Forest therapy can prevent and treat depression: evidence from meta-analyses

Forest therapy involves engaging in a combination of forest-based activities to improve one's health or wellbeing. We conducted an overview of systematic reviews (SRs) and meta-analyses of primary studies to provide the most comprehensive summary of the effect of forest therapy on depression. We included 13 primary studies that matched our eligibility criteria - all were included in four recent SRs and were conducted in the Republic of Korea. We carried out meta-analyses with data extracted directly from these 13 studies and assessed their risk of bias. Outcomes of interest were depressive symptoms, temporary recovery from depression (i.e. remission), response to treatment (i.e. ≥ 50% reduction on depressive symptoms from baseline), adherence to treatment, and adverse effects. Considering pooled estimates from randomized controlled trials with adults, we found that compared to no intervention/usual care, forest therapy produced a greater reduction of depressive symptoms (Hedges'g = 1.18, 95% *CI* [0.86, 1.50], $p < .00001$). Also compared to no intervention/usual care, participants in the forest therapy group were 17 times as likely to achieve remission (Risk Ratio = 17.02, 95% *CI* [3.40, 85.21], $p = .0006$) and three times as likely to have a ≥ 50% reduction on depressive symptoms (Risk Ratio = 3.18, 95% *CI* [1.94, 5.21], $p < .00001$). Forest therapy, on average, reduced depressive symptoms more than engaging in similar activities in a hospital or non-forested urban area, or participating in an intervention focused on diet plus forest-based exercise. We did not find evidence that adherence to forest therapy is different from the adherence to alternative interventions and the adverse effects of forest therapy appear to be rare. These results indicate that, relative to many more conventional alternatives, forest therapy is a more effective short-term intervention for the prevention and treatment of depression in adults.

Keywords: contact with nature; dysthymia; forest bathing; mental health; mood disorder; shinrin-yoku

1. Introduction

Depression is considered one of the most important global health challenges (Cipriani et al., 2018). More than 300 million people worldwide suffer from this disorder, which can harm many aspects of life (e.g. affective relationships and work) and, in the worst-case scenario, lead to suicide (World Health Organization, 2017). Common symptoms of depression are sad mood, anxiety, insomnia, loss of vitality, and lack of interest in life (Fried, 2017). Depression is best conceptualized in a continuum ranging from the presence of a few/mild/rare symptoms to the presence of several/severe/frequent symptoms that lead to a debilitating life condition (Fried, 2017; van de Leemput et al., 2014). The diagnosis of a person as depressed is based on specific criteria and should ideally be done through a structured or semi-structured interview (Nordgaard et al., 2013). Considering that depression is understood as a combination of symptoms (Fried, 2017; van de Leemput et al., 2014), interventions designed to prevent or treat depression should not focus solely on one symptom. By preventing depression, we refer to a process in which a non-depressed person achieves a reduction in depressive symptoms. Such a reduction helps this person to remain non-depressed. By treating depression, we refer to a process in which a depressed person achieves a reduction in depressive symptoms.

Common treatments for depression are psychotherapy and antidepressants (Cuijpers, 2018). These have advantages, such as accessibility to treatment, and have been proven to be efficient in ameliorating depressive symptoms (Cuijpers et al., 2020), but they also present some disadvantages. For example, the use of antidepressants can

have secondary effects like gastrointestinal symptoms (e.g. nausea and diarrhea), weight gain, and metabolic abnormalities (Carvalho et al., 2016), and both antidepressants and psychotherapy lack effectiveness in the short-term (Cuijpers, 2018). Considering these disadvantages of psychotherapy and antidepressants, researchers have called for complementary or even alternative treatments for depression (Lopresti, 2019; Munkholm et al., 2019). One of these alternatives may be direct contact with nature (Lee et al., 2017; Rajoo et al., 2020; van Tulleken et al., 2018). Specifically, previous studies have found encouraging results regarding the potential of forest therapy to prevent and treat depression (e.g. Chun et al., 2017; Kim et al., 2009).

The human health benefits of exposure to trees and forests abound and include restorative capacities such as stress reduction as well as improvement in clinical mental health outcomes (Wolf et al., 2020). To maximize these capacities, forest therapy is often recommended as a form of preventive medicine (Park et al., 2010). Forest therapy, also known as “shinrin-yoku”(Oh et al., 2017; Park et al., 2010; Rajoo et al., 2020), involves engaging in a combination of activities in a forest environment to improve one’s health or wellbeing (Han et al., 2016; Lee et al., 2017; Yu and Hsieh, 2020). Forest therapy may include forms of forest-based exercise but should involve more than just physical activity - typically incorporating other activities that foster positive mental health such as meditation, games using forest elements, and/or group activities (Bang et al., 2018; Chun et al., 2017; Djernis et al., 2019; Han et al., 2016; Lee et al., 2017; Rajoo et al., 2019). In urban environments that increase stress and hinder psychological restoration, direct immersion in forests can help people to calm down and reflect (Collado et al., 2017; Kaplan, 1995; Kim et al., 2009; Kotera et al., 2020; Mayer et al., 2009; Rajoo et al., 2019). There is evidence that even a short period spent in a forest can help people reduce stress, recover their attentional capabilities, and shift towards more

positive emotions (Djernis et al., 2019; Kaplan, 1995; Kotera et al., 2020; Lee et al., 2017; Rajoo et al., 2020; Wen et al., 2019; Yu and Hsieh, 2020). These benefits of exposure to forests provide insights regarding the value of forest environments and the relevance of conserving and utilizing these settings to improve human health (Bratman et al., 2019).

Yet, while an abundance of research suggests forest-based activities produce positive health outcomes (Hansen et al., 2017; Park et al., 2010), less research has explored direct links between forest therapy and depression (Wen et al., 2019). For example, in Wen et al.'s (2019) study of the effects of forest activities on health, only three out of the 28 studies included in their analyses reported the effect of forest therapy on depression. Furthermore, because previous evidence synthesis combined results from depression measures with other constructs, it is difficult to discern if forest therapy is an effective way of preventing and treating depression, specifically (Djernis et al., 2019; Kotera et al., 2020). It is also unknown if forest therapy is safe (i.e. are adverse effects rare?) and acceptable (i.e. do people adhere well to forest therapy?). Such knowledge gaps limit the development of guidelines for practitioners who might be willing to employ forest therapy to prevent and treat depression.

We therefore conducted an overview of systematic reviews (SRs) and meta-analyses to answer the following research question: *Is there sufficient evidence supporting forest therapy as an effective intervention to prevent and treat depression?* Our literature review offers four novel contributions. First, to our knowledge, this is the first review to focus exclusively on the effects of forest therapy on depression. Second, we included more primary studies that reported depression outcomes than previous SRs, and used these studies to provide estimates of the effect of forest therapy on depression. Third, in addition to previous reviews that primarily focused on the alleviation of

depressive symptoms based on statistical significance or standardized effect estimates, we considered more interpretable outcomes (Riedel et al., 2010) such as temporary recovery from depression (i.e. remission), response to treatment (≥ 50% reduction in depressive symptoms from baseline), and treatment acceptability or adherence (i.e. drop-outs for any reason). Fourth, different from previous SRs, we assessed the risk of bias of primary studies using tools that favor the identification of all potential sources of bias (Sterne et al., 2019, 2016).

2. Methods

Our overview of SRs and meta-analyses of the effects of forest therapy on depression was based on guidance from the latest edition of the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2019). We began the study by selecting SRs most relevant to our research question centered on forest therapy and depression. We located SRs by testing the utility of several databases (e.g., MEDLINE and PsycINFO) and search terms such as forest therapy, forest bathing, and shinrin-yoku (see Supplementary File p.1). Through this process, we found three SRs that met our criteria, and a fourth was later identified via social media for researchers. However, if we were to interpret only the results of these four SRs (rather than of the primary studies), we would emerge with a limited answer to our research question. Thus, we decided to analyze all eligible primary studies included by these four SRs. We did this by developing our eligibility criteria (Table 1) and synthesis plan (see Supplementary File p. 1 to 4) based on recent guidance from meta-analysis experts (e.g. Bender et al., 2018; Higgins et al., 2019).

Regarding the eligibility criteria, we made important distinctions between forest therapy, forest exposure, forest exercise, and forest walking. Forest exposure refers to

be in a forest. Forest exercise involves doing physical exercise in a forest, which can include walking. We operationalized forest therapy to include engagement in a combination of forest-based activities to improve one's health or wellbeing. Thus, forest-based exercise combined with other forest-based activities (e.g. meditation, psychotherapy, group activities) met our definition of forest therapy. Nonetheless, just being in a forest or exercising in a forest was not enough to satisfy this definition and qualify as a forest therapy intervention for this study.

< Table 1 about here >

The first author of the present study collected relevant data from the four SRs, assessed the eligibility of primary studies (Table 1), gathered relevant data on eligible primary studies, and assessed the risk of bias of SRs and primary studies. All primary studies included in our meta-analyses were identified on the four SRs, so the first author screened primary studies for eligibility based on the information provided by the four SRs. Decisions regarding the eligibility of primary studies at full-text and their risk of bias assessment were checked by at least one co-author. Most information describing primary studies (e.g. sample size) was collected from the four SRs and then checked within the primary studies (Saldanha et al., 2019). The information used in our meta-analyses was extracted directly from primary studies. The first author checked the information from primary studies at least once after finishing the data extraction phase.

The risk of bias of the four SRs was assessed using the ROBIS tool (Whiting et al., 2016). The risk of bias of the primary studies was assessed using the RoB 2 for randomized controlled trials (RCTs) and cross-over trials (Sterne et al., 2019), and ROBINS-I for non-randomized controlled trials (NRCT) (Sterne et al., 2016). These are the most comprehensive tools available to assess potential bias in SRs, RCTs, cross-overs, and NRCTs. Studies that assigned participants to groups based on a random or

quasi-random process were classified as RCTs (Sterne et al., 2019). Studies that did not describe the randomization process or assigned participants to interventions based on a non-random criterion (e.g. participants' preference) were classified as NRCTs (Sterne et al., 2016).

2.1. Synthesizing Data from Primary Studies

Following recommendations from the Cochrane Handbook, we focused on results from RCTs and analyzed them separately from cross-overs trials, and NRCTs (Higgins et al., 2019). Our main outcome was the standardized mean difference (SMD) between the post-intervention depressive symptoms of two intervention groups. Depressive symptoms scores are usually calculated by summing the score of items on a depression rating scale for an individual. These items often cover a specific symptom frequency and, sometimes, symptom intensity. The mean we used in our analysis was the average score for the sample group in an intervention (e.g. the post-intervention average score of the forest therapy group). When primary studies met all criteria needed to be included in a meta-analysis (see Supplementary File p.1 to 2), we pooled their SMDs because pooled SMDs are more precise than estimates of effect from single studies (Higgins et al., 2019). Following Sawilowky (2009), we interpreted SMDs as: very small = 0.01, small = 0.2, medium = 0.5, large = 0.8, very large = 1.2, and huge = 2.0.

To improve the interpretability of the effect of forest therapy on depression compared to other interventions, we also considered reductions in depressive symptoms based on dichotomous outcomes such as remission from depression and response to treatment (Riedel et al., 2010). Remission refers to a temporary recovery from depression and is often assessed as "the number of patients with a score for depressive

symptoms below a specific cut-off on a validated rating scale" (Cuijpers et al., 2020, p. 93). Response to treatment is usually registered as the number of people who exhibit ≥ 50% reduction of depressive symptoms from baseline following treatment. This threshold is appropriate for the most commonly used scales to register depression: the Hamilton Depression Rating Scale (HDRS or HAMD), Montgomery-Asberg Depression Rating Scale (MADRS), and the Beck Depression Inventory (BDI), but might not be appropriate for other scales (Riedel et al., 2010). None of the primary studies we analyzed reported the number of people who responded to treatment (i.e. responders). Thus, the number of responders in studies using one of these three scales was estimated using the formula described by Furukawa et al. (2005). We do not report the number of responders for primary studies that did not use one of these three scales. We used drop-out for any reason as a proxy for treatment acceptability or adherence (Cipriani et al., 2018; Cuijpers et al., 2020). For dichotomous outcomes, we calculated risk ratios as they are easier to interpret than odds ratios (Higgins et al., 2019). We reported the percentage of reduction in depressive symptoms from baseline in forest therapy and comparison groups as a descriptive statistic (Vickers, 2001). We describe in Equation 1 how this percentage was calculated. We also collected and reported information about any adverse effects of forest therapy treatment described by primary studies' authors.

((Post-intervention mean score - Baseline mean score)/Baseline mean score)*100

Equation 1

Statistical analyses were performed using RevMan 5.3 ("Review Manager (RevMan) [Computer program]," 2014), and figures illustrating the risk of bias of

primary studies were created using robvis (McGuinness, 2019). Data are publicly available at: (inserting link when published).

3. Results

3.1 *Results of systematic reviews*

Selected characteristics (e.g. research question, eligibility criteria, search strategy, risk of bias assessment, and main results) of the four SRs that we reviewed are described in Supplementary File p. 6. By analyzing the eligibility criteria of these SRs, we noted that they were not able to include: (1) unpublished studies; (2) studies in languages other than English and Korean; (3) studies published after October 2019; and, (4) within Korean studies: studies with children or adolescents (< 18 years old), without a comparison group, or published after 2016.

The four SRs were deemed as at high risk of bias because of limitations that could hinder the adequate identification, selection, data extraction, appraisal, or synthesis of relevant primary studies (Table 2). For example, the synthesis methods used in the four SRs conducted before our review were limited. Moreover, no SR focused exclusively on the effect of forest therapy on depression. It is possible, however, to extract some information about the effect of forest therapy on depression because three of the four SRs reported results for each primary study. Djernis et al.'s (2019) SR was the only one that did not report results for each primary study. Instead, the authors provided, for example, a pooled estimate of the effect of forest activities on a combination of psychological constructs. Kotera et al.'s (2020) SR provided estimates of the effect of forest therapy on depression, but only for three of the 13 studies analyzed in our study. The meta-analysis performed by Kotera et al. (2020) combined results from measures of depression with results collected using a measure of mood

state (the Profile of Mood States). More limiting, both Lee et al. (2017) and Wen et al. (2019) used a vote-counting approach seemingly based on the statistical significance of findings. While it is good to know if forest therapy is likely to have a positive effect on depression, patients and practitioners also need to be aware of the magnitude of this effect to make more informed decisions about the use/promotion of forest therapy.

< Table 2 about here >

Using primary studies, we built upon these SRs to provide more precise estimates of forest therapy's impact on depression relative to other alternatives such as no intervention/usual care or walking in a forest. The analyses presented in the next section are based on data extracted directly from primary studies that were part of the four SRs described above.

3.2 Results of primary studies

The four SRs included a total of 101 primary studies. We eliminated 82 primary studies because they were duplicates or did not measure depression as defined in our eligibility criteria (Table 1). Nineteen studies were analyzed at full-text, of which six were eliminated (reasons for exclusion are provided in Fig. 1 and Supplementary Table 1 in the Supplementary File p. 4). Thus, 13 primary studies were included in our analyses (see Fig. 1 for a flow diagram and the Supplementary File p. 5 for the references of all included studies). Primary studies' characteristics are summarized in Table 3. All studies were conducted in the Republic of Korea (total number of participants $N = 649$), and one of them included children. Most participants were older than 39 years old and the percentage of women across studies varied widely. Two studies were conducted with people suffering from major depression (Kim et al., 2009; Woo et al., 2012) and one study reported that most participants were depressed

according to BDI and HDRS (Chun et al., 2017). The other 10 studies did not classify their participants as depressed or non-depressed. However, considering established cut-off points for diagnosing depression on the scales they used, the baseline mean scores of these studies indicate that in eight of these 10 studies the average participant was depressed. The two exceptions were Bang et al. (2018) and Hong (2012). Four studies were RCTs, two were cross-overs, and seven were NRCTs. Most forest therapy interventions involved meditation, physical activities, games, or group activities. Most interventions took a few days or a few weeks, and no intervention was longer than 11 weeks. Across all studies, seven different measures of depression were used.

<Fig. 1 about here>

<Table 3 about here>

Overall, we found support for the effectiveness of forest therapy in reducing depressive symptoms within RCTs, cross-over trials, and NRCTs with adults. For example, RCTs found on average a 60% reduction of depressive symptoms from baseline; the average on cross-over trials was 51% and 22% in NRCT (Table 4). Some studies provided more than one relevant comparison group, generating a total of five comparison groups (Table 5). These comparisons were: (1) forest therapy versus no intervention/usual care (including taking antidepressants as usual); (2) forest therapy versus similar activities in a hospital; (3) forest therapy versus similar activities in an urban area; (4) forest therapy versus diet plus exercise in a forest; and, (5) forest therapy versus walking in a forest. Below, we present results for each comparison.

<Table 4 and 5 about here>

(1) Forest therapy versus no intervention/usual care: Three RCTs assessed this comparison. The SMD of post-intervention scores was similar in these studies and the polled estimate was large, favoring forest therapy (Heges'g = 1.18, 95% *CI* [0.86, 1.50],

$p < .00001$, Fig. 2a). Two of these three studies (Kim et al., 2009; Woo et al., 2012) provided data for remission (operationalized as HRSD score ≤ 7). In these two studies, participants were taking antidepressants following their usual treatment; we refer to the group that took only antidepressants as the usual care for depression group. Participants in the forest groups were 17 times as likely to achieve remission compared to participants in the usual care for depression group (Risk Ratio = 17.02, 95% *CI* [3.40, 85.21], $p = .0006$, Fig. 2b). Also, participants in the forest groups were three times as likely to respond to treatment (Risk Ratio = 3.18, 95% *CI* [1.94, 5.21], $p < .00001$, Fig. 2c). The pooled SMD of NRCTs was similar to that of RCTs (Supplementary Fig. 1 in the Supplementary File p. 7). The pooled results of two NRCTs that used the BDI scale indicated that response to treatment was more likely to occur in the forest group, but these results are inconclusive (Risk Ratio = 1.43, 95% *CI* [0.78, 2.62], $p = .26$, see Supplementary Fig. 2 in the Supplementary File p. 7).

< Fig. 2 about here >

Only one study focused on depression in children. This study assessed the comparison between forest therapy and no intervention/usual care. In Bang et al. (2018), there is a considerable imbalance in the baseline depressive symptoms between the forest group (mean = 12.26) and the no intervention group (mean = 9.39), and an appropriate method to account for this imbalance was not used. For example, by using ANCOVA the researchers could have compared the post-test scores while keeping the baseline score statistically constant (Higgins et al., 2019). Thus, we calculated the mean change from baseline for each group and its standard deviation based on the available results. The mean reduction in depressive symptoms from baseline was greater in the forest therapy group than in the no intervention group, but results are inconclusive (Hedges' $g = 0.29$, 95% *CI* [-0.26, 0.83,], $p = .31$).

(2) Forest therapy versus similar activities in a hospital: Two RCTs assessed this comparison (Kim et al., 2009; Woo et al., 2012). In these RCTs, one group engaged in forest therapy and the other group performed similar activities to the forest therapy group but in a hospital. The pooled SMD of the post-intervention scores of the forest therapy group and the hospital group was medium, favoring forest therapy (Hedges'g = 0.63, 95% *CI* [0.20, 1.06,], p = .004, Fig. 3a). These studies also reported results for remission (operationalized as HDRS score ≤ 7). Participants in the forest group were two times as likely to achieve remission as participants in the hospital group (Risk Ratio = 1.97, 95% *CI* [1.22, 3.21], p = .006, Fig. 3b). Participants in the forest group were also more likely to respond to treatment (Risk Ratio = 1.69, 95% *CI* [0.98, 2.91], p = .06, Fig. 3c). One NRCT assessed this comparison (Lim et al., 2014) and found results similar to the ones of RCTs (Hedges'g = 0.76, 95% *CI* [0.14, 1.38,], p = .02).

< Fig. 3 about here >

(3) Forest therapy versus similar activities in an urban area: A RCT conducted with chronic stroke patients compared forest therapy with similar activities done in an urban environment (Chun et al., 2017). This study found a huge difference between groups' post-intervention scores, favoring forest therapy (Hedges'g = 2.60, 95% *CI* [1.89, 3.30,], p < .00001). Participants in the forest group were 13 times as likely to respond to treatment compared to participants in the urban group (Risk Ratio = 13.05, 95% *CI* [3.41, 49.97], p = .0002).

(4) Forest therapy versus diet plus forest-based exercise: Two cross-over trials assessed this comparison and measured depression using the BDI. The diet plus exercise phase of the trial occurred first. After 28 days (the washout period) the forest therapy phase took place. Hong et al. (2012) found that the forest therapy phase reduced participants' depressive symptoms more than the diet plus forest-based exercise phase

(reduction on BDI score = -12.76, 95% *CI* [-18.82, -6.70], $p = .0001$, Cohen's $d = 1.03$). Hong et al. (2013) found similar results (reduction on BDI score = -4.48, 95% *CI* [-8.09, -0.87], $p = .01$, Cohen's $d = 0.61$). We were unable to calculate a Hedges' *g* and the dispersion of the SMDs because these studies did not report the correlation between individuals' outcome data between the two phases of the trial. A pooled risk ratio indicated that, during the forest therapy phase, participants were more likely to respond to treatment than during the diet plus forest-based exercise phase (Risk Ratio = 3.20, 95% *CI* [1.33, 7.68], $p = .009$, see Supplementary Fig. 3 in the Supplementary file p. 7).

(5) Forest therapy versus walking in a forest: One RCT assessed this comparison (Woo et al., 2012). There was a substantial imbalance in the baseline values of the forest therapy group (mean = 24.21) and the walking in forest group (mean = 18.47), and an appropriate method to account for this imbalance was not used for this comparison (e.g. ANCOVA). We were unable to calculate a standard deviation for the mean change from baseline, so we only report descriptive statistics and differences in the likelihood of response to treatment. The forest therapy group had a reduction of 50% in the baseline symptoms and the walking in a forest group a reduction of 32%. Participants in the forest therapy group were more likely to respond to treatment, but results are inconclusive (Risk Ratio = 1.25, 95% *CI* [0.61, 2.57], $p = .54$).

Finally, we conducted sensitivity analyses to test the robustness of some decisions taken during the synthesis process (Supplementary File p. 8 to 9). These analyses suggest that our findings are robust to these decisions.

3.2.1 Treatment acceptability and adverse effects

Most studies did not provide a flow diagram showing how many participants were assigned to each group and how many participants finished the study. Thus, the

use of participant drop-outs as a proxy for treatment acceptability was not optimal. Nevertheless, drop-outs were documented in six studies. In these studies, the number of drop-outs for any reason was scarce, and there was no evidence of differences between intervention groups (Supplementary Fig. 4 in Supplementary File p. 8). Eleven of 13 studies did not present any information about adverse effects (i.e. if they occurred or if they did not occur). Only two studies reported information about the (no) occurrence of adverse effects. In one study, a participant developed a rash caused by an insect bite in the forest (Kim et al., 2009); in the other study, the authors noted that participants reported no health problems during the forest therapy intervention (Choi and Ha, 2014). Thus, from a total of 311 people involved in forest therapy, in the 13 primary studies that we analyzed, only one (0.3%) had an adverse effect reported.

3.2.2 Risk of bias of primary studies, publication bias, and statistical heterogeneity

We deemed all RCTs and cross-over trials as at high risk of bias (Supplementary File p. 10) and the NRCTs as at serious risk of bias (Supplementary File p. 12). When assessing RCTs, cross-overs, and NRCTs, we followed the recommendations of the tools' developers to determine the risk of bias for each domain and overall for a specific result of each study (Sterne et al., 2019, 2016). Additional information about the risk of bias assessment is provided in the Supplementary File p. 9 to 12.

Due to the small number of studies included in our meta-analyses, it was not appropriate to test for publication bias (i.e. if results from unpublished studies are different from the results of published studies; Higgins et al., 2019). For instance, one of the statistical requirements for using funnel plots to assess publication bias is to include 10 or more studies in a specific meta-analysis (Higgins et al., 2019).

Only one of the meta-analyses we conducted (Supplementary Fig. 1 in Supplementary File p. 7) produced substantial statistical heterogeneity, but we did not try to explain this heterogeneity (e.g. using meta-regression) due to the small number of studies included in this meta-analysis (Higgins et al., 2019).

4. Discussion

. In the present study, we analyzed four recent SRs that explored connections between forest therapy and depression, focusing on forest therapy's capacity to reduce depressive symptoms in comparison to no intervention/usual care and four alternative interventions. Our findings show the effect of forest therapy on depression is greater than the effect of any alternative intervention. People in forest therapy groups had a higher reduction in depressive symptoms than people in the other groups.

When compared to similar interventions in non-forest settings, the benefits of forest therapy were clear. Being involved in therapeutic activities in a forest appears to be more effective than participating in such activities in a hospital or in an urban (non-forested) area. Assuming the only difference between the forest therapy group and the other groups was the intervention setting, these findings suggest that exposure to a forest environment may provide additional benefits beyond the therapeutic activities themselves. This is in line with research showing the benefits of exposure to nature, and forests specifically (Wen et al., 2019; Wolf et al., 2020). For example, Bowler et al. (2010) conducted meta-analyses of studies comparing the effect of the same activity conducted in a natural versus a synthetic environment. They found that individuals who conducted the activities in natural environments expressed less anger, fatigue, and sadness than individuals in synthetic environments. Our results are also in line with

research conducted under stress reduction theory (Ulrich et al., 1991) and attention restoration theory (Kaplan, 1995), which have consistently shown that exposure to natural environments favors stress reduction, mood improvement, and the recovery of attentional capabilities more than non-natural environments.

Our findings also revealed that forest therapy was more effective than depression treatment regimens focused on diet plus forest-based exercise. Whereas diet, exercise, and forest exposure may reduce depressive symptoms, the greater effect of forest therapy on depression may be explained by the activities in which the forest therapy groups participated (Djernis et al., 2019; Kim et al., 2009). The distinction between forest therapy (a combination of activities positive for mental health) and forest exercise is important. Whereas green exercise can yield a variety of positive health outcomes (Bowler et al., 2010; Gladwell et al., 2013), forest therapy, which includes other activities positive for mental health, may be more effective to prevent and treat depression. Similar conclusions can be drawn for the comparison between forest therapy and walking in a forest, as the forest therapy group generally had a higher reduction in depressive symptoms and greater response to treatment than the forest walking group (although the confidence interval for the estimate of the difference between these interventions overlaps zero).

Analyzing the number of drop-outs in the intervention groups across the studies synthesized, we found no evidence that forest therapy was a less acceptable treatment than other alternatives (Supplementary Fig. 4 in the Supplementary File p. 8). We also found that the adverse effects of forest therapy may be rare.

4.1. Limitations

Several limitations should be considered when interpreting the results of our study. First, we selected only four relevant SRs. Nonetheless, as the last SR we included (Kotera et al., 2020) did not provide any new primary study, it seems that our approach was sufficiently comprehensive. Also supporting this view, no new eligible primary study was found in a recently published SR about the effect of forest activities on physiological and psychological outcomes (Rajoo et al., 2020).

Second, the screening process of primary studies and subsequent data extraction was not checked by another reviewer. We judged that it was not necessary to have another reviewer involved in the screening because this process was relatively simple. Regarding data extraction, the first author checked the information describing primary studies and information used in meta-analyses at least once after finishing the data extraction phase.

Third, although the findings from our meta-analyses are encouraging and underscore the potential of forest therapy to prevent and treat depression, we should interpret these findings with some caution due to the limitations of existing primary studies. Overall, the primary studies included a considerable diversity of participants (e.g. health and unhealthy people), interventions, comparison groups, outcome measures, and settings. Nonetheless, young adults were underrepresented, as the mean age/age range of adults was above 39 years and only one study included children (and it yielded inconclusive results). Thus, it remains unclear if the effect of forest therapy on depression is higher or lower on children, adolescents, and young adults.

Fourth, caution should also be executed when interpreting our results because all the studies included in our review were conducted in the Republic of Korea, as these were the only studies we located from anywhere in the world that evaluated forest therapy interventions and reported results for depression outcome measures.

Considering that forest activities are popular elsewhere in Asia (Yu and Hsieh, 2020), future research could systematically search for primary studies conducted in countries such as Japan and Taiwan. This also highlights the need for wider geographic coverage in research about the forest therapy effect on depression.

Fifth, our inability to incorporate unpublished research also casts some doubt about the true effectiveness of forest therapy, as there is evidence that studies are more likely to be published if they reveal statistically significant treatment effects (Higgins et al., 2019). Although the effect of forest therapy might have been overestimated (or underestimated), the publication of forest therapy findings is unlikely to be heavily influenced by financial interests, which favor the publication of positive results, as is the case for antidepressant studies (Munkholm et al., 2019). We examined the reported funding and conflict of interest of primary studies and found no evidence of any conflict of interest.

Finally, methodological limitations of the primary studies in our analyses increase uncertainty about the true effect of forest therapy on depression. Only four RCTs and two cross-over trials were included in our meta-analyses, and all had a high risk of bias. The main limitations of these studies were the lack of blinding, which is infeasible in forest therapy interventions because people experience the treatment environment, and the lack of a protocol describing the analysis plan. The former increases the risk of deviations from the intended intervention and can introduce bias in the assessment of treatment-related outcomes. The latter hinders the possibility of assessing selective reporting. Limitations were also identified in the randomization process and in the way some studies dealt with missing outcome data. Whereas most of these limitations are typically associated with an exaggeration of experimental intervention effects (in our case, forest therapy), in some circumstances the effect can be

underestimated (Sterne et al., 2019, 2016). Moreover, a NRCT was the only source of evidence for the impact of forest therapy on children's depressive symptoms, and other NRCTs provided additional information for two comparisons (i.e. forest therapy versus no intervention/usual care, and forest therapy versus similar activities in a hospital). Similar to RCTs and crossover trials, the NRCTs were not blinded and did not publish an analysis plan. Besides these limitations, NRCTs tend to have a higher risk of bias than RCTs due to confounding, as the assignment of participants to the intervention can be related to baseline variables that influence the outcome (i.e. prognostic factors).

5. Future research opportunities and conclusions

In summary, future literature reviews may extend the evidence we have synthesized by systematically searching for unpublished studies, studies in other languages than English and Korean, and studies with children and adolescents. Future primary studies should document if (and what) adverse effects occurred in the forest therapy and comparison group(s) and report remission from depression and response to treatment. Future research could also examine whether certain aspects of forest therapy (e.g., meditation vs. green exercise) are more beneficial than others when it comes to treating depression. It includes assessing if or how different frequency and duration of forest therapy interventions may influence the reduction in depressive symptoms. The adoption of relevant Consolidated Standards of Reporting Trials (CONSORT) should facilitate the assessment of primary studies' risk of bias and the interpretation of their results (Moher et al., 2010). Our findings also highlight the need for more methodologically rigorous RCTs examining the effects of forest therapy on depression.

Despite some limitations, our review of SRs and primary studies examining the effectiveness of forest therapy as a preventive measure and treatment for depression

yielded the most conclusive evidence to date. Compared to antidepressants, similar activities in a hospital or non-forested urban settings, or even diet and forest-based exercise, forest therapy appears to be more likely to produce outcomes like remission and response to treatment, with adequate acceptability or adherence. Thus, while more studies are needed, we believe practitioners should consider the use of forest therapy as both a preventive measure and a treatment for depression in adults. This is in line with the growing support for the incorporation of therapeutical activities in contact with nature as a mainstream intervention for the prevention and treatment of mental health problems (Buckley et al., 2018).

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Table 1. Eligibility criteria for our overview of systematic reviews examining links between forest therapy and depression based on participants (P), intervention (I), comparator (C), outcome (O), and setting (S) (i.e. PICOS)

PICOS element	**Inclusion criteria**	**Exclusion criteria**
Participants	Studies with humans, healthy or not.	Studies not including humans.
Intervention	Studies reporting any intervention that matched our definition of forest therapy, which we defined as engaging in a combination of activities in a forest to improve one's health or wellbeing. Moreover, in our definition, a forest therapy intervention should include more than just exposure to nature or exercising in a forest, incorporating other activities positive for mental health (e.g. meditation and group activities).	Studies that only involved exposure to nature or exercising in a forest.
Comparator	Studies with any comparison group and studies without a comparison group.	NA
Outcome	Studies where depression was estimated by clinical examination (e.g. by a physician) or by a previously developed (not *ad hoc*) instrument (e.g. questionnaire or standardized interview such as the DSM-IV) designed to diagnose or estimate the intensity of this disorder.	Studies that assessed specific depressive symptoms in isolation (e.g. mood or anxiety).
Setting	Studies of environments that primary study authors described as a *forest* (e.g. urban-forest, campus forest, recreational forest).	Studies not describing a forest.

Table 2. Risk of bias assessment of the systematic reviews included in our overview

Systematic Review	Risk of bias in specific domains				Overall
	1. Study Eligibility Criteria	2. Identification and Selection of Studies	3. Data Collection and Study Appraisal	4. Synthesis and Findings	Risk of Bias in the Review
(Lee et al., 2017)	☹	☹	☹	☹	☹
(Wen et al., 2019)	☹	☹	☺	☹	☹
(Djernis et al., 2019)	☹	☺	☹	☹	☹
(Kotera et al., 2020)	☹	☹	☹	☹	☹

☺ = low risk; ☹ = high risk

Note. Systematic reviews' risk of bias was assessed using ROBIS (Whiting et al., 2016), a tool specially designed for this function. As recommended by ROBIS's developers, we classified the risk of bias for each systematic review domain (eligibility criteria, search strategy and selection, data collection and primary studies appraisal, and synthesis and findings) and the systematic review as a whole.

Table 3. Main characteristics of primary studies included in our meta-analyses examining links between forest therapy and depression

First author and year	Participants	Mean age or range	Women %	Forest therapy group/activities	Forest therapy duration	Forest therapy frequency	Forest therapy *N*	Comparison group/activities	Depression measure*	Study design	Setting	Data collection framework
Han 2016	Office workers from the University of Seoul	39.75	57.4	The intervention included walking and mindfulness meditation.	Two days (noon to noon)	All days	33	(*N* = 28) Normal daily routines	BDI	Non-randomized controlled trial	Saneum Natural Recreation Forest	T1: Just before treatment; T2: just after treatment
Lim 2014	Elderly people from a nursing facility	≥ 50	29.7	Activities included strolling in the forest, experiencing five senses, games, and meditation.	Eleven weeks	Once a week for 90 min.	22	**1:** *(N* = 21) Similar activities in a hospital; **2: (***N = 21*) Normal daily routines	Geriatric depression scale short form-Korea version	Non-randomized controlled trial	Forest	T1: Just before treatment; T2: just after treatment
You 2014	Middle-aged women	~ 50	100	Sallimyok (Forest Therapy); meditation; walking; Qi-Qong.	Two days	All days	10	(*N* = 10) Normal daily routines	Zung Self-Rating Depression Scale	Non-randomized controlled trial	Forest	T1: Just before treatment; T2: just after treatment
Choi 2014	Cancer patients	≥ 50	75.47	Activities included meditation, touching and lying on the wood, and treasure hunt.	Eight weeks	Once a week for 120 min.	26	(*N* = 27) Normal daily routines	Zung Self-Rating Depression Scale	Non-randomized controlled trial	Urban forest	T1: Just before treatment; T2: just after treatment
Shin 2012	Detoxified chronic alcoholics	45.26	8.7	Three days actively interacting with nature, three days challenging activities in nature, three days activities for introspection (e.g. nature meditation, counseling in nature).	Nine days	All days	47	(*N* = 45) Normal daily routines	BDI	Randomized controlled trial	Saneum Recreational Forest	T1: Just before treatment; T2: just after treatment
Chun 2017	Chronic stroke patients	60.8	32.2	Activities included meditation, experiencing the forest through all five senses, and walking.	Four days	All days	30	(*N* = 29) Similar activities in an urban area	BDI and **HDRS-17**	Randomized controlled trial	Recreational forest	T1: Just before treatment; T2: just after treatment
M.-H. Kim 2015	Psychiatric Inpatients	46.91	50	Forest activities included handkerchief dyeing, decorating a frame using natural items, and group work.	Two weeks	Five times (60 min each time)	10	(*N* = 10) Treatment as usual	BDI	Non-randomized controlled trial	Jeonnam Forest Resources Research Center	T1: 5 to 10 minutes before treatment; T2: 5 to 10 minutes after treatment;
Y. G. Kim 2015	Cancer patients	----	84.90	Experiencing feeling (1st day), meditation (2nd day), mindfulness (3rd day), and feedback.	Three days	All days for four hours a day	27	(*N* = 26) Normal daily routines	Hospital Anxiety and Depression Scale	Non-randomized controlled trial	Forest	T1: Just before treatment; T2: just after treatment
Hong 2013	Psychiatric outpatients with mild cognitive impairment	57.46	83.33	Activities in forests included taking herbal medicine, music therapy, and Qigong.	Three days	All days, several hours per day	15	(*N* = 15) Conducted regular diet and exercise program (3 times a day) in the forest	BDI	Crossover trial	Saneum Natural Recreation Forest	T1: Just before treatment; T2: just after treatment
Hong 2012	Hwa-Byung patients	51.6	90	Activities in forests included taking herbal medicine, music therapy, and Qigong.	Three days	All days, several hours per day	16	(*N* = 16) Conducted regular diet and exercise program (3 times a day) in the forest	BDI	Crossover trial	Saneum Natural Recreation Forest	T1: Just before treatment; T2: just after treatment

Woo 2012	Patients with major depression taking antidepressants	45.68	----	Forest activities included cognitive-behavioral therapy, meditation, and relaxation training.	Four weeks	Once a week (for 3 hours)	28	**1:** (*N* = 21) Similar activities in a hospital; **2:** (*N = 15*) Treatment as usual; **3:** (*N* = 17) Walking in a forest.	HDRS-17, **MADRS**, and BDI	Randomized controlled trial	Seoul Arboretum	T1: Just before treatment; T2: just after treatment
Bang 2018	Elementary-school students in grades 4 to 6 at five community centers	11.79	55.56	Forest activities included five senses experience, walking, and games.	Ten weeks	Once a week (for 60 min)	24	(*N* = 28) Normal daily routines	Children's Depression Inventory	Non-randomized controlled trial	Urban forest	T1: Just before treatment; T2: just after treatment
Kim 2009	Patients with major depression taking antidepressants	46.2	85.7	Forest activities included cognitive-behavioral therapy, positive psychology tools, and mindfulness meditation on breath, wind, forest, and sounds.	Four weeks	Once a week (three hours/session)	23	**1:** (*N* = 19) Similar activities in a hospital; **2:** (*N* = 21) Treatment as usual.	BDI, HDRS, **MADRS**	Randomized controlled trial	Hong-Reung; 44-ha arboretum	T1: Just before treatment; T2: T1 + 1 week; T3: T1 + 2 weeks; T4: T1 + 3 weeks

Note: *When results for more than one outcome measure were available, we gave preference to results from one outcome measure based on specific criteria (see Supplementary File p. 2 for more information). The chosen measures are in bold. Underlined studies were written in Korean. BDI = Beck Depression Inventory; HDRS = Hamilton Depression Rating Scale; MADRS = Montgomery-Asberg Depression Rating Scale.

Table 4. Percentage of reduction in depressive symptoms from baseline for forest therapy and other interventions, listed by primary study

First author and year	**Groups**					
	Forest therapy	Similar activities in a hospital	Similar activities in an urban area	No intervention/usual care	Diet plus exercise in the forest	Walking in a forest
Randomized controlled trials						
Chun 2017	-77.46	NA	-1.39	NA	NA	NA
Kim 2009	-50.08	-19.91	NA	-7.57	NA	NA
Shin 2012	-64.04	NA	NA	0.20	NA	NA
Woo 2012	-50.27	-34.81	NA	-10.10	NA	-32.49
Mean (SD)	-60.46 (13.08)	-27.36 (10.54)	-1.39	-5.82 (5.37)	NA	-32.49
Median	-57.16	-27.36	-1.39	-7.57	NA	-32.49
Cross-over trials						
Hong 2013	-46.43	NA	NA	NA	-5.10	NA
Hong 2012	-56.04	NA	NA	NA	-9.91	NA
Mean (SD)	-51.24 (6.80)	NA	NA	NA	-7.51 (3.40)	NA
Median	-51.24	NA	NA	NA	-7.51	NA
Non-randomized controlled trials						
Han 2016	-46.08	NA	NA	-15.85	NA	NA
Lim 2014	-27.71	-16.76	NA	2.18	NA	NA
You 2014	-27.62	NA	NA	-0.58	NA	NA
Choi 2014	-9.61	NA	NA	3.43	NA	NA
M.-H. Kim 2015	-13.03	NA	NA	6.99	NA	NA
Y. G. Kim 2015	-9.79	NA	NA	3.93	NA	NA
Mean (SD)	-22.31 (14.33)	-16.76	NA	0.02 (8.15)	NA	NA
Median	-20.33	-16.76	NA	2.81	NA	NA
Non-randomized controlled trial with children						
Bang 2018	-21.13	NA	NA	-8.73	NA	NA

Table 5. Aggregated sample size (*N*) and studies providing data for each comparison

Comparison	*N*	Primary studies' first author and year
Forest therapy versus no intervention/usual care	525	**Kim 2009; Woo 2012; Shin 2012;** You 2014; Lim 2014; Choi 2014; M-H. Kim 2015; Y-G. Kim 2015; Bang 2018
Forest therapy versus similar activities in a hospital	134	**Kim 2009; Woo 2012;** Lim 2014
Forest therapy versus similar activities in an urban area	59	**Chun 2017**
Forest therapy versus diet plus forest-based exercise	31	Hong 2013; Hong 2012
Forest therapy versus walking in a forest	43	**Woo 2012**

Note: Some forest therapy groups were counted in more than one comparison. Randomized controlled trials are in **bold** and cross-over trials are underlined. The other studies are non-randomized controlled trials.

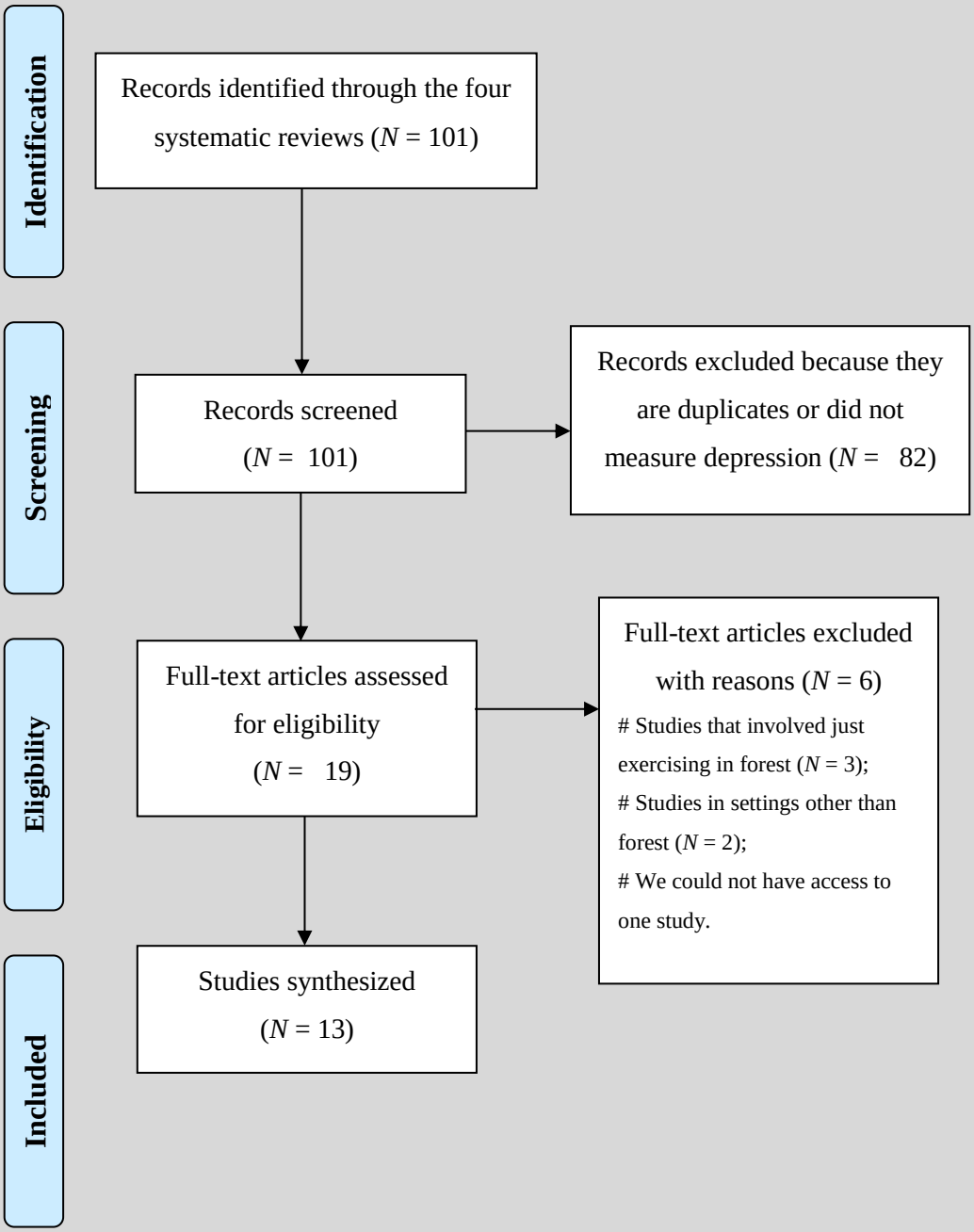

Fig. 1. Flow diagram illustrating the selection process of primary studies.

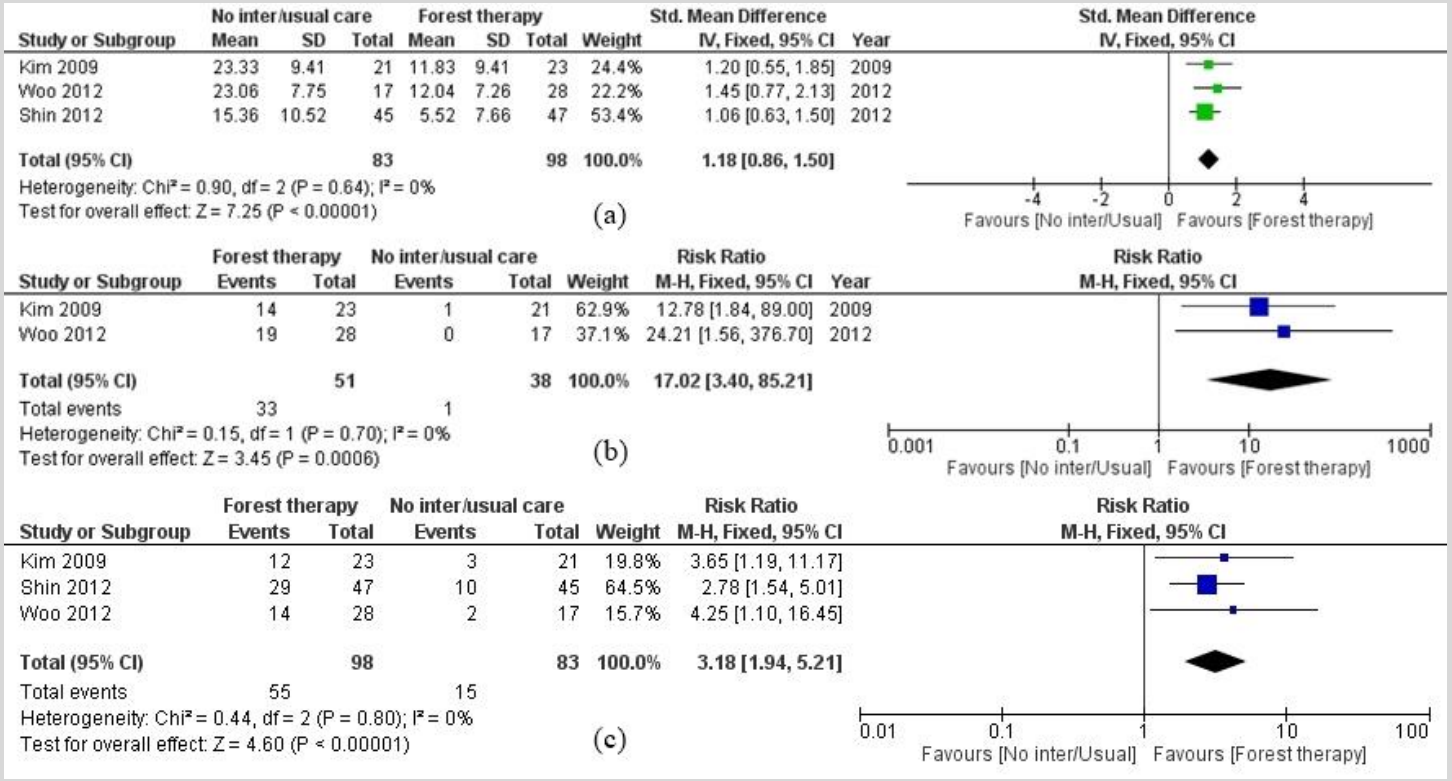

Fig. 2. Results of randomized controlled trials: (a) Comparison of the post-intervention mean score of forest therapy groups versus no intervention/usual care using the inverse variance fixed-effect meta-analysis. (b) Comparison of the risk of temporary recovery from depression (i.e. remission) between forest therapy groups and usual care for depression groups, using the Mantel-Haenszel fixed-effect meta-analysis. (c) Comparison of the risk of response to treatment (i.e. ≥ 50% reduction on depressive symptoms) between forest therapy groups and no intervention/usual care groups, using the Mantel-Haenszel fixed-effect meta-analysis. Events refer to cases of remission (b) or response (c). Green squares refer to standardized mean differences and blues squares to risk ratios. Bigger squares indicated more participants in a study or more events and a bigger diamond indicates greater uncertainty in the estimate. Cross-overs and non-randomized controlled trials were analyzed separately.

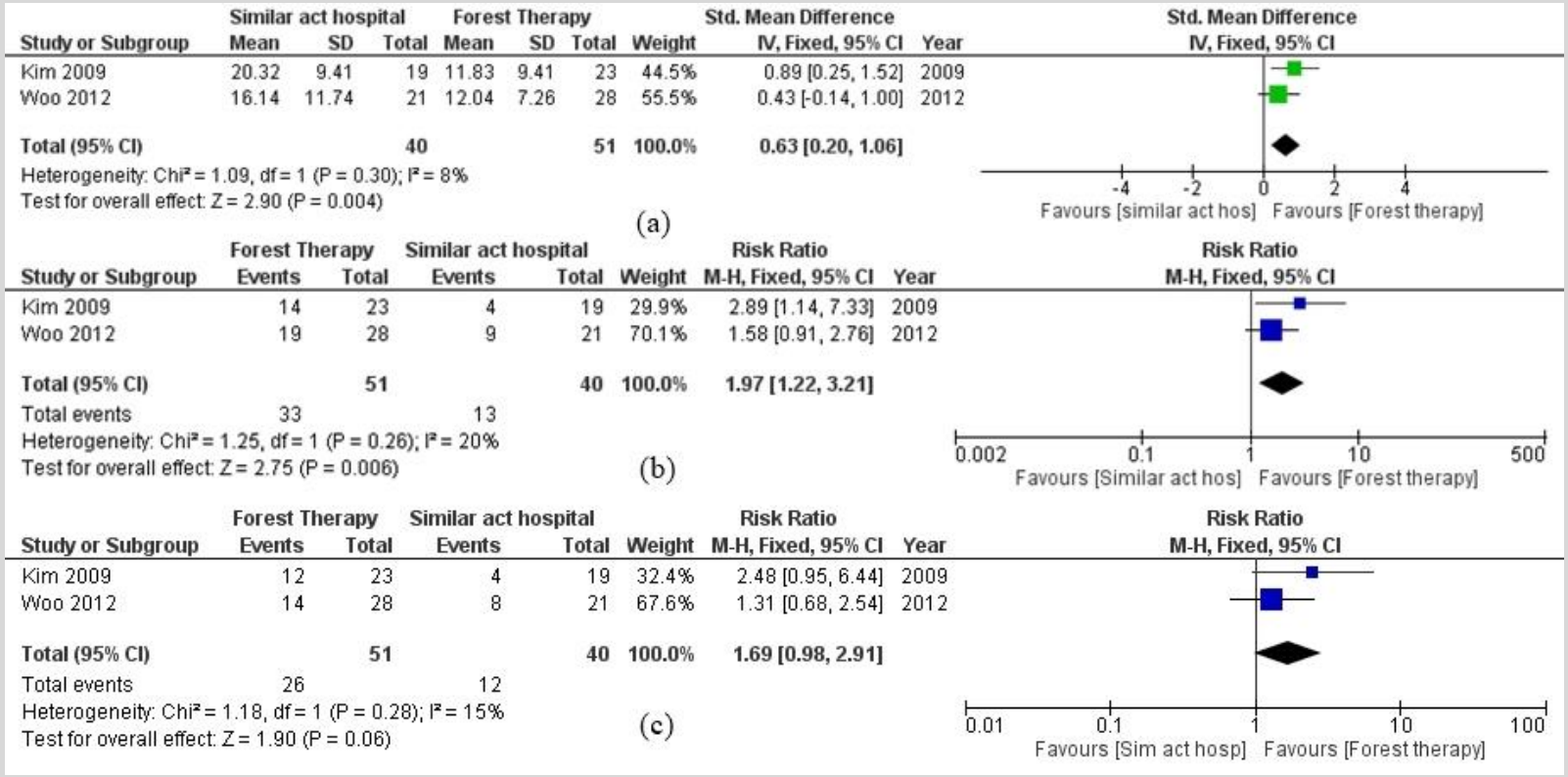

Fig. 3. Results of randomized controlled trials: (a) Comparison of the post-intervention mean score of forest therapy groups versus similar activities in hospital groups using the inverse variance fixed-effect meta-analysis. (b) Comparison of the risk of temporary recovery from depression (i.e. remission) between forest therapy groups and similar activities in hospital groups, using the Mantel-Haenszel fixed-effect meta-analysis. (c) Comparison of the risk of response to treatment (i.e. ≥ 50% reduction on depressive symptoms) between forest therapy groups and similar activities in hospital groups, using the Mantel-Haenszel fixed-effect meta-analysis. Events refer to cases of remission (b) or response (c). Green squares refer to standardized mean differences and blues squares to risk ratios. Bigger squares indicated more participants in a study or more events and a bigger diamond indicates greater uncertainty in the estimate. Cross-over and non-randomized controlled trials were analyzed separately.