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An integrative review of the evidence for *Shinrin-Yoku* (Forest Bathing) in the management of depression and its potential clinical application in evidence-based osteopathy

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ABSTRACT

There is growing interest in the idea of integrating Nature Therapies into the multidisciplinary management of complex conditions such as depression. *Shinrin-Yoku* (Forest Bathing), a practice involving spending time in a forested environment while paying attention to multi-sensory stimuli has been proposed as one such modality. The objectives of this review were to critically analyse the current evidence base on the efficacy of Shinrin-Yoku for the treatment of depression, and to examine how the findings may reflect and/or inform osteopathic principles and clinical practice. An integrative review of the evidence for *Shinrin-Yoku* in the management of depression published between 2009 and 2019 was conducted resulting in $n = 13$ peer-reviewed studies meeting inclusion criteria. Two themes emerged from the literature, the positive effect of *Shinrin-Yoku* on self-reported mood scores, and physiological changes arising from forest exposure. However, the methodological quality of the evidence is poor and experiments may not be generalisable. Suggestions were made for improving the research base via mixed-method studies in a biopsychosocial framework, and aspects of the research which may be applicable to evidence-based osteopathy were noted.

1. Introduction

Depression is a common mental disorder, and has been estimated by the World Health Organization to affect 4.4% of the global population (World Health Organisation, 2017). Rates of depression may vary from country to country (Liu et al., 2020), with the UK Government estimating that over 16% of English citizens are affected with the condition (Baker 2018). High rates of depression are a significant public health issue, but forming a robust healthcare policy and effective clinical management of the condition are equally challenged by the fact that depressions' aetiology and classification are subject to extensive debate (Beck and Alford 2014). In contrast to biomedical diseases which may be subject to binary classification between the disease and the healthy state, depression has not been shown to exhibit a single biomarker which differentiates the asymptomatic from the symptomatic (Patel 2017). Depression is ultimately a subjective experience influenced by a wide variety of factors, from social and cultural determinants (Lund et al., 2018), to genetics and epigenetics (Ménard et al., 2016), and personality traits (Klein et al., 2011). The biopsychosocial (BPS) model of health and disease emerged as an attempt to account for the multi-causal nature of complex conditions such as depression in clinical analysis and healthcare management (Wade and Halligan, 2017). The BPS framework may be a better model for understanding the multidimensional aetiology of depression, though Garcia-Toro and Aguirre (2007) caution that there can be a lack of conceptual links between the biomedical and psychosocial fields, and that the clinical judgement of which elements are most pertinent to any one patient is potentially arbitrary and subject to bias. In addition, authors such as Cormack et al. (2022) have critiqued clinical misrepresentation of the BPS model and have argued that an enactivist philosophy could help to overcome neurological and biomedical reductionist approaches to complex health conditions, as embodied cognition, pain, and potentially depression, can be viewed as emergent properties of the individual-environmental interaction (Stilwell and Harman, 2019).

In the period following an acute musculoskeletal (MSK) injury, the co-occurrence of depression increases the probability of a patient developing persistent pain (Currie and Wang, 2005) and is associated with fear-avoidant behaviour and catastrophising cognitions (Baez

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et al., 2018; Darnall et al., 2017). The effective self-management of chronic conditions is challenged by catastrophising and its inverse relationship with self-efficacy (Damush et al., 2016), and fear-avoidance may result in decreased engagement with exercise and other behaviours for which there is robust quality evidence of general health benefits (Warburton and Bredin 2017). While depression may be predictive of the persistence of pain, persistent pain may also increase the probability of a patient developing depression (Sharpe et al., 2017; Sheng et al., 2017), though the bidirectional relationship between depression and pain is complicated and may be mediated by other BPS factors. Given the impact of depression on pain, quality of life, and long-term health outcomes, it is essential that BPS therapeutic modalities can integrate strategies for the management of the condition into clinical care.

Osteopathy, as a system of diagnosis, treatment and advice (Fryer 2017), emerged in the 19th century as a form of healthcare which aimed to treat the individual through interventions informed by principles of body-unity and a rejection of mind-body duality (Zegarra-Parodi et al., 2019). Contemporary osteopathic practice is primarily focused on the treatment and management of MSK issues, though many of the commonly used osteopathic models exploring the relationships between pain and biomechanics are no longer supported by evidence (Lederman 2017). As a result, there have been calls for osteopathic practice to improve both its primary research base and to better apply this evidence in clinical settings (Vogel 2015). Authors such as Penny (2013) have proposed a theoretical convergence between Osteopathy and the BPS model - through integrating research from the latter, osteopathic principles and practice could move towards a model of evidence-based healthcare - while Esteves et al. (2020) have suggested that osteopathy should be open to incorporating novel models and theoretical frameworks provided the underlying evidence is sound. Building on the critiques of both the BPS model and osteopathy, authors such as Bohles et al. (2021) have viewed osteopathic interventions from an enactivist position, suggesting that osteopathy may have the potential to aid in psychological conditions such as depression through the induction of predictive coding errors in patients via introceptive changes, potentially allowing for a novel generative model of the world away from the painful/depressed state. Work by Cerritelli et al. (2021) demonstrates a practical application of this as a trial ($n = 32$) revealed statistically significant changes in regional cerebral blood flow and heart rate variability (HRV - a proxy for increased parasympathetic nervous system activity) in chronic low back pain patients following osteopathic interventions. While this trial involved a small sample size, its results do reflect a broader trend in current osteopathic research (Casals-Gutiérrez and Abbey, 2020) which may lead to a general reconceptualization of osteopathic practice towards an enactive model. In order to promote patient self-efficacy, self-management strategies congruent with this trend should be considered alongside direct clinical interventions.

Nature Therapy (NT) is a broad suite of practices involving engagement with nature-rich environments or natural stimuli (Song et al., 2016) which have received increased attention due to restrictions imposed globally arising from the COVID-19 crisis (Pouso et al., 2021). NT is underpinned by three main theories. Attention Restoration Theory (ART) is a cognitive model in which natural environments reduce the demand on voluntary attentional control mechanisms relative to urban spaces (Bratman et al., 2015). Stress Reduction Theory (SRT) focuses on the emotional and physiological changes emerging from nature experiences (Gidlow et al., 2016). While there is increasing research utilising both ART and SRT as theoretical frameworks, both theories may apply concurrently and there is uncertainty relating to their underlying mechanisms (Frumkin et al., 2017). Underpinning ART and SRT is the Biophilia Hypothesis – a psycho-evolutionary model which proposes that humans have an innate attraction to life or life-like processes (Grinde and Patil 2009). This hypothesis has been critiqued for lacking clarity in its definition, demonstrating ambiguity in its description of how natural stimuli are cognitively processed, and founded on a selection bias with respect to the specific ecosystems in which *Homo sapiens* evolved (Joye and De Block 2011). Despite this robust critique, as our species first emerged approximately 300,000 years ago (Schlebusch et al., 2017) it is a reasonable assumption that physiological functions have adapted for optimal survival in natural environments, though specific biophilic tendencies are likely to be mediated by a wide range of factors, from individual personality to broader cultural influences.

Arising from theories of systems research, Lehman et al. (2017) emphasise the role of contextual dynamics in the BPS model. Viewed in this light, the external environment functions as a macrosystem influencing the individual, and NT interventions involving immersion in natural settings may alter contextual parameters leading to a reduction in the stress-state (SS). The inter-relationship between stress and depression has been confirmed by multiple systematic reviews (e.g., Hammen 2005; Von Werne Baes et al., 2012), and a reduction in stress may produce a correlational reduction in symptoms of depression. As the capacity for self-healing is a core osteopathic tenet, it could be argued that the reduction of the SS allows for psychological self-healing to take place, and this potentially reflects osteopathic principles in application. Osteopathic thinkers such as Littlejohn (1996) suggested that environmental factors must be addressed in order for the individual to be restored to normal functioning, and recent research from Cerritelli and Esteves (2022) has outlined an enactive-ecological model of care whereby the patient-practitioner dyad could lead to mental state alignment and a novel ecological niche for the patient, though Shaw et al. (in press) have outlined multiple challenges to implementing this model. Assuming the validity of an ecological-enactive approach, interventions such as NT may be useful adjunct methods to a primary clinical intervention, as a self-management strategy in which other beneficial ecological niches are explored.

Brief NT exposure studies have demonstrated immediate reduction in stress biomarkers, while regular nature engagement has been linked with a statistically significant reduction in the risks associated with diabetes and asthma (Twohig-Bennett and Jones, 2018). Claims of longitudinal benefits of NT may be challenged on the basis of socioeconomic inequalities with regards to nature access as a result of residential location or transportation disadvantage. Rates of greenspace use are consistent across socioeconomic groups when the areas are readily accessible (Mitchell and Popham 2008), but accessibility is a highly proprietary feature of any given natural area, and must be taken into account when reviewing epidemiological data. Additional challenges in interpreting NT research arise from significant variation in the stimuli involved in various interventions, and the continuum of physical activities which may be involved. In any given study, exercise-induced health benefits must be controlled for, and meta-analysis of widely differing NT interventions is subject to significant heterogeneity. One form of NT, *Shinrin-Yoku* (SY), directly translated as 'forest-bathing', is a practice which emerged in Japan in the 1980s involving sitting or slow-paced walking in a forested area while paying attention to the multi-sensory experience (Tsunetsugu et al., 2007). SY studies have been conducted on its potential to reduce hypertension (Ideno et al., 2017) manage diabetic blood-glucose levels (Ohtsuka et al., 1998), and stimulate immune function (Li et al., 2007; Li 2010). In order to investigate the effect of SY on SS, a growing body of research is combining psychological and physiological measures in experimental field studies. Profile of Mood States (POMS) rating scales are frequently used to assess subjective ratings of dimensions such as depression-dejection (Andrade and Rodríguez 2018). Various physiological markers such as salivary cortisol as a proxy for stress (Hellhammer et al., 2009) and salivary

α-amylase and heart-rate variability (HRV) as proxies for autonomic nervous system activity (Rohlederet al 2004; Sgoifo et al., 2015) have been tested in these experiments. Correlations of mood changes with objective physiological measures strengthens the evidence base for the validity of the SS theory, the potential theoretical convergence with the BPS/osteopathic models, and the potential efficacy of SY as an intervention. However, in order for any strong conclusions to be drawn this evidence base must first be critically evaluated for methodological rigour. Therefore, this review aims to first, critically review the current evidence base on the efficacy of SY for the treatment of depression, second, to critically examine how the above findings may reflect and/or inform osteopathic principles and finally, comment on how these findings may be integrated into clinical practice.

2. Methodology

An integrated review of the SY literature was conducted – this methodology was chosen as it aims to critically define concepts, review conceptual frameworks and to analyse methodological issues within a complex topic (de Souza et al., 2010). As quantitative and qualitative research may be included, empirical findings rooted in biomedical positivism and themes derived from thematic or phenomenological inquiry could be combined. This leads to the possibility of a nuanced critique of a topic which may not be fully explored by a single paradigm of inquiry and from which meaningful conclusions can be derived from a structured and logical analysis of the included studies (Petticrew et al., 2013).

2.1. Inclusion/Exclusion criteria

The included population for this review were adults with or without depression (including anxiety, fear avoidance, catastrophising, or low self-efficacy), treated with SY, with no-intervention, patient advice, or alternative environments (e.g., urban environments) as controls in RCTs, randomised crossover studies, or other peer-reviewed randomised experiments in addition to systematic or integrative reviews of the above. SY was defined as sitting/standing/gentle walking in a forested environment, with an emphasis on paying attention to sensory stimuli. Studies using non-forested or virtual environments were excluded. Studies involving an athletic component (higher intensity exercise than gentle walking), or other BPS treatment modalities (CBT, ACT, mindfulness, etc.) were excluded. Quantitative outcomes were clinical reductions in POMS depression-dejection ratings or other defined scales such as those suggested by Zimmerman et al. (2005), with physiological data noted as a secondary outcome. Systematic reviews which addressed the effects of SY on depression along with other health outcomes were included, provided that the studies made clear and justified analysis of research matching the inclusion criteria of this review. Qualitative outcomes included any phenomenological or thematic analysis of participants in SY studies as per the quantitative inclusion criteria. Peer-reviewed studies published between 2009 and 2019 in the English language were evaluated. Studies which lacked peer-review, research involving depression as a co-morbidity with other conditions (e.g. hypertension, diabetes, etc.), and studies which did not report psychological outcomes were excluded. Studies which failed to address how they achieved ethical approval, did not meet the standards set in Declaration of Helsinki (World Health Organisation 2001), or failed to sufficiently anonymise the participants were excluded.

2.2. Search strategy

The *Medline/PubMed, Cinahl, Cochrane, Scopus, Web of Science, Cochrane* and *PsychInfo* databases were searched using the key terms, phrases and using the appropriate Boolean operators as set out in Table 1. Searches were adapted as per the requirements of each database.

2.3. Identification of studies

Searches were conducted in August 2019 resulting in $N = 2567$ records which were then imported into EndNote (Basic). Screening process followed the PRISMA process as per Fig. 1. Duplicate results ($n = 2308$) were removed, and $n = 349$ records were screened by title and abstract, resulting in $n = 92$ records for full text screening. An additional $n = 33$ records were identified in reference lists, via Scopus tracking of citations of included studies, and through reviewing the publication lists of key authors.

Of the resulting $n = 125$ full text articles, $n = 62$ were found to not fully meet the inclusion criteria, and a further $n = 46$ were removed as per Fig. 1, resulting in $n = 15$ records included for full quality assessment and analysis. Critical analysis resulted in the elimination of $n = 2$ studies due to poor methodological quality, resulting in a final sample of $n = 13$ studies for this review [Fig. 1].

3. Results

3.1. CASP results and quality assessment

Following the above search strategy, $n = 15$ papers were selected for in-depth analysis of methodological quality (utilising appropriate Critical Appraisals Skills Programme tools), rigour, and reported outcomes. CASP questions were answered with yes/can't tell/no responses and scored 2/1/0 respectively, and studies were grouped according to their study type and ranked according to total scores expressed as percentages (Table 2). As this is a novel field of research, a minimum threshold for quality could not be assumed a priori. The minimum threshold for quality was set at 40% in a post-hoc analysis – while preferable to establish this in advance, post-hoc results may be useful if viewed with caution (Srinivas et al., 2015). Two studies were excluded from falling below this threshold. While 40% is a low figure, it is worth evaluating methodological issues in current publications in order to improve the evidence base.

3.2. Data extraction

Data was extracted from $n = 13$ papers, grouped according to study type, and listed in alphabetical order. For included RCTs and crossover studies, the author(s), year of publication, country of publication, participants, intervention, control, self-assessed measurements of depression, other psychological or physiological scales, methodology, and outcomes were noted. Outcomes were deemed to be significant for p values < 0.05. For included systematic reviews, the authors, year of publication, databases used, included study type, setting, aim and design, and findings in relation to depression and methodology were noted.

Full extraction tables are available in Appendix 3.

3.3. Methodological quality

The methodological quality of included papers is generally poor, averaging 59.02%. As 54.54% of included primary studies have sample sizes of $n \leq 50$, it is challenging to generalise results to a wider population. Blinding of study participants in SY research (involving full sensory immersion) is not possible, so it is imperative that researchers

are fully blinded to the intervention and data collection phases, that randomisation is concealed, and that data is appropriately coded and anonymised. Only two primary studies refer to the coding of self-assessed psychological data, but none explicitly state if researchers were blinded to the field experiments. Analysis of variance (ANOVA) between intervention and control groups was only conducted in one RCT and one crossover study. While crossover experimental design reduces the effect of confounding variables from within group differences (Greenland 1996), the absence of ANOVA in RCTs introduces uncertainty into any subsequent results. The lack of ANOVA in crossover studies also leads to an absence of collection/reporting of demographic or sociological data which may affect the generalisability of conclusions. Recruitment of participants introduces a significant potential bias in the final $n = 11$ primary studies. As students have been frequently utilised as study subjects, it is notable that only $n = 3$ studies emphasised that participating students were recruited from non-forestry/psychology courses, while $n = 8$ failed to note participating student or volunteer background. Participating students from forestry/psychology backgrounds may be aware of the intervention and possible outcomes, and or may be recruited through ethically questionable practices (providing course credits, etc.) which are commonly endorsed by institutional review (Leentjens and Levenson 2013).

Both systematic reviews failed to adhere to a rigorous definition of SY with regards to their literature searches, and as a result several studies incorporating diverse methodologies (involving CBT, counselling, etc.) with populations involving significant comorbidities are included in their analysis. Hansen et al. (2017) did not include any quality assessment of included studies. Lee et al. (2017) included $n = 16$ articles involving adults without health comorbidities as a subsection of their $n = 28$ records for critical analysis. Both reviews failed to note potential recruitment bias.

3.4. Thematic analysis

Following an inductive review of the data/results of the included studies, two key themes can be seen to emerge. First, subjective changes in self-assessed psychological ratings following SY can be seen in all studies, though changes in ratings of depression vary in statistical significance and effect size. Second, objective physiological changes with SY interventions were reported in eight studies, though in the case of primary studies, the specific metrics recorded were a function of the research design.

4. Discussion

All included studies bar Lee et al. (2014) demonstrated a statistically significant reduction in self-assessed ratings of depression utilising POMS or the Modified form of Stress Response Inventory (SRI-MF) tools following forest exposure relative to control conditions. These results reflect findings from the wider research base on NT modalities which suggest that engagement with the natural world can reduce depressive symptoms (e.g. Bratman et al., 2019; van den Bosch and Meyer-Lindenberg 2019; Hartig et al., 2014). As such, detailed critical analysis of one intervention such as SY may reveal methodological and epistemological challenges which may apply to the wider field of NT. Although this positive effect was noted, the poor methodological standard of research identified during CASP quality analysis means that these results should be viewed with caution. Several potential sources of bias were identified in all studies - as subject blinding is impossible in SY, and patient expectations may have a significant effect on both psychological and physiological responses (Mustafa, 2017), it is essential that all other aspects of the methodology are sound in order to draw robust conclusions from their results.

Sample sizes of included studies varied significantly, ranging from $n = 15$ (Horiuchi et al., 2014) to $n = 565$ (Song et al., 2018). As studies with larger sample sizes were conducted on multiple forest sites over an extended time-frame, rather than improving generalisability, the larger studies effectively incorporate more heterogeneity of intervention. Several included studies were published in non-medical journals (e.g. Journal of Forest Research, etc.). This may result in a) a publication bias in favour of studies supporting the use and funding of forest research, and b) the publication of medical articles which have not been peer-reviewed by academics from medical fields.

POMS is the self-assessment tool used in the majority of included studies and is regarded has having good internal validity (Curran et al., 1995) but may be subject to social desirability biases (van de Mortel 2008). It is challenging to assess if different language versions of the tool are directly comparable, and this indicates a broader issue with SY/NT research, as the language and cultural beliefs surrounding depression are nuanced and subject to significant variation (Haroz et al., 2017) as would be expected under a BPS framework. The absence of qualitative research on SY identified in this review reflects the findings of Hansen et al. (2017) and suggests a research gap through with cultural beliefs about depression and its treatment through NT could be explored (Hagmayer and Engelmann 2014). Ordóñez-Barona (2017) notes that views of nature are a function of culture, and culture itself may emerge as a meta-construct in response to the natural world (Stoffle et al., 2003), leading to the possibility that local variations in response to SY are probable. In order to apply SY/NT interventions for a given population, primary mixed methods research within a BPS framework is required.

Assuming that the construct validity of POMS and depression holds true in spite of the above critique, the variation in results across the included studies requires discussion. There is significant heterogeneity in study design, ranging from 15 min of silent standing (Bielinis et al., 2018b) to multi-day experiments involving sitting, walking, and unsupervised free time (Lyu et al., 2018) in forest settings. If it were theoretically possible to elucidate a dose-response curve for SY, a common methodological protocol is first required, but this is challenged by the fact that SY can be considered a complex intervention as per the definition of Guise et al. (2017) as it involves multi-sensory stimuli, uncertain and complicated causal pathways, and the possibility of psychosocial moderators and mediators of effect. As such, it may not be possible to determine the 'active' components of the intervention (Mustafa 2017), though Horiuchi et al. (2014) attempt to address one of these factors with an experimental SY enclosure in which views of the forest are concealed. This could not be ethically replicated in an experiment involving a walking component. One other influence on the complexity of the intervention is the dynamic structure of a forest or ecosystem itself, involving cyclical diurnal and seasonal changes with frequently non-linear processes of succession and adaption (Puettman et al., 2013). While Bielinis et al. (2018a) replicated the SY intervention in winter and spring with increased reduction in depression scores in the former, a continuum of responses through an annual cycle may be possible. Forests are a function of local biogeographical factors, and while some studies included descriptions/measurements of local weather/light conditions, vegetation assemblages (e.g. Horiuchi et al., 2014), others (e.g. Im et al., 2016) fail to account for any local environmental data. Two issues arise from the environmental data or lack

thereof. First, the specificity of local environmental factors may be inversely proportional to the generalisability of the study, as factors implicated in purported mechanisms of SY such as visual stimuli or species' specific volatile organic compounds (Meneguzzo et al., 2019) become heterogenous and non-replicable in other settings. Second, SY research assumes that therapeutic benefits arise directly from the intervention, rather than removing the adverse effects of the control – namely the urban environment. Accurately modelling urban and forest environments to create controlled variables in SY research may not be epistemologically possible.

Several studies included a randomised crossover methodology. This theoretically negates confounding variables in group differences and requires smaller sample sizes to meet the same statistical type I/II error risks as an RCT (Wellek and Blettner 2012), but central to the validity of this methodology is the use of a washout period between interventions to reduce or eliminate the impact of carryover effects. Washout periods varied in the included studies from 30 min (Horiuchi et al., 2014) to 24 h (e.g. Takayama et al., 2019) and variations in washout periods was noted in both systematic reviews. No SY dose-response has been established in the literature to justify any given washout period. Brief washouts may fail to reduce carryover effects, and longer duration washouts may not be feasible with regards to NT interventions, as participants would need to be continually monitored to ensure limited contact with natural environments. As such, crossover studies of SY should be discontinued in favour of RCT design with qualitative components as previously described.

Due to an absence of highly quality SY research and significant theoretical challenges to achieving generalisable results, SY exhibits a similar epistemological challenge to osteopathy. However, aspects of these interventions can be implemented in an 'evidence-informed' manner (Nevo and Slonim-Nevo 2011); the theme of physiological responses to SY may be illustrative in this regard.

Several included studies incorporated physiological measurements – while many of the methodological issues addressed previously will still apply, self-assessment biases are eliminated, and the resulting conclusions may have marginally increased validity. Reductions in pro-inflammatory cytokines and biomarkers of oxidative stress following SY were identified by Mao et al. (2012) and Im et al. (2016), while Lee et al. (2014) and Song et al. (2019) noted post-intervention decreases in heart rate and increases in HRV. Horiuchi et al. (2014) found that exposure to the forest without concealed vision resulted in a significant reduction in cerebral oxygenated haemoglobin – a proxy for relaxation – though there was no significant change in HRV noted between concealed and unconcealed forest conditions. Similar physiological results were identified by Hansen et al. (2017) and reflect wider findings from the NT literature (e.g. Bratman et al., 2019). The causal relationship between physiological measurements and depression is likely to be bidirectional and involve non-linear components such as neural variability (Dinstein et al., 2015), but reduced rates of HRV has been strongly correlated with the severity of depressive symptoms (Hartmann et al., 2019). This suggests that SY may have the potential to induce positive changes in multiple aspect of the integrated neuroimmunoendocrine system as predicted by the models underpinning NT, though further empirical support is required.

Should these findings be supported by higher quality research, this may have implications for osteopathic principles. Assuming that the functional status of the neuroimmunoendocrine axis is intimately linked by various degrees of magnitude to environmental conditions via multiple causal pathways, then the principle of the 'body is a unit' (Paulus 2013) may require revision. As written, this principle implies a dualistic separation of the human organism from its environment - the enactive-ecological model of Cerritelli and Esteves (2022) implies that this dualism needs to be revised, as the self is an emergent property of the body-environment interaction in enactive philosophy (Stilwell and Harman, 2019). Further high quality research in NT/SY conducted through an enactive philosophical lens could be used as additional empirical support for this enactive-ecological model, as varying approaches converge on the implications of viewing the 'body-ecosystem' as a unit.

On a clinical level, NT/SY may have the potential to be integrated into BPS osteopathic management of conditions for which depression is a contributory factor via the merging of third wave cognitive behavioural therapy with osteopathy (Carnes et al., 2017). As this approach emphasises the identification and reframing of patient goals around personal values (Crombez et al., 2012), osteopaths could inquire about nature-related values with patients and when applicable, discuss how engagement with NT modalities such as SY could function as an expression of committed action. Critically, this could be implemented into supported self-management strategies, as this may lead to improved patient self-efficacy with attendant reductions in pain and depression levels (Damush et al., 2016). The potential shift of the patient away from the stress state may facilitate improved or normalised self-healing processes, and future experimental research could compare and contrast the effect of osteopathic management with and without NT engagement. However, as depression, engagement with NT, and ecosystem components are functions of local cultural normative values and ecological variables, research must be specific to a given population for whom the intervention is intended. In addition, access to spaces facilitating NT/SY may be limited by socioeconomic factors, transport access, and issues of environmental injustice (Mitchell 2019). Barriers to access must be identified and addressed for any scaled NT programme.

4.1. Limitations

There are several limitations to this review. Study selection and quality assessment was conducted by a single author, and there is a potential for subjective biases in the determination of study inclusion and quality. As the abstract and titles of multiple non-English language papers (Japanese, Korean, Chinese, and French) were available in English but full texts had not been translated, it became apparent that a language bias is present in this study, as multiple primary sources were excluded from analysis. In addition, the inclusion of primary data from non-English language studies in English-language systematic reviews introduces an element of uncertainty in any subsequent conclusions as the studies which informed them cannot be scrutinised. As this is a novel field, methodological quality of the studies was established in a post-hoc analysis, and as such, should be viewed with caution. Many of the studies included in this review calculated the reduction in self-rated depression scores in generally healthy sample groups, specific research will need to be conducted on populations with clinically diagnosed depression. While integrative reviews may be a rigorous means of deriving clinically applicable information from a body of research, there is a lack of clarity in the methodological literature as to how themes can be derived from quantitative studies, and in the absence of a gold standard approach, an inductive interpretation based on the research outcomes was used.

5. Conclusion

Depression is an inherently complex condition which is best understood within the context of the BPS model, and understanding this is essential for evidence-based musculoskeletal care due to the

interrelationship between depression and pain. There is a novel body of evidence suggesting that NT may have a role in supporting wellbeing, and SY has been cited as one intervention in this paradigm. An integrative review of the literature was conducted into the effect of SY and depression. Physiological changes following SY exposure could be seen to reflect a view of the individual's physiological interaction with the external environment – improved mixed-methods research in an enactive-ecological paradigm may require osteopaths to revise fundamental principles with respect to the idea of 'body-ecosystem' unity. While it may not be possible to determine the specific outcome of NT/SY, these approaches may be integrated into clinical management as a strategy of encouraging committed action towards nature-based values as per modern behavioural psychology approaches.

5.1. Clinical relevance

- Nature Therapies, including *Shinrin-Yoku* (forest bathing) may have broadly positive psychological and physiological benefits to patients.
- While the research base for *Shinrin-Yoku* is of poor quality, further research using mixed-methodologies in a biopsychosocial framework could elucidate how individuals/groups respond to nature engagement.
- Osteopaths and other professions operating within a biopsychosocial framework may want to ask open questions of patients about nature related values and signpost practices such as *Shinrin-Yoku* as part of a strategy of committed action towards personal values.

CRediT authorship contribution statement

Richard Doran-Sherlock: Conceptualization, Methodology, Formal analysis, Investigation, Writing. **Simon Devitt:** Supervision, Validation, Writing – review & editing. **Payal Sood:** Supervision, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare that there is no conflict of interest.

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Appendix 1. Tables

Table 1
Search Terms

Primary Search Terms	
Shinrin Yoku	"shinrin-yoku" OR "shinrin yoku" OR "shinri*" OR "forest bathing" OR "forest therapy"
Depression	"depression" OR "anxiety" OR "self-efficacy" OR "fear-avoidance" OR "avoidance" OR "catastrophi*"

* Indicates the use of proximity operators.

Table 2
Summary CASP Results

Study Type	Authors and Publication date	Score	Percent (%)
RCT	Bielinis, Takayama, Boiko, Omelan and Bielinis (2018b)	16	72.72
	Bielinis et al. (2019)	14	63.63
	Mao et al. (2012)	14	63.63
	Bielinis, Omelan, Boiko and Bielinis (2018a)	12	54.54
	Lyu et al. (2018)	11	50.0
Crossover Study	Im et al. (2016)	17	77.27
	Horiuchi et al. (2014)	16	72.72
	Song et al. (2019)	14	63.63
	Lee et al. (2014)	13	59.09
	Takayama et al. (2019)	12	54.54
	Song et al. (2018)	10	45.45
Systematic Review	Hansen et al. (2017)	9	45.0
	Lee et al. (2017)	9	45.0

Appendix 2. Figures

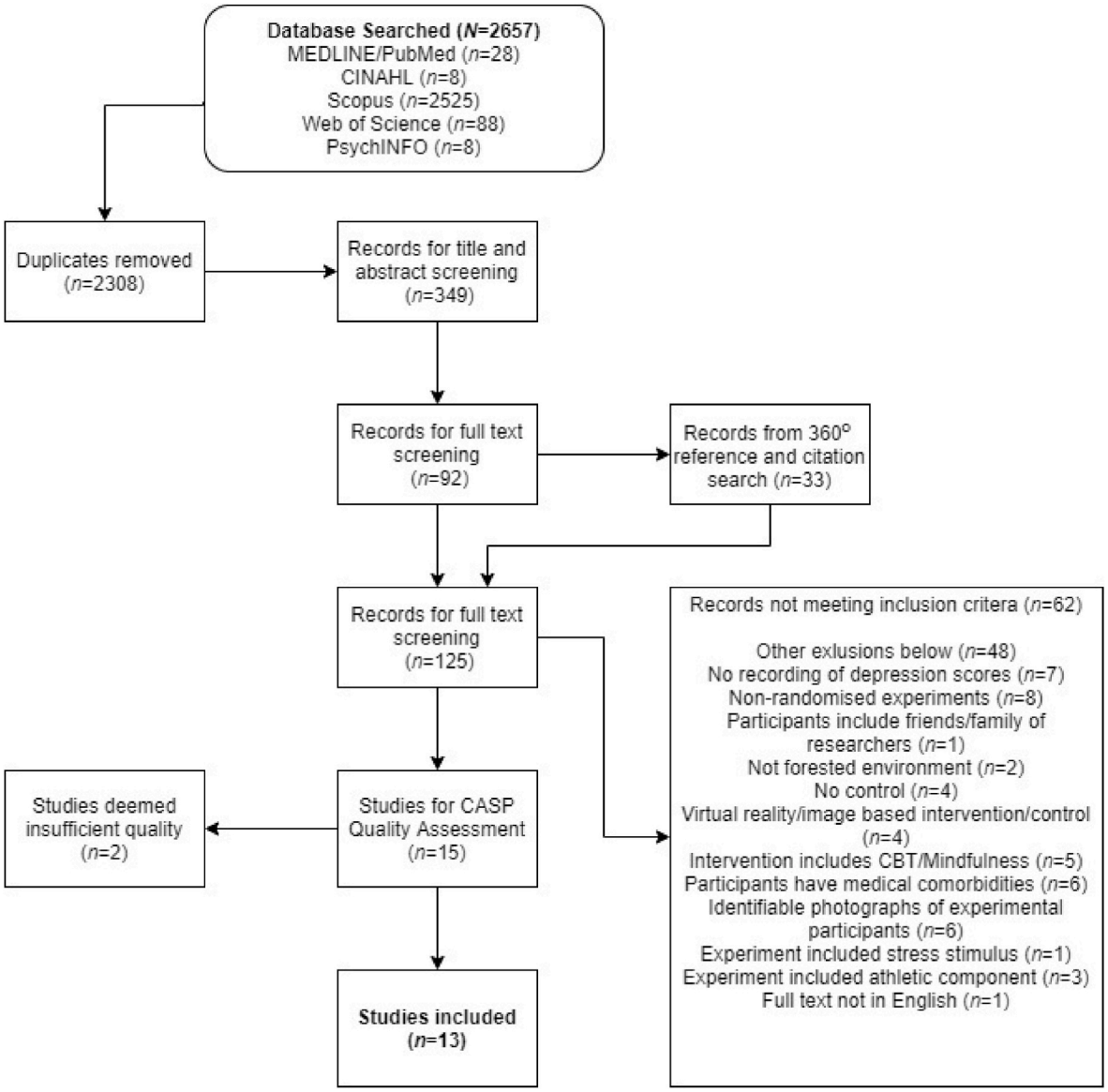

Fig. 1. PRISMA Flow Diagram of the Screening Process.

Appendix 3. Full Data Extraction Tables

RCT Data Extraction

Paper	Country	Participants	Intervention	Control	Measurements	Methodology	Outcomes
Bielinis et al. (2018a)	Poland	n = 54 asymptomatic students (24 women, 30 men), age 21.35 ± 1.39 Intervention: n = 26 Control: n = 26	15 min silent standing in forest in winter and spring	15 min silent standing in urban area in winter and spring	Profile of Mood States (POMS) Positive and Negative Affect Schedule (PANAS) Restoration Outcome Scale (ROS)	RCT with pre/post-test design, intervention repeated in two seasons with same groups.	Post-test reduction of depression-dejection POMS scores relative to control and pre-test conditions ($F = 5.49$, $p < 0.001$), with increased effect in winter.

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Paper	Country	Participants	Intervention	Control	Measurements	Methodology	Outcomes
					Subjective Vitality Scale (SVS)		PANAS positive subscale higher in forest in both seasons ($p < 0.001$) ROS scale higher in both forested conditions (winter > spring) ($p < 0.001$)
Bielinis et al. (2018b)	Poland	n = 62 asymptomatic students (26 female, 36 male), age 21.45 ± 0.018 Intervention: n = 31 (13 female, 18 male) Control: n = 31 (13 female, 18 male)	15 min silent standing in forest in winter	15 min silent standing in urban area in winter	POMS PANAS ROS SVS	RCT with pre/post-test design.	POMS depression-dejection: control group pre experiment 0.61 ± 0.12, post experiment 1.13 ± 0.16; intervention group pre experiment 0.62 ± 0.11, post experiment 0.35 ± 0.10, $p < 0.05$
Paper	Country	Participants	Intervention	Control	Measurements	Methodology	Outcomes
Bielinis et al. (2019)	Poland	n = 32 asymptomatic female students, age 20.97 (S.D. = 0.65) Intervention: n = 16 Control: n = 16	15 min silent standing in forest in winter	15 min silent standing in urban area in winter	POMS PANAS ROS SVS	RCT with pre/post-test design.	POMS depression-dejection reduced in forest (mean 0.85 (SD 0.72) pre-test, mean 0.48 (SD 0.54) post-test) relative to urban control (mean 0.71 (SD 0.56) pre-test, mean 0.95 (SD 0.55) post-test, $p < 0.05$ Marginal increase in PANAS positive ($p = 0.033$), significant increase in ROS and SVS ($p < 0.05$) in forest group
Lyu et al. (2018)	China	n = 120 asymptomatic students (60 female, 60 male) Intervention: n = 30 (15 female, 15 male) for each of three experimental groups Control: n = 30 (15 female, 15 male)	15 min of seated forest exposure, 15 min of walking, and 4 h of free time in three forested sites (two natural bamboo forests, one managed bamboo park for three consecutive days	15 min of seated forest exposure, 15 min of walking, and 4 h of free time in urban control for three consecutive days	POMS Total Mood Disturbance (TMD) – calculated from POMS	RCT with post-test design. ANOVA of control/intervention groups shows no significant difference between four experimental groups	No significant difference in depression POMS score between viewing the landscape and walking in sites in both forest and control settings ($p > 0.05$) No significant difference between urban and managed forest
Mao et al. (2012)	China	n = 20 asymptomatic male university students, age 20.79 ± 0.54 Intervention: n = 10 Control: n = 10	Two 1.5 h walks in forested area for two consecutive days	Two 1.5 h walks in urban area for two consecutive days	POMS Serum Total Superoxide Dismutase (T-SOD) antioxidant levels Malondialdehyde (MDA) lipid peroxidation Cytokine Production Serum Cortisol Serum Testosterone Plasma Endothelin-1 (ET-1) Lymphocyte Assay Platelet Activation	RCT with post-test design for POMS, pre/post-test design for blood metrics. ANOVA of control/intervention groups shows no significant difference between intervention/control groups	Post-test reduction of depression-dejection relative to urban control, $p < 0.05$ Significant reduction in pro-inflammatory cytokines, MDA levels, and serum cortisol in intervention group Significant increase in total B cells with intervention No significant change in T-SOD, platelet activation, serum testosterone

Crossover Study Data Extraction

Paper	Country	Participants	Intervention	Control	Measurements	Methodology	Outcomes
Horiuchi et al. (2014)	Japan	n = 15 asymptomatic volunteers (4 women, 11 men), age 36 ± 8 years	15 min of seated forest exposure	15 min of seated forest exposure/forest exposure with concealed vision	POMS Blood Pressure (BP) Heart Rate (HR) Saliva Amylase (sAMY)	Randomised order crossover trial with 30 min washout period, pre/post-experimental measures	Non significant change in depression-dejection POMS rating in enclosed condition (1.2 ± 0.4 pre-test, 0.9 ± 0.4, post-test, p = 0.345), significant change in intervention (1.5 ± 0.5 pre-test, 0.2 ± 0.1, post-test, p = 0.001) Decreased cerebral oxygenated haemoglobin, no significant changes in salivary amylase, heart rate variability or blood pressure between intervention and control
Im et al. (2016)	South Korea	n = 41 asymptomatic students (27 women, 14 men)	2 h of forest exposure	2 h of urban exposure	Stress Response Inventory Modified Form (SRI-MF) Serum Cytokine GPx: Glutathione Peroxidase	Randomised order crossover trial with 2 h washout period in rural area, pre/post-experimental physiological measures and post-test psychological self-assessment	SRI-MF depressive ratings reduced in forest environment (mean 6.02 (SD 5.18)) relative to urban control (mean 8.76 (SD 5.73)), p = 0.024

Paper	Country	Participants	Intervention	Control	Measurements	Methodology	Outcomes
Lee et al. (2014)	South Korea	n = 48 asymptomatic males, age 21.1 ± 1.2	12–15 min of forest walking	12–15 min of urban walking	POMS State-Trait Anxiety Inventory (STAI) Heart Rate Variability (HRV) HR BP	Randomised order crossover trial with 24 h washout period, pre/post-experimental psychological and physiological measures	No statistically significant reduction in depressive ratings, BP, between forest and control settings No significant difference in walking speed between intervention/control Significant decrease in HR in forest Significant decrease in STAI in forest (p < 0.01)
Song et al. (2018)	Japan	n = 624 asymptomatic male students, age 21.7 ± 1.6 years	15 min of forest walking	15 min of urban walking	POMS STAI	Randomised order crossover trial with 24 h washout period, post-experimental psychological self-assessment n = 624 participants divided into four groups of n = 12 (n = 39 no data collected)), each group randomised into two groups of n = 6, experiment conducted in 52 forest sites with urban controls over period of nine years, washout period ~24 h, experiment repeated in complementary location	Small but significant reduction in POMS depressive ratings in forest environment (mean 40.6 ± 3.7) relative to urban control (mean 41.6 ± 5.3, p < 0.01), with a greater decrease noted among participants with higher trait anxiety levels

Paper	Country	Participants	Intervention	Control	Measurements	Methodology	Outcomes
Song et al. (2019)	Japan	n = 72 asymptomatic female students, age 21.0 ± 1.3	15 min viewing of natural forest	15 min viewing of urban area	POMS STAI HRV BP HR	Randomised order crossover trial with 24 h washout period, pre/post-experimental psychological self-assessment and physiological measurements Errors in data collection resulted in 7 participants being omitted from POMS analysis, 20 participants omitted from blood pressure and pulse rate analysis	Small but significant reduction in POMS depressive ratings in forest environment (mean 0.4 ± 0.1) relative to urban control (mean 0.7 ± 0.2, p < 0.05) Increased heart rate variability, decreased heart rate and STAI anxiety in forested areas relative to control

Paper	Country	Participants	Intervention	Control	Measurements	Methodology	Outcomes
Takayama et al. (2019)	Japan	n = 46 asymptomatic male students	15 min of walking and 15 min of viewing natural forest	15 min of walking and 15 min of viewing urban area	POMS PANAS ROS SVS PRS Development of Health and Life Habit Inventory 2 (DIHAL.2) World Health	Randomised order crossover trial with 24 h washout period, pre/post-experimental psychological self-assessment n = 46 participants divided into four groups of n = 11/12, each group randomised into two groups of n = 5/6, experiment conducted in 4 forest sites with urban controls, washout period	POMS depression scores for forest (mean 44 (SD 5.61) pre-test, mean 42.37 (SD 4.97) post-test, p = 0.006) relative to urban control (mean 43.52 (SD 6.37) pre-test, mean 43.63 (SD 5.52) post-test, p = 0.025) show small but significant decreases

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Paper	Country	Participants	Intervention	Control	Measurements	Methodology	Outcomes
					Organization Quality of Life 26 (WHOQOL26) Sukemune-Hiew Resilience Test (SHR) Lazarus Type Stress Coping Inventory (SCI)	~24 h, experiment repeated in complementary location	Increased PRS values, decreased negative PANAS in forest settings

Systematic Review Data Extraction

Paper	Databases Used	Included Study Type	Setting	Aim & Design	Depression Findings	Methodology Findings
Hansen et al. (2017)	Articles Culled from CINAHL, PsycINFO, PubMed, PubMed Central, Scopus, additional records from hand searched sources	n = 64 articles retrieved of which $n = 1$ systematic reviews, $n = 11$ RCTs, $n = 20$ supporting documents, $n = 2$ literature reviews, $n = 3$ qualitative studies, $n = 8$ crossover studies, $n = 23$ other experiments	School of Nursing and Health Professions, University of San Francisco	Broad review with the aim of offering inquiry into current literature relating to SY and NT	Broad research base (interventions, study designs, populations, etc.) makes it difficult to make specific claims in relation to depression - majority of evidence suggests SY may have a positive effect on stress reduction	Variations in format of intervention, small sample sizes, and high risk of bias in studies, lack of formal critical appraisal of included information makes specific claims challenging
Lee et al. (2017)	Articles culled from Pubmed, EMBASE, CINAHL, PsycARTICLES, KISS, RISS, Dbpia	$n = 28$ articles retrieved of which $n = 6$ RCTs, $n = 11$ non-equivalent control group design, $n = 11$ crossover trial design $n = 16$ articles included adults without health comorbidities, involving a mixture of students, office workers, senior citizens, and the families of alcoholics Interventions ranged from 15 min of forest exposure to multi-day forest programmes and weekly recurring forest therapy sessions	Faculty of College of Nursing, Seoul National University	Systematic review with the aim of providing a broad overview and synthesis of evidence on usefulness of forest therapy on adults with depression	Significant reduction in self-assessed ratings of depression in 11 of n = 16 (articles included adults without health comorbidities)	Variations in format of intervention, small sample sizes, and high risk of bias in studies

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