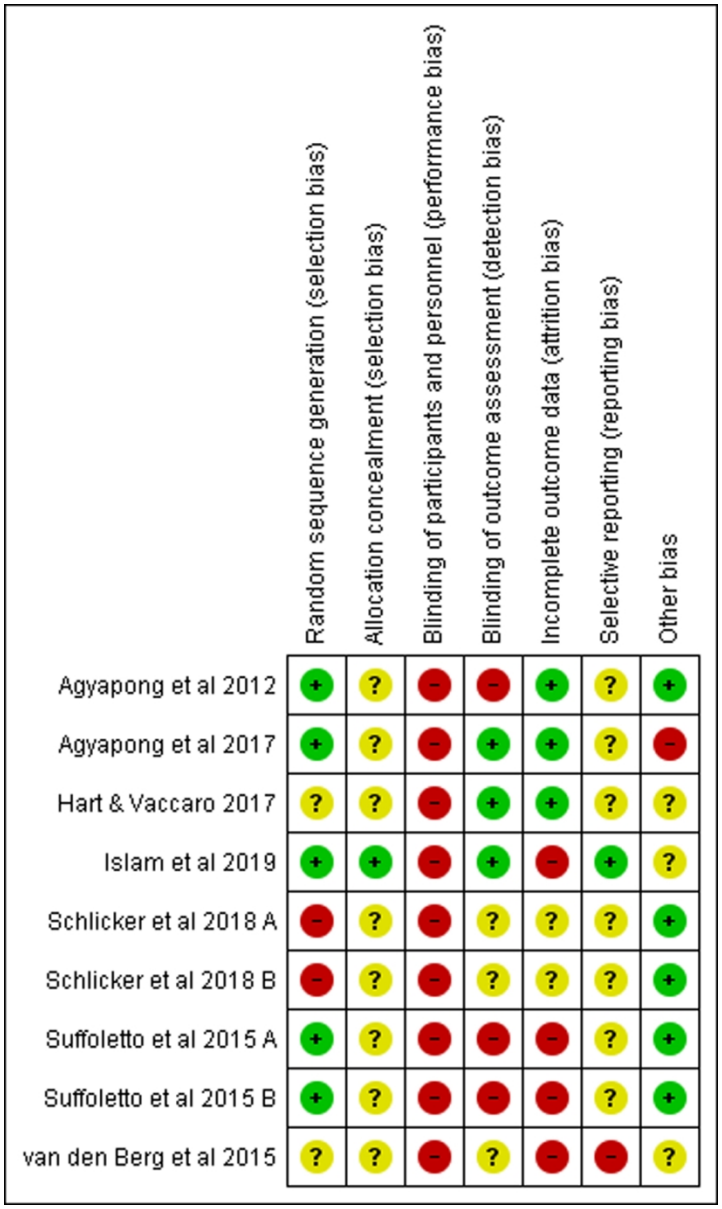


Figure 2 Risk of bias summary- review authors' judgments about each risk of bias item for each included study

96x161mm (300 x 300 DPI)

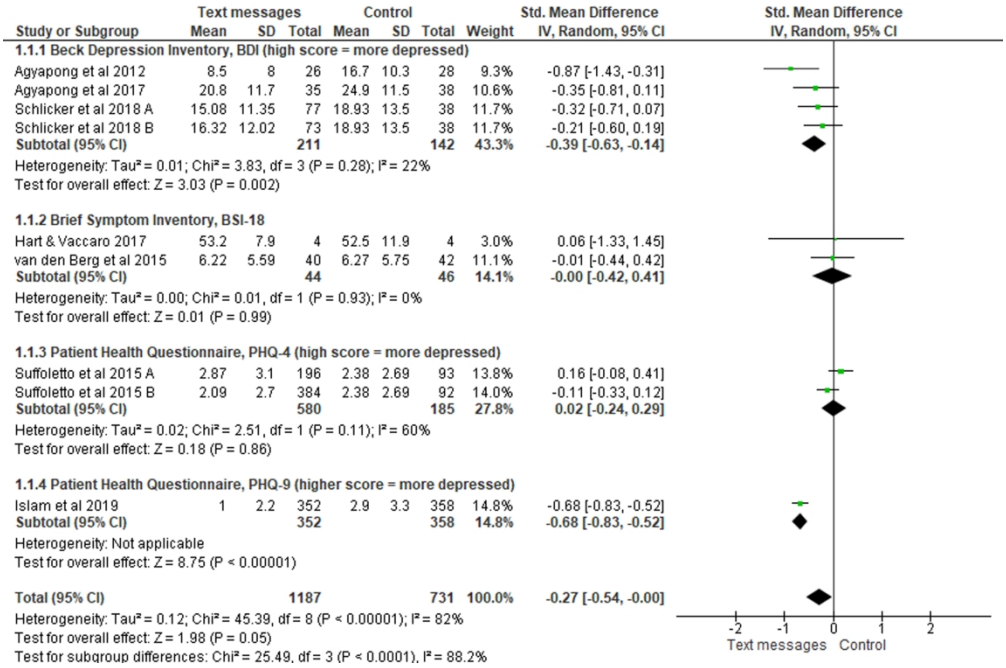


Figure 3 Forest plot comparison- Text messages vs. control, Depression- mean scores at end of treatment.

224x148mm (300 x 300 DPI)

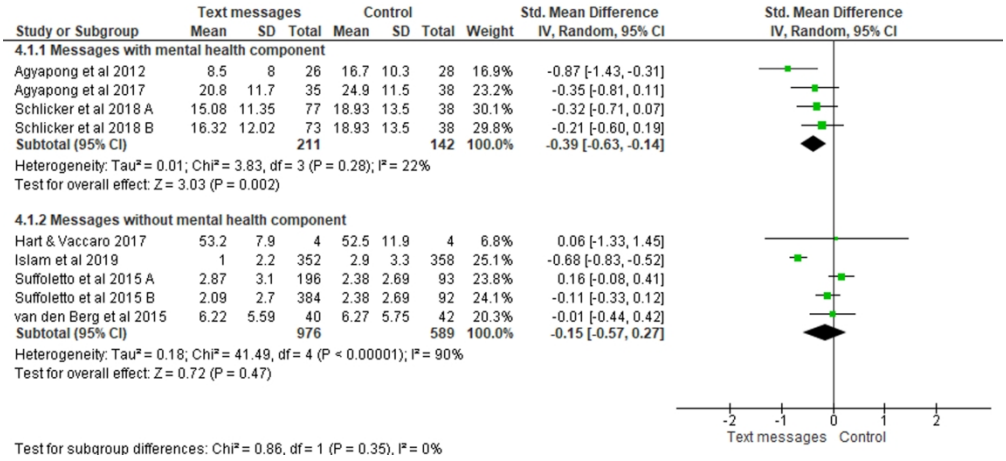


Figure 4 Forest plot of comparison- Text messages vs. control, content of the messages, Depression- mean scores at end of treatment.

224x101mm (300 x 300 DPI)

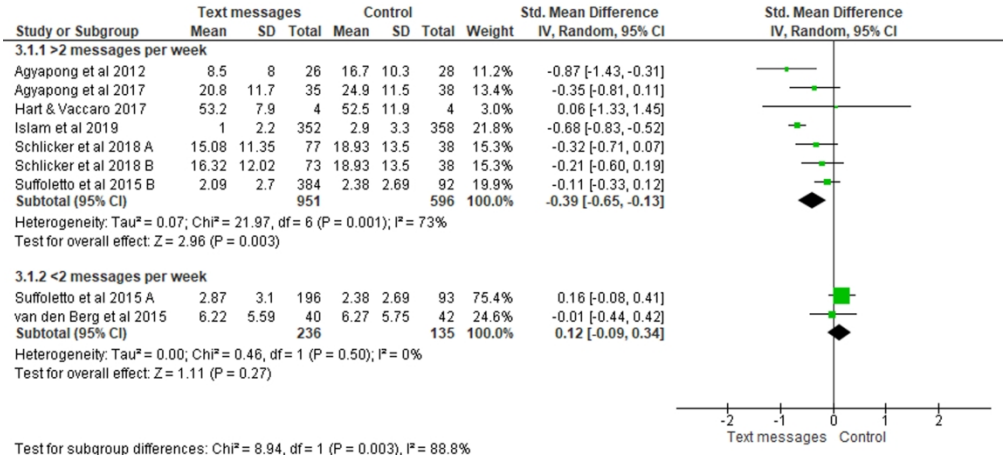


Figure 5 Forest plot of comparison- Text messages vs. control, frequency of messages, Depression- mean scores at end of treatment.

224x101mm (300 x 300 DPI)

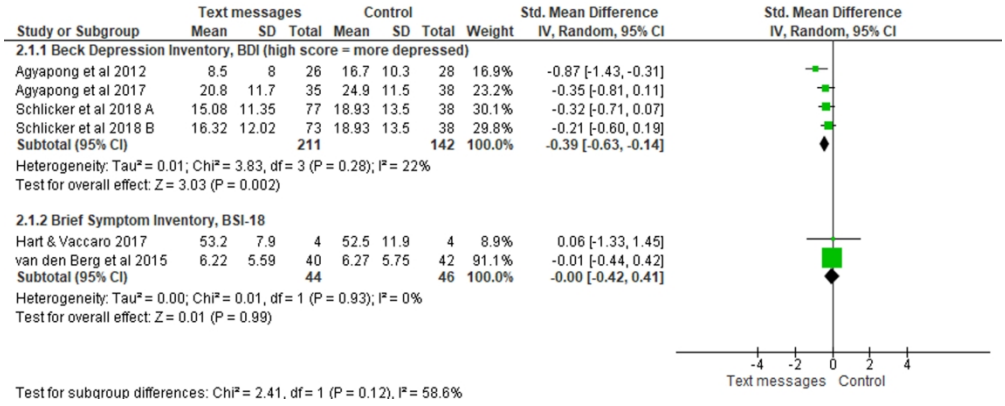


Figure 6 Forest plot of comparison- 2 Text messages vs. control, studies with depression as primary outcome, outcome- 2.1 Depression- mean scores at end of treatment.

224x88mm (300 x 300 DPI)

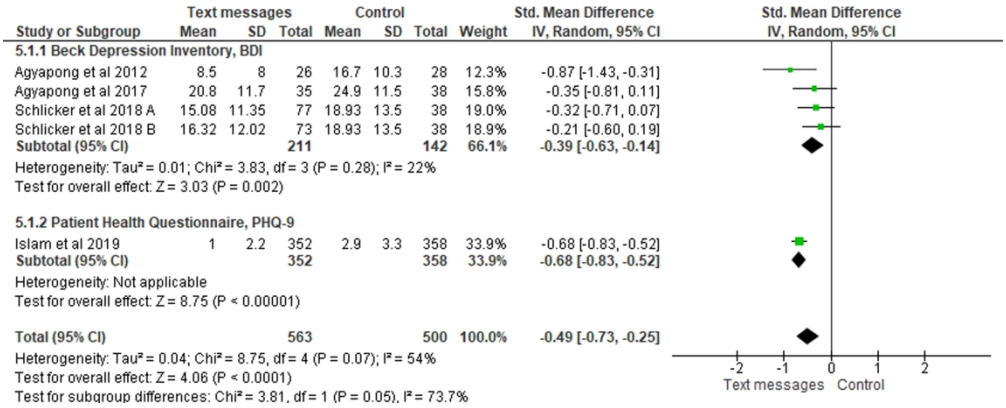


Figure 7 Forest plot of comparison- 2 Text messages vs. control, studies with standard depression rating scales, outcome- 2.1 Depression- mean scores at end of treatment.

221x88mm (300 x 300 DPI)