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Effectiveness of online mindfulness-based interventions in improving mental health: A review and meta-analysis of randomised controlled trials

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HIGHLIGHTS

- We examined the effectiveness of online mindfulness-based interventions (MBIs).
- 15 RCTs were included comparing online MBIs to control conditions.
- Online MBIs have significant small to moderate effects on mental health.
- Study quality is satisfactory for most studies.
- More research is needed to examine long-term effects and moderators of online MBIs.

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ABSTRACT

Mindfulness-based interventions (MBIs) are increasingly being delivered through the Internet. Whereas numerous meta-analyses have investigated the effectiveness of face-to-face MBIs in the context of mental health and well-being, thus far a quantitative synthesis of the effectiveness of online MBIs is lacking. The aim of this meta-analysis was to estimate the overall effects of online MBIs on mental health. Fifteen randomised controlled trials were included in this study. A random effects model was used to compute pre-post between-group effect sizes, and the study quality of each of the included trials was rated. Results showed that online MBIs have a small but significant beneficial impact on depression ($g = 0.29$), anxiety ($g = 0.22$), well-being ($g = 0.23$) and mindfulness ($g = 0.32$). The largest effect was found for stress, with a moderate effect size ($g = 0.51$). For stress and mindfulness, exploratory subgroup analyses demonstrated significantly higher effect sizes for guided online MBIs than for unguided online MBIs. In addition, meta-regression analysis showed that effect sizes for stress were significantly moderated by the number of intervention sessions. Effect sizes, however, were not significantly related to study quality. The findings indicate that online MBIs have potential to contribute to improving mental health outcomes, particularly stress. Limitations, directions for future research and practical implications are discussed.

Contents

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1. Introduction

Although mindfulness has been employed for centuries within Buddhist traditions, it is only since the 1970s that mindfulness has become a target of therapeutic intervention for common psychological problems such as stress, worry, anxiety and depression (Keng, Smoski, & Robins, 2011). Mindfulness could be defined as the ability to observe thoughts, bodily sensations or feelings in the present moment with an open and accepting orientation toward one's experiences (Bishop et al., 2004; Kabat-Zinn, 1990). Currently, mindfulness practices have been incorporated into various therapies in the field of mental health care, such as Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 1982, 1990), Mindfulness-Based Cognitive Therapy (MBCT; Segal, Williams, & Teasdale, 2002), Dialectical Behaviour Therapy (DBT; Linehan, 1993), and Acceptance and Commitment Therapy (ACT; Hayes, Strosahl, & Wilson, 1999). Through facilitating awareness and non-judgmental acceptance of moment-to-moment experiences, these mindfulness-based interventions (MBIs) are assumed to alleviate intense emotional states (Baer, 2003; Keng et al., 2011). Extensive descriptions of MBSR, MBCT, DBT and ACT as well as their underlying mechanisms of change can be found elsewhere (Baer, 2003; Bishop, 2002; Feigenbaum, 2007; Hayes, Luoma, Bond, Masuda, & Lillis, 2006; Metcalf & Dimidjian, 2014; Praissman, 2008; Ruiz, 2010).

In the past two decades, MBIs have become increasingly popular (Baer, 2003; Keng et al., 2011). Along with this growing interest in MBIs, there has been an exponential increase in the number of studies addressing the non-clinical and clinical utility of these interventions. As evidenced by a substantial number of meta-analyses, MBIs have proven effective in reducing psychological distress, most notably anxiety and depression, and improving well-being and quality of life in a broad range of populations, including healthy populations (Chiesa & Serretti, 2009; Khoury, Sharma, Rush, & Fournier, 2015), individuals with mental disorders (Chiesa & Serretti, 2011; Klainin-Yobas, Cho, & Creedy, 2012; McCarney, Schulz, & Grey, 2012; Piet & Hougaard, 2011; Strauss, Cavanagh, Oliver, & Pettman, 2014; Vøllestad, Nielsen, & Nielsen, 2012) and individuals suffering from chronic somatic illnesses (Abbott et al., 2014; Bohlmeijer, Prenger, Taal, & Cuijpers, 2010; Cramer, Lauche, Paul, & Dobos, 2012; Lauche, Cramer, Dobos, Langhorst, & Schmidt, 2013; Ledesma & Kumano, 2009; Piet, Wurtzen, & Zachariae, 2012; Veehof, Oskam, Schreurs, & Bohlmeijer, 2011; Zainal, Booth, & Huppert, 2013).

Previous meta-analyses have reported inconsistent findings with regard to the effects of MBIs on depression and anxiety, with effect sizes varying between 0.3 and 0.8 (Abbott et al., 2014; Bohlmeijer et al., 2010; Cavanagh, Strauss, Forder, & Jones, 2014; Cramer et al., 2012; Hofmann, Sawyer, Witt, & Oh, 2010; Khoury et al., 2015; Klainin-Yobas et al., 2012; McCarney et al., 2012; Piet et al., 2012; Strauss et al., 2014; Veehof et al., 2011; Vøllestad et al., 2012; Zainal et al., 2013). There are also multiple meta-analyses which have assessed the impact of MBIs on stress with effect sizes ranging from 0.4 to 0.7 (Abbott et al., 2014; De Vibe, Bjørndal, Tipton, Hammerstrøm, & Kowalski, 2012; Khoury et al., 2015; Zainal et al., 2013). Effects on mindfulness, as found in several earlier meta-analyses are more consistent and in the moderate range, between approximately 0.4 and 0.5 (Cavanagh et al., 2014; Khoury et al., 2015; Piet et al., 2012; Visted, Vøllestad, Nielsen, & Nielsen, 2014). More recently, Gotink et al. (2015) synthesized the results of meta-analyses that investigated the effectiveness of MBSR and MBCT as compared to waitlist controls and treatment as usual in different populations. They found an effect size of 0.37, 0.49, 0.51 and 0.39 for depression, anxiety, stress and quality of life, respectively.

Not surprisingly, given the rapid development of information technologies, MBIs—like other psychotherapeutic interventions—are increasingly being delivered through the Internet. Online interventions have a number of advantages over face-to-face interventions. Online interventions: (1) are easily accessible, without long waiting lists; (2) available 24/7 to people in their own environment, saving traveling time and enabling people to work at their own pace; (3) permit users to remain anonymous without needing to adopt a patient role; (4) do not necessarily require involvement of a therapist educated in mindfulness; and (5) are less costly (Andersson & Titov, 2014; Cuijpers et al., 2009). Moreover, a cross-sectional survey among 500 adults in the United States showed that many people prefer individual and online formats for mindfulness meditation interventions above group formats (Wahbeh, Svalina, & Oken, 2014). The internet was found to be the first choice format for 42% of the participants, suggesting that, for many individuals, online MBIs may be an acceptable alternative to face-to-face formats.

While multiple randomised controlled trials (RCTs) have provided empirical evidence for the effectiveness of online MBIs in the context of mental health and well-being (e.g. Boettcher et al., 2014; Buhrman et al., 2013; Dowd et al., 2015; Ly et al., 2014; Pots et al., 2016;

Trompetter, Bohlmeijer, Veehof, & Schreurs, 2014; Zernicke et al., 2014), to our knowledge, no published meta-analyses have examined the specific effects of online-delivered MBIs on mental health outcomes. However, two published meta-analyses investigating the effects of MBIs did include studies that employed online interventions. The first investigated the impact of self-help interventions, including components of mindfulness, on mindfulness/acceptance, depression and anxiety (Cavanagh et al., 2014). Cavanagh et al. (2014) found that self-help interventions that included components of mindfulness had a beneficial impact on mindfulness/acceptance skills ($g = 0.49$), anxiety ($g = -0.33$) and depression ($g = -0.37$) compared to control conditions. Although the meta-analysis conducted by Cavanagh et al. (2014) included eight (out of fifteen) studies that used an online intervention (of which four were multi-component interventions), their findings were inconclusive regarding the effectiveness of online-delivered MBIs. The second meta-analysis conducted by Öst (2014) evaluated the effectiveness of ACT across various psychiatric and somatic disorders. This study, however, only used the primary outcome measure, resulting in an overall effect size of $g = 0.42$ (Öst, 2014). In addition, only three of the sixty RCTs included in the study exclusively used online intervention. Finally, the meta-analysis of Öst (2014) did not examine the separate effects of ACT on depression, anxiety, stress or well-being nor the specific effects of online MBIs.

Since the publication of these two meta-analyses, both of which included data collected up until November 2013, a number of RCTs investigating the effectiveness of online MBIs have appeared in the scientific literature (e.g. Dowd et al., 2015; Pots et al., 2016; Trompetter et al., 2014; Zernicke et al., 2014). Based on the fact that most studies investigating the effects of online MBIs have been published in the last three years, and that interventions delivered through the Internet, in general, receive considerable attention nowadays (Barak, Klein, & Proudfoot, 2009), we anticipate a further rise in the number of online-delivered MBIs in the upcoming years. Hence, we consider it timely and important to meta-analytically test the effectiveness of online MBIs in terms of mental health outcomes. Accordingly, the primary aim of this explorative meta-analysis was to estimate the overall effect of online MBIs on depression, anxiety, stress and well-being, in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009). MBSR, MBCT and ACT are the most frequently studied online MBIs and also the focus of this article. Since MBIs are based on the premise that enhancing mindfulness skills will contribute to better mental health outcomes, our secondary aim was to explore the effects of online MBIs on mindfulness.

2. Method

This study was conducted in accordance with the PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions (Moher et al., 2009).

2.1. Search strategy

A systematic literature search was conducted in three electronic databases: PsycINFO, PubMed and Web of Science. Each database was initially searched for English language journal articles from the first available date until 27 November 2014, using the following search terms: (mindful* or acceptance or meditation) and (intervention* or therap* or treatment* or program*) and (online or e-health or Internet* or web* or computer or app or apps) and (random* or trial or RCT or control*). In PsycINFO and PubMed, MesH terms and thesaurus terms were added, respectively (see the Appendix A for the full search strings). During the preparation of the meta-analysis, the search was repeated three times to identify newly published trials. The last search was conducted on 23 March 2015.

In addition, three clinical trial registers (www.clinicaltrialsregister.eu, www.isrctn.com, and www.clinicaltrials.gov) were searched on 26 February 2015, to detect completed trials that had not yet been published (see the Appendix A for the full search strings). We contacted six authors of potentially relevant records of which one author responded.

2.2. Selection of studies

After the removal of duplicates, the remaining titles were reviewed, and then the abstracts of the potentially relevant articles were screened. Finally, the full-texts of the selected articles were obtained and assessed for eligibility. The screening of titles, abstracts and full-text articles, respectively, was independently conducted by two authors (MS, WP). Disagreements between the authors were discussed until consensus was reached. If any disagreement persisted, the last author (EB) was consulted.

Due to the explorative nature of this meta-analysis, we opted for rather broad inclusion criteria. We included studies that: (1) employed MBIs (including MBSR, MBCT and ACT) either with or without guidance; (2) administered the MBI via the Internet or a computer application (including virtual classrooms); (3) used validated outcome measures to examine the effects of the intervention on depression, anxiety, stress or well-being; (4) administered the intervention to a population 18 years and older; (5) used a control condition whether inactive or active; and (6) used a randomised controlled design.

Exclusion criteria were: (1) The intervention was merely a psychoeducational program and did not involve exercises for enhancing mindfulness or acceptance. (2) The intervention combined MBI and other forms of therapy (e.g. cognitive behavioural therapy), making it difficult to disentangle the effects of the MBI from the other included therapies. (3) The article did not provide sufficient data to calculate pre-post effect sizes per condition and the author was unable to provide this necessary data.

Five authors were contacted, all of whom provided additional data on request.

2.3. Data extraction and quality assessment

Data extraction was undertaken by the first author (MS) and checked by the second author (WP). Disagreements were resolved by discussion. For each included study, the following data were extracted: first author; country and year of publication; population characteristics, including type of sample, age, sex (% female) and number of participants per condition; intervention characteristics, including type of intervention (e.g. MBSR, MBCT, ACT), guidance (with/without), delivery mode (e.g. website), number of sessions and duration in weeks; control group (e.g. waitlist); assessment times (i.e. pre, post, follow-up); and outcome measures for depression, anxiety, stress, well-being and mindfulness.

The methodological quality of each study was independently assessed by two authors (MS, WP), who used seven criteria based on the Jadad scale (Jadad et al., 1996) and the Cochrane Collaboration's tool for assessing risk of bias (Higgins, Altman, & Sterne, 2011). The following criteria were applied: (1) adequate sequence generation and allocation concealment; (2) blinding of main outcome assessments, that is, outcome measures were administered online or by an independent person who was not involved in the study (Blinding of participants was not possible in most cases.); (3) reasons for drop-out and withdrawal were described; (4) handling of missing data, that is, intention-to-treat analyses were conducted, in which all randomised participants were included, or there were no drop-outs; (5) the sample size was based on an adequate power analysis; (6) study groups were similar with regard to prognostic indicators at baseline and this was explicitly assessed, or adjustments were made to correct for baseline imbalance; and (7) diagnostic assessment of the primary outcome was conducted by a professional (not by self-reporting or screening), or there were no diagnostic assessments necessary for the recruitment (e.g. students).

One point was assigned for each criterion that was met, with a maximum score of 7. Disagreements between the two authors who assessed the quality of the studies were resolved by discussion. The quality of a study was assessed as "high" when all seven criteria were met, "medium" when five or six criteria were met, and "low" when four or less criteria were met.

Twelve authors were contacted because insufficient information was provided in the article with regard to the data extraction and/or to make an accurate quality assessment. Consequently, ten authors provided supplementary information.

2.4. Calculation of effect sizes

For each comparison between an online MBI and a control group, effect sizes were calculated per outcome variable, i.e. depression, anxiety, stress and well-being. For well-being, we also used instruments related to well-being such as life satisfaction (e.g. SWLS, QOLI). If more than one instrument was used to measure depression, anxiety, stress or well-being, we used the most valid instrument, so that each study outcome had one effect size. One study (Cavanagh et al., 2013) used the PHQ-4 to measure depression and anxiety. Since this questionnaire does not allow to calculate separate scores for depression and anxiety, we excluded this questionnaire. Additionally, we calculated effect sizes for mindfulness measures whenever possible.

Two studies investigated the effectiveness of two different online MBIs compared to the same control group (Mak, Chan, Cheung, Lin, & Ngai, 2015; Morledge et al., 2013). In these cases, we calculated an effect size for both comparisons. On the other hand, for the three studies that included two control groups and one experimental group (Pots et al., 2016; Trompetter et al., 2014; Wolever et al., 2012), we used only one control group to calculate an effect size. For these studies, we chose the inactive control condition (i.e. waitlist or no intervention) as this was the most common comparison group across all the studies. The number of studies using an active control condition (Pots et al., 2016; Trompetter et al., 2014) was too small to allow for subgroup analyses based on the type of control group (i.e. inactive versus active).

For each comparison, Hedge's *g*, i.e. Cohen's *d* corrected for small sample bias, was calculated per relevant outcome measure, using means and standard deviations. First, we calculated standardised pre-post effect sizes, using the formula $d = (M_1 - M_0) / SD_0$, where M_1 and M_0 are the Means at post- and pre-test, respectively, and SD_0 is the pre-test standard deviation. Since we were interested in obtaining the effect size of the experimental effect minus the effect in the control group, we calculated *d* per condition, i.e. for the experimental condition (d_E) and the control condition (d_C). These *d*s represent how many standard deviations difference there is between the means of the pre- and the post-test of the respective condition. Subsequently, we calculated the difference between d_E and d_C, $\Delta(d)$, which shows us with how many standard deviations the experimental condition changed more compared to the control condition. Finally, using the software program Comprehensive Meta Analysis (CMA) version 2.2.064, $\Delta(d)$ was corrected for small sample bias, indicated as Hedge's *g*. Values of *g* can be interpreted in a similar manner as values of *d*. Using a second-order meta-analysis, Lipsey and Wilson (1993) have shown that an effect size from 0.00 to 0.32 can be considered a small effect, 0.33 to 0.55 a moderate effect and 0.56 to 1.20 a large effect. Because there was too much variability in follow-up periods, we did not calculate effect sizes of the change between pre-test and (longer-term) follow-up.

2.5. Meta-analytic procedures

All meta-analytic analyses were conducted with CMA version 2.2.064. Due to the diversity in intervention and population characteristics (see Table 1) and the rather broad inclusion criteria, we expected considerable variability in effect sizes and levels of heterogeneity. Consequently, it was decided *a priori* to use the random effects model. The random effects model is based on the assumption that the effect size may differ between studies not only due to random error within studies, but also as a result of true variation in effect sizes between studies (Hedges & Vevea, 1998).

Five separate meta-analyses were performed for (1) depression, (2) anxiety, (3) stress, (4) well-being and (5) mindfulness. Forest plots of pre-post between-group effect sizes were produced for each outcome variable, both with and without outliers. A study was considered an outlier when its 95% confidence interval (CI) was outside the 95% CI of the overall mean effect size (on both sides). Outliers were identified through visual inspection of the forest plots. Subsequently, the analyses were repeated, but only with medium and high quality studies (including outliers).

Heterogeneity of effect sizes was examined using *Q* and I^2 statistics. A significant Q statistic ($p \leq 0.05$) indicated significant heterogeneity, i.e. the presence of one or more variables that moderated the observed effect size. The I^2 statistic was used to estimate the percentage of heterogeneity across the primary studies not attributable to random sample error alone. A value of 0% indicated no heterogeneity. Values of 25%, 50% and 75% reflected low, moderate and high degrees of heterogeneity, respectively (Higgins & Thompson, 2002).

Pre-specified exploratory subgroup analyses were performed (including outliers) to examine differences in effect sizes based on: (1) intervention type: mindfulness or ACT; (2) therapist guidance: with or without; and (3) population: healthy, psychological symptoms, or physical symptoms. The moderating effects of the study quality and number of intervention sessions on effect sizes were assessed using meta-regression analyses, according to the mixed effects model.

Publication bias was assessed in three ways. First, a funnel plot was created by plotting the overall mean effect size against study size. Whereas a symmetric distribution of studies around the effect size indicates the absence of publication bias, a higher concentration of studies on one side of the effect size than on the other indicates publication bias (Sterne, Egger, & Moher, 2008). Second, a fail-safe *N*, a formal test of funnel plot asymmetry, was calculated for each analysis. The fail-safe *N* indicates the number of unpublished non-significant studies that would be required to lower the overall effect size below significance (Egger, Davey Smith, Schneider, & Minder, 1997). The findings were considered robust if the fail-safe $N \geq 5n + 10$, where *n* is the number of comparisons (Rosenberg, 2005). Third, Duval and Tweedie's (2000) trim-and-fill procedure was applied. This procedure imputes the effect sizes of missing studies and produces an adjusted effect size accounting for these missing studies (Duval & Tweedie, 2000).

3. Results

3.1. Selection of studies

A flow diagram of the study selection process is presented in Fig. 1. The electronic database searches produced 805 records after removal of duplicates. After reviewing the titles, we identified 150 potentially eligible records. Based on the abstracts, 34 of these 150 articles were selected for further examination. Full-text versions of these articles were obtained and assessed for eligibility. This led to the inclusion of 15 RCTs, totalling 17 comparisons of an online MBI with a control group (in two trials, two comparisons are made using a single control group). Additionally, 176 records were identified through searching trial registers, of which seven were assessed as potentially relevant. No unpublished data were made available.

3.2. Description of included studies

Four studies were conducted in the United States, four in Sweden, two in The Netherlands, and one each in the United Kingdom, Ireland, Austria/Switzerland, China, and Canada. Characteristics of the included trials are presented in Table 1.

Table 1
Characteristics of studies included in the meta-analysis.

First author (year)	Population, country	% F[a]	Mean age (range)[b]	Intervention (*n*)	Guidance (with/without)	Delivery mode	*n* sessions, duration in weeks	Control group (*n*)	Measurements[c]	Outcome measures				
										Depression	Anxiety	Stress	Well-being	Mindfulness
Aikens et al. (2014)	Employees, US	50%	U (U)	MBSR (44)	With (G/I)	Website and virtual online classroom	7 sessions, 7 weeks	Waitlist (45)	Pre, post	–	–	PSS-14	–	FFMQ
Boettcher et al. (2014)	Adults diagnosed with an anxiety disorder, Sweden	71.4	38 (22–65)	Internet-based Mindfulness Treatment (45)	Without	Website	8 sessions, 8 weeks	Online discussion forum (46)	Pre, post	BDI-II	BAI	–	QOLI	–
Buhrman et al. (2013)	Chronic pain patients, Sweden	59.2	49 (27–69)	ACT (38)	With (I)	Website	7 sessions, 7 weeks	Online discussion forum (38)	Pre, post	HADS-D	HADS-A	–	QOLI	–
Cavanagh et al. (2013)	Students, UK	88.5	25 (19–51)	Internet-based Mindfulness Treatment (54)	Without	Website	U, 2 weeks	Waitlist (50)	Pre, post			PSS	–	FFMQ
Dowd et al. (2015)	Adults with self-reported chronic pain, Ireland	90.3	45 (19–76)	MBCT (62)	Without	Website	12 sessions, 6 weeks	Psycho-education (62)	Pre, post, 7.5-month FU	HADS-D	HADS-A	–	SWLS	MAAS
Glück and Maercker (2011)	Students, employees, Austria/Switzerland	73.5	35 (20–73)	MBSR (28)	Without	Website	2 sessions, 2 weeks	Waitlist (21)	Pre, post, 3.5-month FU	–	–	PSQ	–	FMI
Hesser et al. (2012)	Adults diagnosed with tinnitus, Sweden	43.4	49 (20–78)	ACT (35)	With (I)	Website	8 sessions, 8 weeks	Online discussion forum (32)	Pre, post, 1-year FU	HADS-D	HADS-A	PSS	QOLI	–
Levin et al. (2014)	Students, US	53.9	18 (18–20)	ACT (37)	Without	Website	2 sessions, 3 weeks	Waitlist (39)	Pre, post	DASS –D	DASS-A	DASS-S	–	–
Ly et al. (2014)	Adults with MDD, Sweden	70.4	36 (20–61)	MBCT (41)	With (I)	Smartphone application	U, 8 weeks	BA treatment (40)	Pre, post, 6-month FU	BDI-II, PHQ-9-D	BAI	–	QOLI	-I
Mak et al. (2015)	Students, employees, China	66.3	23 (17–53)	MBSR (107)	Without	Website	8 sessions, 8 weeks	Waitlist (107)	Pre, post, 3-month FU	DASS-D	DASS-A	PSS	SWLS, WHO-5	FFMQ
				MBSR-HAPA (107)	Without	Website	8 sessions, 8 weeks							
Morledge et al. (2013)	Healthy individuals, US	88.9	U	MBSR (184)	With (G)	Website	8 sessions, 8 weeks	Waitlist (184)	Pre, post, 12-week FU	–	–	PSS	–	MAAS
				MBSR (183)	Without	Website	8 sessions, 8 weeks							
Pots et al. (2016)	Adults with mild to moderate depressive symptoms, The Netherlands	75.8	47 (20–73)	ACT (82)	With (I)	Website	9 sessions, 12 weeks	Waitlist (87) Expressive writing (67)	Pre, post, 6-month FU	CES-D	HADS-A	–	MHC-SF	FFMQ-SF
Trompetter et al. (2014)	Adults with chronic pain, The Netherlands	76.0	53 (20–84)	ACT (82)	With (I)	Website	9 sessions, 9–12 weeks	Waitlist (77) Expressive writing (79)	Pre, post, 6- and 12-month FU	HADS-D	HADS-A	–	MHC-SF	FFMQ-SF
Wolever et al. (2012)	Employees, US	77.2	43 (U)	MBSR (52)	With (G)	Virtual online classroom	12 sessions, 12 weeks	No intervention (53) Yoga (90)	Pre, post	CES-D	–	PSS	–	CAMS-R
Zernicke et al. (2014)	Cancer recovery patients, Canada	72.6	58 (29–79)	MBSR (30)	With (G)	Virtual online classroom	8 sessions, 8 weeks	Waitlist (32)	Pre, post	POMS-D	POMS-A	CSOSI	–	FFMQ

Note. ACT, acceptance and commitment therapy; BA, behavioural activation; BAI, Beck Anxiety Inventory; BDI-II, Beck Depression Inventory-II; CAMS-R, Cognitive and Affective Mindfulness Scale-Revised; CDC, Centers for Disease Control Chronic Fatigue Syndrome Symptom Inventory; CES-D, Center for Epidemiological Studies Depression Scale; CFS, chronic fatigue syndrome; CSOSI, Calgary Symptoms of Stress Inventory; DASS-A, Depression Anxiety and Stress Scale—Anxiety subscale; DASS-D, Depression Anxiety and Stress Scale—Depression subscale; DASS-S, Depression Anxiety and Stress Scale—Stress subscale; F, female; FFMQ, Five Facets of Mindfulness Questionnaire; FFMQ-SF, Five Facet Mindfulness Questionnaire—Short Form; FMI, Freiburg Mindfulness Inventory; FU, follow-up; G, group-based; HADS-A, Hospital Anxiety and Depression Scale—Anxiety subscale; HADS-D, Hospital Anxiety and Depression Scale—Depression subscale; HAPA, health action process approach; I, individual; ITT, intention-to-treat; MAAS, Mindful Attention Awareness Scale; MBCT, mindfulness-based cognitive therapy; MBSR, mindfulness-based stress reduction; MDD, Major Depressive Disorder; MHC-SF, Mental Health Continuum-Short Form; PHQ-9-D, Patient Health Questionnaire—Depression Scale; POMS-A, Profile of Mood States—Anxiety Subscale; POMS-D, Profile of Mood States—Depression Subscale; PSS, Perceived Stress Scale; PSQ, Perceived Stress Questionnaire; PWB-SA, Psychological Well-Being Self-Acceptance scale; QoL, quality of life; QOLI, Quality of Life Inventory; SF-36, RAND 36-Item Short Form Health Survey; U, unknown; UK, United Kingdom; US, United States; WHO-5, 5-item World Health Organization Well-Being Index.

[a] % female of the total study population at baseline.

[b] Mean age (SD and/or range) of the total study population at baseline.

[c] We only report measurements that will be used in the meta-analysis. Follow-up times are since baseline.

3.2.1. Population characteristics

The total population comprised 2360 participants of which 1211 participants were in the experimental conditions and 1149 in the control conditions (913 when excluding the control conditions not included in the meta-analysis). In all but one study (Hesser et al., 2012), the majority of the sample was female. All participants were adults, with a mean age ranging from 18 to 58 years. The total sample size ranged from 49 in a pilot study (Glück & Maercker, 2011) to 551 in a large-scale trial (Morledge et al., 2013). Five of the 15 studies were conducted in a population with a somatic illness, including chronic pain ($n = 3$), tinnitus ($n = 1$) and cancer recovery patients ($n = 1$). In three studies, participants were characterized by psychological illnesses, i.e. anxiety ($n = 1$) or depression ($n = 2$). Non-clinical populations, such as students or employees, were used in the remaining seven studies.

3.2.2. Intervention characteristics

Eight of the 17 comparisons examined MBSR, two MBCT and five ACT. The 10 comparisons examining MBSR or MBCT used modified protocols instead of pure MBSR or MBCT, in the sense that the intervention: (1) comprised more or less than eight sessions, (2) used shortened exercises, (3) was adapted to a specific target population (e.g. cancer recovery patients) and/or (4) did not involve a retreat. Two comparisons used an Internet-based mindfulness treatment which could not be classified as MBSR or MBCT (Boettcher et al., 2014; Cavanagh et al., 2013). In nine comparisons, therapist guidance was offered during the intervention. In five of these comparisons, guidance consisted of individual coaching and feedback (e.g. answering questions, feedback on assignments, positive encouragement) delivered through e-mail, an enclosed and encrypted webpage and/or telephone. In three comparisons, guidance was provided in the form of weekly 1- or 2-hour (online) classes (group-based), of which one study additionally provided (pre-programmed) individual e-mail coaching and feedback. In one comparison, participants were reinforced through messages posted on an online message board. MBIs were most commonly delivered via a website ($n = 14$). Other delivery modes included a smartphone application ($n = 1$) and a virtual online classroom ($n = 2$). One comparison (Aikens et al., 2014) used a combination of a website and a virtual online classroom. Sessions were usually weekly, ranging from 2 to 12 sessions. The intervention duration varied from 2 to 12 weeks.

3.2.3. Adherence

Adherence to the intervention was addressed in ten studies, using various definitions of adherence (e.g. 100% of the sessions completed, ≥5 sessions completed, or 6–8 weeks). When adherence was defined as completion of all sessions, adherence rates varied between 39.5% and 92% (based on five studies).

3.2.4. Comparison group

Nine studies compared an online MBI to a waitlist control group, of which two studies (Pots et al., 2016; Trompetter et al., 2014) also included an active control group (i.e. expressive writing). In five studies, the control group received access to an online discussion forum ($n = 3$), a psycho-educational program ($n = 1$), or a behavioural activation program ($n = 1$). In the remaining study, the control group received no intervention.

3.2.5. Outcomes

Outcome measures were administered as follows: depression in 12 comparisons, anxiety in 11 comparisons, stress in 11 comparisons, well-being in 9 comparisons and mindfulness in 12 comparisons. All instruments had good psychometric properties. Eight studies reported follow-up data, with follow-up periods varying between 12 weeks and one year.

3.3. Quality of studies

The quality assessment scores ranged from 3 to 7 points (see Table 2). Most studies ($n = 10$) were of medium quality, three of low quality and two of high quality. All studies met the criteria of blinding and intention-to-treat analysis. Description of withdrawals/drop-outs (Criterion 3) was the most poorly rated, with only three studies meeting this criterion.

3.4. Meta-analysis

The pre-post between-group effects for depression, anxiety, stress, well-being and mindfulness are presented in Table 3. Below, the results are discussed per outcome measure.

3.4.1. Effects on depression

For depression (12 comparisons), a significant, small effect was observed ($g = 0.29$, 95% CI: 0.13 to 0.46, $p = .001$). The level of heterogeneity was moderate ($I^2 = 58.35$). Two outliers were detected (Boettcher et al., 2014; Ly et al., 2014). After omitting these studies from the analysis, we found a similar effect, with $g = 0.27$ (95% CI: 0.16 to 0.39, $p < .001$), and heterogeneity reduced substantially ($I^2 = 6.33$). When only studies scored as medium or high quality were included in the analysis (including outliers), a similar significant effect size was observed ($g = 0.28$, 95% CI: 0.08 to 0.47, $p = .005$), with a substantial level of heterogeneity ($I^2 = 65.29$).

3.4.2. Effects on anxiety

Based on 11 comparisons, we found a significant, small effect of online MBIs on anxiety, with $g = 0.22$ (95% CI: 0.05 to 0.39, $p = .010$) and no outliers. The level of heterogeneity was moderate ($I^2 = 56.98$). After removal of low quality studies from the analysis, the effect size was virtually the same ($g = 0.21$, 95% CI: 0.03 to 0.40, $p = .022$), and heterogeneity remained substantial ($I^2 = 60.58$).

3.4.3. Effects on stress

For stress (11 comparisons), a significant, moderate effect was found ($g = 0.51$, 95% CI: 0.26 to 0.75, $p < .001$). Heterogeneity was considerable ($I^2 = 82.46$), and one outlier was detected (Wolever et al., 2012). After removal of the outlier, the effect size dropped to $g = 0.39$ (95% CI: 0.21 to 0.57, $p < .001$), but still remained in the moderate range, and the level of heterogeneity remained high ($I^2 = 65.63$). Also when studies of low quality were omitted from the analysis, the effect size for stress was in the moderate range ($g = 0.40$, 95% CI: 0.20 to 0.59, $p < .001$), with substantial heterogeneity ($I^2 = 69.41$).

3.4.4. Effects on well-being

The overall mean effect size for 9 comparisons on well-being was $g = 0.23$ (95% CI: 0.09 to 0.38). This effect was statistically significant ($p = .001$) and can be considered a small effect. The level of heterogeneity was low to moderate ($I^2 = 32.86$), and no outliers were identified. After removal of low quality studies, the effect size for well-being slightly increased to $g = 0.25$ (95% CI: 0.10 to 0.40, $p = .001$), and heterogeneity was moderate ($I^2 = 36.16$).

3.4.5. Effects on mindfulness

For mindfulness, we were able to compare the effects of an online MBI to a control condition in 10 studies, totalling 12 comparisons. The findings revealed that online MBIs have a significant impact on mindfulness, with a small effect size of $g = 0.32$ (95% CI: 0.23 to 0.42, $p < .001$). Heterogeneity was low ($I^2 = 12.23$). One outlier was identified (Aikens et al., 2014). After removal of this outlier, the observed effect size was virtually the same ($g = 0.30$, 95% CI: 0.21 to 0.39, $p < .001$), with absence of heterogeneity ($I^2 = 0$). When we included only studies of medium or high quality in the analysis, we found the same effect size for

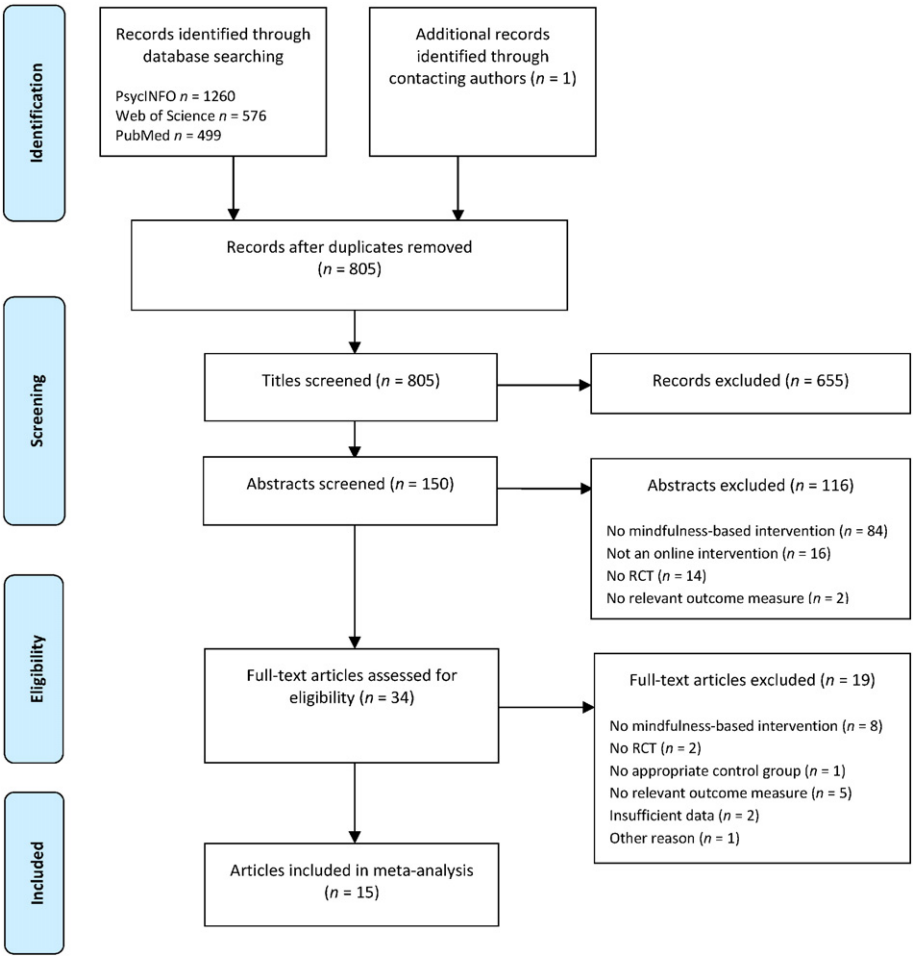

Fig. 1. Flowchart of the study selection process.

mindfulness ($g = 0.32$, 95% CI: 0.21 to 0.43, $p < .001$). The level of heterogeneity was low with $I^2 = 26.60$.

3.5. Subgroup analyses

Exploratory subgroup analyses are presented in Table 4. For stress ($Q = 20.12$, $df = 1$, $p < .001$) and mindfulness ($Q = 5.50$, $df = 1$, $p = .019$), significantly higher effect sizes were found for online MBIs with therapist guidance than for online MBIs without therapist guidance, but effect sizes did not vary based on intervention type (i.e. mindfulness or ACT) or population (i.e. healthy, psychological symptoms or physical symptoms). For depression, anxiety and well-being, no significant differences between subgroups were found.

3.6. Meta-regression analysis

Using meta-regression analysis, we found no evidence that effect sizes were moderated by study quality. For stress, the number of sessions had a significant positive influence on the effect size, with more sessions resulting in higher effect sizes. This was found when we included the outlier (slope: 0.10, $Z = 2.22$, $p = 0.026$), but not when we excluded the outlier (slope: 0.04, $Z = 0.78$, $p = 0.43$).

3.7. Publication bias

Some indication for publication bias was found. For anxiety, stress and well-being, funnel plots were somewhat skewed in favour of studies with a positive outcome. Furthermore, the fail-safe N indicated that the findings for depression, stress and mindfulness were robust, whereas the fail-safe numbers for anxiety (33) and well-being (28) were lower than required (respectively 65 and 55).

When omitting either outliers or low quality studies, the findings for stress and mindfulness were still found to be robust. After removing outliers, the fail-safe N (56) for depression was slightly lower than required (60). When low quality studies were excluded from the analysis, findings did not appear robust for depression, anxiety and well-being, with fail-safe numbers of 48, 24 and 29, respectively.

After adjusting for potential publication bias with Duval and Tweedie's trim-and-fill procedure, the effect sizes for depression, anxiety, stress, well-being and mindfulness remained the same. However, for depression, four studies were imputed after removal of outliers and the adjusted effect size was $g = 0.18$ (95% CI: 0.04 to 0.31). When only studies of medium or high quality were included in the analysis, two studies were imputed for stress and the effect size was adjusted to $g = 0.30$ (95% CI: 0.10 to 0.50).

4. Discussion

4.1. Main findings

The aim of this explorative meta-analysis was to estimate the overall effects of online MBIs on depression, anxiety, stress, well-being (primary outcomes) and mindfulness (secondary outcome) compared to controls. When all studies were taken into account, we found small but

Table 2
Methodological quality of studies included in the meta-analysis.

First author (year)	1. Adequate allocation sequence generation and allocation concealment	2. Blinding of main outcome assessments	3. Description of withdrawals/ drop-outs	4. Intention-to-treat analysis is performed or there are no drop-outs	5. The sample size is based on an adequate power analysis.	6. The groups are similar on prognostic indicators at baseline (and this was explicitly assessed) or adjustments were made to correct for baseline imbalance (using appropriate covariates).	7. Diagnostic assessment was conducted by a professional, or there were no diagnostic assessments necessary for the recruitment	Score
Aikens et al. (2014)	Yes	Yes	Yes	Yes	No	Yes	Yes	6
Boettcher et al. (2014)	Yes	Yes	No	Yes	Unclear	Yes	Yes	5
Buhrman et al. (2013)	Yes	Yes	No	Yes	Yes	No	No	4
Cavanagh et al. (2013)	Yes	Yes	No	Yes	Unclear	Yes	Yes	5
Dowd et al. (2015)	Yes	Yes	No	Yes	Yes	Yes	No	5
Glück and Maercker (2011)	No	Yes	No	Yes	No	No	Yes	3
Hesser et al. (2012)	Yes	Yes	No	Yes	Unclear	Yes	Yes	5
Levin et al. (2014)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	7
Ly et al. (2014)	Yes	Yes	No	Yes	Unclear	Yes	Yes	5
Mak et al. (2015)	Yes	Yes	No	Yes	Yes	No	Yes	5
Morledge et al. (2013)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	7
Pots et al. (2016)	Yes	Yes	No	Yes	Yes	Yes	Yes	6
Trompetter et al. (2014)	Yes	Yes	No	Yes	Yes	Yes	No	5
Wolever et al. (2012)	Yes	Yes	No	Yes	Unclear	Unclear	Yes	4
Zernicke et al. (2014)	Yes	Yes	No	Yes	Yes	Yes	Yes	6

significant effect sizes for depression, anxiety, well-being and mindfulness, and a significant moderate effect size for stress. Based on the fail-safe N, the effects on depression, stress and mindfulness appear robust.

This meta-analysis shows the most promising findings for stress. The observed effect of online MBIs on stress, including the outlier, is comparable to the effect size found for traditional MBSR and MBCT ($d = 0.51$) as found in a recent systematic review and meta-analysis of systematic reviews of RCTs (Gotink et al., 2015). The fact that a considerably greater beneficial impact on stress was observed, relative to the other outcomes, can be explained as the majority of studies that administered a stress outcome measure employed MBSR (8/11), which was originally developed for reducing stress in people with chronic pain (Kabat-Zinn, 1982). However, the observed effect size for stress dropped from 0.51 to 0.39 after removal of one extreme positive outlier (Wolever et al., 2012), suggesting that the effect on stress may be somewhat overestimated. One potential explanation for the divergent findings of Wolever et al. (2012) is that the intervention duration in this particular study was relatively long (12 sessions) compared to the other studies (ranging from 2 to 8 sessions). We found a moderating effect of the number of sessions on the effectiveness of online MBIs in reducing stress, although this effect seemed to be driven by the aforementioned outlier (Wolever et al., 2012). Because only one study that evaluated an online MBI with 12 sessions was included in our meta-analysis, no definite conclusions can be drawn. Moreover, the study quality of Wolever et al. (2012) was low.

Contrary to the literature, which has demonstrated that online psychotherapeutic interventions are equally effective as face-to-face interventions (Barak, Hen, Boniel-Nissim, & Shapira, 2008), the effect sizes for depression and anxiety in this meta-analysis were in general lower than the medium to large effect sizes found for face-to-face MBIs in previous research (e.g. Abbott et al., 2014; Cavanagh et al., 2014; Gotink et al., 2015; Hofmann et al., 2010; Khoury et al., 2015; Piet et al., 2012; Vøllestad et al., 2012; Zainal et al., 2013). These findings may suggest that online MBIs are, as yet, not equally effective as traditional face-to-face MBIs in reducing depression and anxiety. Nevertheless, drawing any conclusions based on these findings would be premature since only a relatively small number of trials addressing the effectiveness of online MBIs on depression and anxiety could be included in the present meta-analysis.

Moreover, considerable variability existed across the studies, e.g. in terms of study population. It is possible that particular subgroups may benefit more from online delivered MBIs than other groups. For instance, a meta-analysis of Barak et al. (2008) showed that Internet-based psychotherapeutic interventions are more suitable for individuals with psychological symptoms than for individuals with physical symptoms. Although we did not find strong evidence for this notion, effect sizes appeared to be larger for populations with psychological symptoms (e.g. depression, anxiety) than for healthy populations or populations with physical symptoms (e.g. chronic pain) on all outcome measures, except for stress (for stress, comparisons were only possible for healthy populations and populations with physical symptoms). However, these differences did not reach statistical significance, possibly due to the small number of studies per subgroup. Since about half of the included studies ($n = 7$) were conducted in healthy samples (e.g. students and employees), the effectiveness of online MBIs in alleviating depression and anxiety might be underestimated. Healthy populations are likely to have lower baseline scores on psychological symptoms, such as depression and anxiety, leading to less room for improvement compared to clinical populations. In other words, the small effect sizes for depression and anxiety may be attributed to a floor effect.

Another possible explanation for the small effect sizes of online MBIs compared to face-to-face MBIs has to do with adherence. Non-adherence occurs when people stop using the intervention or use the intervention in a way its developers did not intend. This is a common issue in online psychological interventions and may diminish the

Table 3
Pre-post between-group effects.

Outcome measures	N_{comp}	Hedge's *g*	95% CI	*Z*	Heterogeneity		Fail-safe *N*
					Q-value	I^2	
All studies (*including outliers*)							
Depression	12	0.29	0.13 to 0.46	3.44**	26.41**	58.35	76
Anxiety	11	0.22	0.05 to 0.39	2.58*	23.25*	56.98	33
Stress	11	0.51	0.26 to 0.75	4.07***	57.01***	82.46	225
Well-being	9	0.23	0.09 to 0.38	3.23**	11.92	32.86	28
Mindfulness	12	0.32	0.23 to 0.42	6.60***	12.53	12.23	145
All studies (*excluding outliers*)							
Depression	10	0.27	0.16 to 0.39	4.67***	9.61	6.33	56
Stress	10	0.39	0.21 to 0.57	4.20***	26.19**	65.63	125
Mindfulness	11	0.30	0.21 to 0.39	6.51***	6.62	0	101
Medium and high quality studies							
Depression	10	0.28	0.08 to 0.47	2.80**	25.93**	65.29	48
Anxiety	10	0.21	0.03 to 0.40	2.30*	22.83*	60.58	24
Stress	9	0.40	0.20 to 0.59	4.00***	26.15**	69.41	114
Well-being	8	0.25	0.10 to 0.40	3.29**	10.96**	36.16	29
Mindfulness	10	0.32	0.21 to 0.43	5.78***	12.26	26.60	114

Note. N_{comp}, number of comparisons; CI, confidence interval.
* p < .05.
** p < .01.
*** p < .001.

effectiveness of an intervention (Christensen, Griffiths, & Farrer, 2009; Donkin et al., 2011; Wangberg, Bergmo, & Johnsen, 2008). Adherence is especially relevant in mindfulness training, as regular practise is assumed essential for developing mindfulness skills (e.g. Carmody & Baer, 2008). In those studies included in our meta-analysis that reported adherence, adherence rates varied between 35% and 92%. Due to variations in definitions and measurements of adherence along with the lack of clarity around how adherence was measured (e.g. self-reported or using log-data), we were not able to systematically study whether adherence to the intervention is significantly associated with

Table 4
Subgroup analyses (including outliers).

Outcome measure	Criterion	Subgroup	N_{comp}	Hedge's *g*	95% CI	I^2	*Z*
Depression	Intervention type	Mindfulness	7	0.21	0.01 to 0.42	68.44	2.01*
		ACT	5	0.40	0.15 to 0.66	0	3.10**
	Guidance	With	7	0.29	0.06 to 0.53	57.33	2.48*
		Without	5	0.29	0.03 to 0.55	66.12	2.18*
	Population	Healthy	4	0.21	−0.07 to 0.50	0	1.48
		Psychological symptoms	3	0.41	0.07 to 0.76	89.51	2.35*
		Physical symptoms	5	0.29	0.01 to 0.56	0	2.05*
Anxiety	Intervention type	Mindfulness	6	0.11	−0.10 to 0.31	60.55	1.01
		ACT	5	0.37	0.13 to 0.60	12.43	3.07**
	Guidance	With	6	0.26	0.02 to 0.50	50.47	2.09*
		Without	5	0.19	−0.06 to 0.43	65.73	1.46
	Population	Healthy	3	0.10	−0.19 to 0.39	0	0.69
		Psychological symptoms	3	0.41	0.09 to 0.72	81.11	2.52*
		Physical symptoms	5	0.19	−0.06 to 0.45	10.97	1.49
Stress	Intervention type	Mindfulness	9	0.54	0.27 to 0.82	85.18	3.86***
		ACT	2	0.34	0.28 to 0.96	61.22	1.08
	Guidance	With	5	0.89	0.65 to 1.12	75.96	7.41***
		Without	6	0.19	−0.01 to 0.38	0	1.88
	Population	Healthy	9	0.47	0.20 to 0.73	85.06	3.41**
		Psychological symptoms	0	–	–	–	–
		Physical symptoms	2	0.73	0.12 to 1.35	0	2.33*
Well-being	Intervention type	Mindfulness	5	0.28	0.09 to 0.48	36.05	2.84**
		ACT	4	0.17	−0.06 to 0.40	40.59	1.42
	Guidance	With	5	0.15	−0.05 to 0.36	23.05	1.47
		Without	4	0.31	0.11 to 0.52	45.09	3.02**
	Population	Healthy	2	0.19	−0.02 to 0.41	0	1.77
		Psychological symptoms	3	0.43	0.20 to 0.66	56.87	3.61***
		Physical symptoms	4	0.11	−0.09 to 0.32	0	1.10
Mindfulness	Intervention type	Mindfulness	10	0.31	0.20 to 0.42	8.09	5.57***
		ACT	2	0.39	0.15 to 0.63	55.25	3.21**
	Guidance	With	6	0.43	0.30 to 0.56	20.33	6.60***
		Without	6	0.22	0.10 to 0.34	0	3.63***
	Population	Healthy	8	0.32	0.21 to 0.42	11.71	5.84***
		Psychological symptoms	1	0.56	0.24 to 0.87	0	3.46**
		Physical symptoms	3	0.23	0.01 to 0.45	0	2.09*

Note. N_{comp}, number of comparisons; CI, confidence interval.
* p < .05.
** p < .01.
*** p < .001.

effectiveness. Hence, we cannot rule out that non-optimal adherence may have prevented (some of) the online MBIs from reaching their full potential in terms of mental health outcomes.

This poses the question as to how adherence to online MBIs may be enhanced. Previous research indicates that providing support has a positive influence on adherence and enhances the effectiveness of online psychological interventions (Andersson & Cuijpers, 2009; Richards & Richardson, 2012; Spek et al., 2007). Consistently, for stress and mindfulness, significantly larger effect sizes were found for online MBIs with therapist guidance ($g = 0.89$ and $g = 0.43$, respectively) than for online MBIs without therapist guidance ($g = 0.19$ and $g = 0.22$, respectively) (see also Table 4). However, we did not find a significant influence of therapist guidance on depression, anxiety and well-being. In this respect, we would like to stress that the subgroup analyses were underpowered and that these findings should be interpreted with caution.

Offering therapist guidance to participants of online MBIs may thus potentially improve adherence and treatment outcomes, however, not without a few disadvantages. For instance, involvement of a therapist is costly and may restrict the scalability of the intervention. These barriers may be overcome by using automated support instead of human support. Examples of automated support, which may be helpful in the context of online MBIs, are automated text messages and personalised experience stories. Such messages and stories can address participants' possible doubts about the mindfulness programme and/or the restlessness and sleepiness they might be experiencing, by providing suggestions on how to successfully cope with these hindrances.

Automated support has proven effective in improving adherence and effectiveness of interventions (Furmark et al., 2009; Morgan, Jorm, & Mackinnon, 2012; Titov et al., 2010). In addition, a recent RCT (Kelders, Bohlmeijer, Pots, & Van Gemert-Pijnen, 2015) suggests that automated support may be as effective as human support, when enriched with persuasive e-health technologies such as text messages, interaction, tailoring and personalisation (for an overview, see Oinas-Kukkonen & Harjumaa, 2009). In another recent study (Kelders et al., 2015), a human-supported web-based ACT intervention and an automated-supported we-based ACT intervention, both of which aimed to aid people with mild to moderate depressive symptoms, were compared to one another in terms of adherence and effectiveness. This comparison showed similar adherence rates as well as similar improvements in depression and anxiety after six months. That persuasive e-health technologies may enhance adherence and effectiveness of online interventions is also confirmed by a systematic review of adherence to web-based interventions (Kelders, Kok, Ossebaard, & Van Gemert-Pijnen, 2012).

With respect to study quality, we found that when low quality studies were omitted from the analysis, virtually the same effects were found for each outcome measure except for stress for which the effect size dropped from 0.51 to 0.40. However, the meta-regression analysis indicated that there was no significant relationship between the methodological quality of the studies and effect sizes for any of the outcome measures. While this finding is in line with previous meta-analyses investigating the effects of MBIs (Bohlmeijer et al., 2010; Hofmann et al., 2010; Klainin-Yobas et al., 2012; Powers, Zum Vörde Sive Vörding, & Emmelkamp, 2009; Strauss et al., 2014; Veehof et al., 2011), there are also meta-analyses which indicate that higher quality studies yield smaller effect sizes (A-Tjak et al., 2015; Khoury et al., 2013). Nonetheless, we recommend researchers conducting RCTs on online MBIs to comply with the criteria for designing high quality trials, in order to build a body of sound scientific knowledge on the effectiveness of online MBIs.

4.2. Limitations and directions for future research

This meta-analysis had several limitations. First, despite the growing empirical literature on the effectiveness of online MBIs in terms of mental health outcomes, we were only able to include a relatively small number of RCTs in our meta-analysis. Second, the effect sizes of the included studies varied considerably per outcome, which may be explained by differences in study characteristics, such as population, intervention type (e.g. ACT, MBSR or MBCT), and outcome measures. The small number of studies and substantial variability across studies warrants caution in interpreting and generalising the observed effect sizes. Third, although we conducted several subgroup analyses in order to explore potential moderators of the effects of online MBIs, it must be acknowledged that these analyses were underpowered and that the findings should be interpreted tentatively. Fourth, given the small number of studies and the fact that only two studies concerned MBCT, it was not possible to conduct separate meta-analyses for ACT, MBSR and MBCT, respectively. These interventions use somewhat different approaches, for example, MBCT and ACT incorporate elements of cognitive behavioural therapy as opposed to MBSR. Furthermore, ACT uses mindfulness techniques, but does not require meditation, whereas MBCT and MBSR are meditation-based. Hence, the interventions might not be equally effective. Finally, it was not possible to conduct a meta-analysis of the long-term effects of online MBIs because of the high variability in follow-up periods (ranging from 12 weeks to 1 year). This is considered important, because multiple trials have shown that effects of online MBIs are maintained up to one year after baseline (e.g. Hesser et al., 2012; Pots et al., 2016).

Given the widespread attention for mindfulness and the potential value of online MBIs for clinical practice, additional research to establish the beneficial effects of online MBIs and to gain insight in their moderators of effectiveness is warranted. Future research might focus on a number of specific areas, including: (1) testing whether the observed beneficial effects of online MBIs on depression, anxiety, stress, well-being and mindfulness are maintained over time; (2) assessing the clinical utility of online MBIs across various subgroups (e.g. psychological versus somatic illnesses) and in various (clinical) populations; and (3) identifying moderators of the effects of online MBIs (e.g. type of intervention: ACT, MBSR or MBCT; delivery mode: smartphone versus computer).

In addition, we encourage researchers in the field to take into account study quality criteria. Although most studies were of satisfactory quality, only two studies (Levin, Pistorello, Seeley, & Hayes, 2014; Morledge et al., 2013) could be classified as high quality. In particular, the description of withdrawals/drop-outs (Criterion 3) and the sample size being based on an adequate power analysis (Criterion 5) were often not adequately addressed. Finally, we strongly recommend researchers to not only report on study dropouts, but to address adherence to the intervention as well (e.g. number of sessions completed and length of time practiced). Given the dose–response relationship that has been found for the use of online interventions (Christensen et al., 2009; Donkin et al., 2011; Wangberg et al., 2008), adherence seems an important factor to take into account when considering the effectiveness of online MBIs. This finding is corroborated in the study of Trompetter et al. (2014) which yielded significantly greater gains for adherers than for non-adherers.

4.3. Conclusions and implications

To our knowledge, this is the first meta-analysis that evaluates the specific effects of online MBIs on mental health and well-being. It has been argued that online interventions in the context of public mental health are a promising strategy to alleviate psychological symptomatology and reduce the prevalence of severe mental health problems (Barak et al., 2008; Fledderus, Bohlmeijer, Pieterse, & Schreurs, 2012; Pots et al., 2016; Ybarra & Eaton, 2005). Our findings, in turn, contribute to a better understanding of the effectiveness of online MBIs. Although research exploring the effectiveness of online MBIs is still in its infancy, we conclude that there is emerging evidence that online MBIs have the potential to improve mental health outcomes, most notably stress.

We found small effects for most outcomes (i.e. depression, anxiety, well-being, and mindfulness). Nonetheless, the wide reach and low cost of online MBIs may facilitate improved mental health and well-being in many people (with psychological distress). Online MBIs may be used in various manners and for various purposes. For instance, online MBIs might be an acceptable and useful alternative for people who may benefit from cultivating their mindfulness skills, but cannot be reached with traditional (individual or group-based) face-to-face formats (e.g. Wahbeh et al., 2014). In addition, online MBIs may be offered to individuals who are on a waitlist to receive a face-to-face MBI. Furthermore, online MBIs may be integrated in other (online) psychotherapeutic interventions (e.g. cognitive behavioural therapy) aimed at decreasing distress and/or enhancing well-being (e.g. Bohlmeijer et al., 2010; Veehof et al., 2011).

Appendix A. Full electronic search strategies

Search strategy: *PsycINFO* (*EBSCO*):

#1 TI (mindful* OR acceptance OR meditation) OR AB (mindful* OR acceptance OR meditation) OR KW (mindful* OR acceptance OR meditation)
#2 DE "Mindfulness" OR DE "Acceptance and Commitment Therapy" OR DE "Meditation"
#3 TI (intervention* OR therap* OR treatment* OR program*) OR AB (intervention* OR therap* OR treatment* OR program*) OR KW (intervention* OR therap* OR treatment* OR program*)
#4 TI (online OR e-health OR Internet* OR web* OR computer* OR app OR apps) OR AB (online OR e-health OR Internet* OR web* OR computer* OR app OR apps) OR KW (online OR e-health OR Internet* OR web* OR computer* OR app OR apps)
#5 DE "Mobile Devices" OR DE "Computers"
#6 #6: DE "Online Therapy" OR DE "Computer Assisted Therapy"
#7 #7: TI (random* OR trial OR RCT OR control*) OR AB (random* OR trial OR RCT OR control*) OR KW (random* OR trial OR RCT OR control*)
#8 DE "Clinical trials" OR DE "Treatment Effectiveness Evaluation"
#9 #1 OR #2
#10 #4 OR #5
#11 #3 AND #10
#12 #11 OR #6
#13 #7 OR #8
#14 #9 AND #12 AND #13
#15 #14 (Filters: English, journal article)

Search strategy: *Web of Science*

#1 TS = (mindful* OR acceptance OR meditation)
#2 TS = (intervention* OR therap* OR treatment* OR program*)
#3 TS = (online OR e-health OR Internet* OR web* OR computer* OR app OR apps)
#4 TS = (random* OR trial OR RCT OR control*)
#5 #1 AND #2 AND #3 AND #4
#6 #5 (Filters: English, journal article)

Search strategy: *PubMed*

#1 mindful*[tiab] OR acceptance[tiab] OR meditation[tiab]
#2 "Mindfulness"[Mesh] OR "Acceptance and Commitment Therapy"[Mesh] OR "Meditation"[Mesh]
#3 intervention*[tiab] OR therap*[tiab] OR treatment*[tiab] OR program*[tiab]
#4 online[tiab] OR e-health[tiab] OR Internet*[tiab] OR web*[tiab] OR computer*[tiab] OR app[tiab] OR apps[tiab]
#5 "Computers"[Mesh] OR "Mobile Applications"[Mesh]
#6 random*[tiab] OR trial[tiab] OR RCT[tiab] OR control*[tiab]
#7 "Controlled Clinical Trial"[Mesh] OR "Randomized Controlled Trial"[Mesh] OR "Random Allocation"[Mesh] OR "Treatment Outcome"[Mesh]
#8 #1 OR #2
#9 #4 OR #5
#10 #6 OR #7
#11 #3 AND #8 AND #9 AND #10
#12 #11 (Filters: English, journal article)

Search strategy: *www.clinicaltrialsregister.eu*

#1 (mindfulness OR acceptance OR meditation)
#2 (online OR Internet OR e-health OR computer OR web OR app)
#3 (intervention OR therapy OR treatment OR program)
#4 #1 AND #2 AND #3

Search strategy: *www.isrctn.com*

#1 (mindfulness OR acceptance OR meditation)
#2 (online OR Internet OR e-health OR computer OR web-based OR app)
#3 (intervention OR therapy OR treatment OR program)
#4 #1 AND #2 AND #3

Search strategy: *www.clinicaltrials.gov*

#1 (mindfulness OR acceptance OR meditation)
#2 (online OR Internet OR e-health OR computer OR web)
#3 (RCT OR random OR control)
#4 #1 AND #2 AND #3
#5 #4 (Filters: closed studies, interventional studies, adult, senior)

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