A Review of the Current Evidence for the Health Benefits Derived from Forest Bathing

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A Review of the Current Evidence for the Health Benefits Derived from Forest Bathing

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Abstract: Forest bathing, known as Shinrin-Yoku, is the Japanese practice of taking short trips to a forest and immersing oneself within the atmosphere of the environment. Over the last twenty years, emerging evidence from the fields of complementary medicine, allied and environmental health has shown promising results for human health, including cardiovascular, immune, and neuro-endocrine benefits, as well as improvement in mental wellbeing. More recent research suggests that these improvements in physiological and psychological health may be in part due to phytoncides (airborne aromatic compounds) that are inhaled by breathing in the forest air. Autonomic nervous system regulation has also been identified as a potential mechanism for the improvements seen. This article reviews the current evidence for the health benefits derived from forest bathing to determine the need for future research, including the potential for studies to be conducted in Australian environments. Methods: A search was undertaken in PubMed (including PMC), Medline Complete, and SCOPUS using the search term "forest AND bathing." A review of the methods and references of selected papers were reviewed to identify additional sources of published research. The inclusion criteria applied were human studies published between 1998 and 2017, available in full text, English language, with methodology that included direct exposure to a forest environment. Results: Thirty-one papers were determined to meet the inclusion criteria and are included in this current review. Conclusion: The current evidence demonstrates significant benefit for human health in relation to cardiovascular, immune, and neuro-endocrine function. Furthermore, significant psychological benefit has been associated with forest bathing. The review has identified that the majority of the current research has been conducted in Japan and other regions of Asia. Further research in other regions, such as the Australian environment, warrants consideration.

Keywords: Forest Bathing, Shinrin-Yoku, Cardiovascular, Immune, Neuro-Endocrine, Psychological

Introduction

The term *Shinrin-yoku*, literally meaning "forest bathing," was conceived by the Japanese Forestry Agency in 1982 as a health intervention that recognised the potential therapeutic effects of immersion in a forest environment (Park et al. 2009). This is not to be confused with the practice of "green exercise," where programmed physical and recreational activities in outdoor natural environments are undertaken to achieve health benefits (Gladwell et al. 2013). The practice of Shinrin-yoku is much more passive, allowing the participant to take in the forest environment through the senses without exertion (Song, Ikei, and Miyazaki 2016).

The majority of the research reviewed within this study has been limited to Japanese and Chinese forest environments, which presents an obvious gap in the literature. For instance, various geographic locations possess distinct forest species and topography that can potentially provide health benefits yet to be observed, e.g., the eucalyptus forests of the Blue Mountains, Australia. This observation was prompted by the study of Guan et al. (2017), who discovered that there was a specific effect of a tree species on young adults suffering from anxiety.

Despite observable limitations in the body of knowledge, there has been a growing attention on the multiple health benefits of Shinrin-yoku over the last twenty years. The aim of this literature review is to appraise the published research findings for the physiological and psychological therapeutic benefits. These benefits have been categorized into the following topics: 1) cardiovascular, 2) immune, 3) neuro-endocrine, and 4) psychological. Even though, current evidence suggests benefit within these areas, further research needs to be conducted to

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better understand the favourable correlations and causations experienced in a variety of environments.

Methods

A search of three electronic databases (PubMed, Medline Complete, and SCOPUS) was undertaken using the term "forest AND bathing" and limited to only those published between 1998 and 2017. Inclusion criteria were stated as full text papers (including original research and systematic reviews), available in English, and reporting human studies. Papers that were not available in full text, in English language, were animal studies, or n = 1 case studies were excluded, as was any paper that was not specifically reporting on the practice of forest bathing (Shinrin-yoku).

Following the initial search, duplicate studies were removed before the application of inclusion and exclusion criteria. Portable Document Format (PDF) files for all papers included in this review have been retained and stored electronically.

Results

The initial search returned a total of 220 results. After removal of duplicates (n = 134), the remaining eighty-six papers were analysed in accordance with the inclusion and exclusion criteria. Further fifty-two papers were excluded following this analysis. One (1) title was excluded as the authors were unable to locate a full text copy of the study, and a further two (2) studies were later determined not to be specific to forest bathing and were subsequently excluded. The remaining thirty-one papers were retained and formed the basis of this review.

Cardiovascular

Cardiovascular disease (CVD) is the most prevalent cause of mortality in Europe (Nicholas et al. 2014), China (Mao et al. 2017), and Australia (Waters et al. 2013), while recent data suggests that coronary heart disease has been increasing among Japanese urban men (Iso 2011). Due to this increased global incidence of CVD and the improvement in field test technology, several papers have chosen to measure heart rate variability, pulse rate, blood pressure, and CVD-related pathological factors as the framework for cardiovascular change.

Two papers specifically looked at the impact of forest bathing on the elderly (60–75 years) who suffered from hypertension (Mao et al. 2012a) and chronic heart failure (CHF) (72.86 ±5.85) (Mao et al. 2017), spanning seven days with a sample size of twenty-four, and four days with a sample size of thirty-six participants, respectively. Both studies investigated known cardiovascular disease factors that included endothelin-1 (ET-1), renin, angiotensinogen (AGT), angiotensin II (Ang II), angiotensin II type 1 receptor (AT1), and angiotensin II type 2 receptor (AT2); whereas, B-type natriuretic peptide (BNP) was included as a directly correlated biomarker for CHF (Mao et al. 2017), as homocysteine levels (Hcy) correlated to the hypertension study (Mao et al. 2012a). Additionally, the same author analysed similar oxidative stress markers, such as ET-1, malondialdehyde (MDA), and superoxide dismutase (SOD) in twenty male university students, who were exposed to a two-day forest environment study (Mao et al 2012b).

All three studies where subjects experienced forest bathing demonstrated a significantly lower ET-1, while BNP was significantly lower in the CHF study. Meanwhile significant lower levels of Hcy, AGT, AT1 were observed in the seven-day hypertension experiment. A reduction of serum MDA was shown to be significant in both four-day CHF and two-day university student studies, yet the SOD levels were found to be elevated and unchanged respectively. In contrast, the AT2 receptor increased significantly in the forest bathing group, where all other RAS constituents were unremarkable in the four-day CHF study.

Mao et al. (2012a) states that the use of angiotensin converting enzyme inhibitors (ACEI) and Ang II receptor blockers (ARB) could have influenced the results on the seven-day hypertension study. However, Mao et al. (2017) failed to mention what medications were taken by the subjects within the four-day CHF study or how this may have affected the results. Neither the age of the subjects nor the length of the study showed a variation in the results of ET-1 or MDA levels within these three studies.

Heart rate variability (HRV) was measured in several studies to investigate the reactivity of the cardiovascular system to forest bathing via branches of the autonomic nervous system (ANS), where parasympathetic activity can be seen in a high frequency (HF) spectrum analysis and sympathetic activity can be seen in a ratio of low:high frequency (LF/HF) spectrum analysis. Lee et al. (2014), Lee et al. (2011), Park et al. (2009) and Tsunetsugu, Park, and Miyazaki (2010) found significantly higher HF values and significantly lower LF/HF values during forest bathing exposure. These findings have been supported by a review of the evidence from previous studies across Japan (Park et al. 2010). However, one study stood alone that produced contrasting HRV results that reported a nonsignificant decreased HF and a nonsignificant increase LF/HF outputs (Yu et al. 2017). The author admits that the research design could have had something to do with the contradicting results, where measurements were taken between forest and urban environments instead of recording the outputs in a single environment as previous studies performed.

Of the thirty-one papers investigated in this review, twelve papers specifically utilised variations in heart rate, diastolic and systolic pressure, as well as overall blood pressure to quantify the benefits of forest bathing (see Table 1). The article by Song et al. (2013) was the only one that looked at the effects of forest nathing on heart rate and blood pressure versus behaviour types that found no change on Type A behaviour pattern, but beneficial change was found with Type B behaviour pattern. The remaining eleven papers found significant effects in the reduction of heart rate and blood pressure except the findings of Lee et al. (2011) with systolic and diastolic pressure and Lee et al. (2014) with diastolic pressure.

Table 1: Significant Findings for Heart Rate and Blood Pressure

Study	***Method***	***Pulse/Heart Rate***	***Diastolic***	***Systolic***	***Blood Pressure***
Yu et al. (2017)	Original	**	**	**	
Ideno et al. (2017)	Systematic review	**	**	**	**
Hansen et al. (2017)	Review	*			*
Ochiai et al. (2015)	Original		**	**	
Song et al. (2016)	Review	*	*	*	*
Lee et al. (2014)	Original	**	-	*	
Song et al. (2013)	Original	#**	#**		
Mao et al. (2012a,b)	Original	*	*	*	
Lee et al. (2011)	Original	**	-	-	
Park et al. (2010)	Review	*	*	*	*
Tsunetsugu et al. (2010)	Review	*			*
Ohtsuka et al. (1998a,b)	Original	-			*

Source: Data Compiled by the Authors

Note: **p<0.01, *p<0.05 indicates statistically significant, dashes (-) signify no significant difference, #Type B behaviour pattern (Song et al. 2013).

Immune

The pathogenesis of disease is composed of the interplay between oxidative stress and inflammatory permutation. This review found ten papers that used well-established biomarkers to measure the status of the inflammatory and immune systems when exposed to forest environments. Li et al. (2007) measured natural killer (NK) activity, T-lymphocytes ($CD3^+$), perforin, granzyme A and B (GrA/B), and granulysin (GRN) expressing lymphocytes in human peripheral blood lymphocytes (PBLs) in twelve male subjects aged 43.1 ±6.1 years, who were free of infectious disease that may have affected immunological analysis. After a two-day, three-night forest bathing trip, where subjects walked for two hours in the morning and two hours in the afternoon, a significantly increased percentage of lymphocytes and monocytes were recorded with a significantly decreased percentage of peripheral blood granulocytes; however, the white blood cell count was unaffected. NK activity was significantly increased in eleven of the twelve subjects, and there were also significant increases discovered in the percentage of cytolytic molecules; perforin, GRN, GrA/B expressing cells in the PBL; as well as a significantly decreased percentage of T-Cells ($CD3^+$). Two later studies by Li et al (2008a; 2008b) utilised the same research design on thirteen females 28.8±4.6 and twenty males 45.1±6.7, respectively, that confirmed the findings of the author's previous study, as well as discovering that the increased NK activity and the increased numbers of NK cells lasted up to thirty days in the forest bathing groups. More recently, Mao et al. (2012b) measured the impact of forest bathing on twenty male

university students, 20.79±0.54, which further supported the findings of previous studies, where pro-inflammatory cytokines IL-6 and TNF-α were significantly reduced and B (CD_3^-/CD_{19}^+) lymphocyte levels were found to be significantly higher in the forest bathing groups.

Bing et al. (2016), Mao et al. (2017), and Mao et al. (2012a) investigated the effects of forest bathing on subjects who suffered from chronic disease; chronic obstructive pulmonary disease (COPD), chronic heart failure (CHF), and essential hypertension, respectively. Bing et al. (2016) and Mao et al. (2017) measured a significant decrease of serum pro-inflammatory cytokines; interferon-y (IFN-y), interleukin-6 (IL-6), interleukin-8 (IL-8), interleukin-1β (IL-1β), tumour necrosis factorα (TFN-α), and C-reactive protein; whereas, the Mao et al. (2012a) study produced similar findings except for unaltered TNF-α levels that were recorded for the group exposed to a forest environment. In addition, Bing et al. (2016) explained that perforin and granzyme-B perform a pivotal function in the disease process of COPD, where a significantly increasing population of T-cells are present in the bronchial epithelial cells and peripheral blood of COPD patients. Thus, the significant decrease observed in the proportions of T ($CD8^+$) cells, NK cells and NKT-like cells expressing perforin combined with a slight reduction of granzyme B expression in the T ($CD8^+$) lymphocytes suggests that the forest bathing trip improved the health of the COPD patients.

Importantly, Song, Ikei, and Miyazaki (2016) expanded our understanding of this phenomena by reporting how several studies discovered that a forest-derived olfactory stimuli exists, where indoor exposure to Hinoki cypress wood oils have been shown to produce an increase in NK cell activity and improve immune function. Li et al. (2006) had previously demonstrated that the volatile substances found in the forest, phytoncides, have been shown to significantly enhance human NK activity and increase the expression of intracellular cytolytic molecules perforin, GrA and GRN *in vitro*, where the effect is both dose- and time-dependent.

A supplementary finding discussed by two reviews of Tsunetsugu, Park, and Miyazaki (2010) and Park, Tsunetsugu, and Kasetani (2010), included in this article was the use of immunoglobulin A (IgA) as an immune system marker for scientific field studies. Even though, Park, Tsunetsugu, and Kasetani (2010) reported a decrease of IgA levels in two field studies for the groups exposed to a forest environment, Tsunetsugu, Park, and Miyazaki (2010) questioned the validity of utilising IgA, due to a significantly negative correlation found between baseline values and values recorded when subjects were exposed to either forest or urban environments.

Neuro-Endocrine

The two axes of the neuro-endocrine system that have been shown to be most affected by Forest bathing are the hypothalamic-pituitary-adrenal axis (HPA) and the sympathetic adrenal-medullary axis (SAM). Under stressful conditions cortisol is released by the HPA axis and shown to be implicated in immunological activity (Park et al. 2010), whereas salivary amylase has become a reliable measure of plasma noradrenaline and increased activity of the SAM axis (Yamaguchi, Deguchi, and Miyazaki 2006). Recent research that holds particular interest for the potential health benefits of forest bathing has shown that fragrance can affect the human immune and endocrine systems through measurements found in urinary dopamine and cortisol levels, NK activity and T-lymphocyte percentage (Li et al. 2006).

Two early studies by Ohtsuka, Yabunaka, and Takayama (1998) determined that blood glucose levels were significantly reduced in non-insulin dependent diabetic populations. Each study followed the same research design, which offered patients an option of a 3-km or a 6-km walk, dependent on each subject's level of fitness. Interestingly, both studies reported a 39.7 percent decrease in blood glucose levels after Shinrin-yoku, while no significant difference were shown between the groups who walked the short or longer distances. In contrast, Li et al. (2016) discovered that there was no effect on blood glucose, glycated haemoglobin A_{1c} (HbA_{1c}), insulin, total cholesterol (CHO), low-density lipoprotein (LDL) CHO, high-density lipoprotein (HDL) CHO or high-sensitivity C-reactive protein in serum.

One methodological discrepancy was observed while comparing the two papers by Ohtsuka, Yabunaka, and Takayama (1998a) and Ohtsuka, Yabunaka, and Takayama (1998b). Ohtsuka, Yabunaka and Takayama (1998a) assessed the level of HbA_{1c} for eighty-two patients before the first and after the last trial of Shinrin-yoku. However Ohtsuka, Yabunaka, and Takayama (1998b) failed to report the same test result for a similar population of forty-eight patients. Nevertheless, both studies found no significant difference in HbA_{1c} levels between the short or long-distance walks.

To gain further insight into the influence that forest bathing has on the neuro-endocrine system, specific biomarkers have been chosen to determine the benefit. Variations of four biomarkers were documented in thirteen studies within this review (see Table 2). The results were statistically generated from the measurements taken pre and post exposure to a forest environment.

Table 2: Biomarker Variations Demonstrating Forest Bathing Benefit

Study	***Method***	***Cortisol***	***Amylase***	***Adrenaline Noradrenaline***	***Dopamine***
Hansen et al. (2017)	Review	V*	V-	V*	
Bing et al. (2016)	Original	V*		V*	
Li et al. (2016)	Original			V*	^*
Song et al. (2016)	Review	V*		V-	
Ochiai et al. (2015)	Original	V*		V*	
Mao et al. (2012b)	Original	V*			
Lee et al. (2011)	Original	V*			
Qing et al. (2010)	Review			V*	
Park et al. (2010)	Review	V*	V-		
Tsunetsugu et al. (2010)	Review	V*			
Li et al. (2008a)	Original			V*	
Li et al. (2008b)	Original			V*	
Yamaguchi et al. (2006)	Original		V-		

Source: Data Compiled by the Authors

Note: V* significant decrease ($p<0.05$), ^* significant increase ($p<0.05$), V- decrease not significant ($p>0.05$).

One study in this review investigated the effect of forest bathing on musculoskeletal function and pain. Kang et al. (2015) randomly divided 64 patients with neck pain into a forest bathing alone group (FBA) and a forest bathing with exercise (FBE) group for a research program that immersed the subjects in a forest for 5 days. Two rehabilitation medical physicians provided support by clinically evaluating each patient with the Visual Analogue Scale (VAS), neck disability index (NDI), EuroQol 5D-3L VAS (EQ VAS) and index (EQ index), McGill pain

questionnaire (MPQ), cataloguing the number of trigger points in the posterior neck region (TRPs), and cervical ranges of motion (C-ROM) 7-10 days before the study began, the first day of the study and the last day of the program. Four rehab physicians and three physiotherapists developed a stretching and strengthening exercise regime for the FBE group including a 2 hour walk in the forest versus the FBA group whose activity was exclusively a 2-hour walk in the forest. Only one of the comparative pain assessment methods applied to the two groups, post-intervention, was the TRP's of the FBE that demonstrated a significantly lower number ($p=0.013$) than the FBA group. However, all scales used to evaluate pain and function for both groups produced significant improvement when first and last day values were statistically compared ($p<0.001$).

Psychological

Several studies previously reviewed the physiological effects of forest bathing included some measure of the effects on the psychological and emotional states of the participants (Yamaguchi et al. 2006; Tsunetsugu et al. 2010; Mao et al. 2012b; Song et al. 2013; Hansen et al. 2017). In most of the cases the psychological benefit was shown to correlate with various physiological parameters (salivary amylase, cortisol, HRV) associated with improved autonomic nervous system regulation, resulting in improved parasympathetic function. These studies commonly concluded that the forest environment was conducive with an improved environment induced stress response (Yamaguchi et al. 2006; Lee et al. 2011).

Morita et al. (2007) evaluated the effects of exposure to the forest environment using the Multiple Mood Scale – Short Form (MMS-SF) and the State-Trait Anxiety Inventory A-State Scale (STAI-S). The MMS-SF measures eight mood responses, six of which were included in the study (hostility, depression, boredom, friendliness, wellbeing, liveliness) along with a measure of anxiety using the STAI-S. The study concluded that walking in a forest was beneficial for acute emotional reactions, particularly in relation to hostility and depression when compared to a control urban environment, and adjusting for the benefits derived from physical activity alone. Further to these findings, the study showed evidence that the effect of forest bathing was more pronounced in individuals with a history of chronic negative affect emotional states, but was likely to be dependent on the individual's preference for walking in a forest environment.

Several studies investigating the effects of the forest environment on mood states used the Profile of Mood States (POMS) questionnaire to measure the effect of forest bathing on anger-hostility, fatigue-inertia, depression-dejection, confusion-bewilderment, and vigor-activity subscales. Yu et al. (2017) found an increase in vigor-activity subscales, with an associated reduction in all negative affect subscales ($p<0.01$), findings which correlated with improvements in physiological measures of HRV, DBP, SBP, and pulse rate. Similar results had previously been reported by Ochiai et al. (2015) in middle-aged males with high-normal blood pressure. Park et al. (2011) reported similar findings in the POMS subscales, including significant improvement in Total Mood Disturbance (TMD) scores, but reported that improvement in these measures was dependent on environmental conditions such as wind, heat, and humidity when compared to an urban environment control. Takayama et al. (2014) reported that short-term forest bathing (conducted over four separate forest sites) saw significant improvement in POMS subscales, as well as in subjective vitality and sense of restorativeness, as measured by the Subjective Vitality Scale (SVS) and Restorative Outcome Scale (ROS), respectively.

One specific study investigated whether there was a tree-species-specific effect on perceived anxiety in young adults (Guan et al. 2017). The study concluded that birch and oak forests were most beneficial for alleviating anxiety associated with school work and social contact, whilst work-related stress improved most from exposure to oak and maple forests. Interestingly, this study also concluded that heavier body weight people derived more benefit than lighter body weight people in oak forests, improving social communication in heavier body weight participants; however, the study did not provide any further reasoning for this finding.

Discussion

This article set out to review the current evidence for the health benefits derived from forest bathing, a predominantly Japanese practice referred to as Shinrin-yoku. The parameters of this study were confined to forest bathing to specifically exclude the broader and more varied practices collectively referred to under the more ubiquitous term "nature therapy."

Thirty-one papers published from 1998 to 2017 were reviewed and classified according to the reported effects as cardiovascular, immune, neuro-endocrine, or psychological benefits. It is acknowledged that several of the studies investigated multiple physiological and psychological variables that could be incorporated into more than one of these groupings.

For the cardiovascular group, the most significant findings were related to the benefits of exposure to forest environments on blood pressure and hypertension. In most of these studies, significant improvement was seen in SBP, DBP, and heart rate results, which correlated significantly with a number of related biochemical markers, including ET-1, AGT, Ang II, AT-1, AT-2, Hcy, BNP, and MDA. HRV was also shown to improve significantly, indicating an improvement in autonomic nervous system regulation of cardiac function, and the resultant improvement in overall blood pressure.

The immune group predominantly reported on the effect of forest bathing on inflammatory state through measures of NK and T-Cell activity and perforin, granzymes, granulysin, IL-6 & 8, TNF-α, and IFN-γ. Most studies reported significant improvement in all measures, resulting in an overall improvement of inflammatory state shown to be beneficial for people affected by COPD and CHF. Some evidence suggests that these benefits may be derived from inhaling phytoncides, described as aromatic compounds emitted by trees into the forest atmosphere, which when inhaled are readily absorbed through the respiratory membranes and exert a systemic immune modulatory effect.

Improvement in the regulation of the HPA and SAM axis were reported in the neuro-endocrine group, with some evidence suggesting this may also be associated with inhaled aromatic compounds exerting a positive effect on dopamine and cortisol levels, as well as immune biomarkers (NK and T-Cell activity). Some studies reported significantly improved blood glucose levels after forest bathing; however, these results were not replicated in the study by Li et al. (2016). Early studies have also reported a potential benefit of forest bathing for pain management in patients with chronic neck pain. The results determined significant improvement in self-reported pain levels; however, further studies replicating these results are needed before any conclusions can be drawn.

In all studies that investigated the benefits of forest bathing on psycho-emotional states, the results reported significant improvement in positive affect emotional state, including improved vigor and restorativeness, and decreased depression, anxiety, and hostility. Some studies showed a correlation between the improved psycho-emotional state and improved regulation of the autonomic nervous system, suggesting a psycho-physiological benefit derived from the forest environment. One study (Guan et al. 2017) concluded that these effects are tree-species-specific, which may indicate that the effect is again related to airborne phytoncides.

Despite perceived limitations to many of the studies reviewed, such as low participant numbers and little variation in the type of forest environment visited, the current evidence for the health benefits derived from forest bathing can be viewed positively. Many of the studies were controlled, with comparison between forest and urban environments, and most studies measured effects using multiple physiological and psychological analyses, showing a strong correlation between exposure to the forest environment and significant improvements in health and wellbeing.

Conclusion

The authors acknowledge that there are some limitations to this review. Firstly, confining the search to only include those papers specifically referring to forest bathing means other studies referring to the broader practices of nature therapy have not been represented. This may have influenced the finding that the majority of studies reviewed were conducted within Japan, with a complete absence of studies undertaken outside of the Asian regions. Furthermore, the finding that many of the studies reviewed involved relatively small participant cohorts suggests that a larger systematic review, including meta-analysis, may have been a more informative methodological approach.

A number of limitations of the reviewed studies is also seen. It was common to find that the same authors were included across multiple papers, and in some cases studies were conducted using the same methods, making it difficult to clearly differentiate whether more than one paper was referring to the same experimental intervention. All of the studies reviewed were conducted in the Asian region, mostly in Japan, within forest environments that had little biodiversity from each other, which might suggest that the benefits derived are to some degree regionally specific. However, this could also be argued to be a limitation of the current review more than the reviewed studies themselves.

That said, the results presented were consistently statistically significant, suggesting that exposure to the forest environment is likely to have significant benefits for humans in relation to cardiovascular, immune, and neuro-endocrine health, as well as mental and emotional wellbeing. It is recommended that further research be directed towards determining causation, given that all of the studies reviewed have positively determined correlation. Furthermore, research in natural environments from other regions of the world, such as the Australian native bushland, is encouraged.

Conflict of Interest

This study was approved by the Research Management Committee of Endeavour College of Natural Health, Australia. The authors declare there is no conflict of interest.

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