

Effects of Forest Bathing (Shinrin-yoku) on Immune Function and Stress Reduction: a Systematic Review and Meta-analysis

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Background: Forest bathing (jap. *Shinrin-yoku*) is an increasingly recognized nature-based intervention with potential benefits for psychological well-being and physical health. Previous studies suggest that exposure to forest environments may reduce stress by modulating the hypothalamic–pituitary–adrenal axis and autonomic nervous system while enhancing immune function through increased natural killer (NK) cell activity and changes in inflammatory biomarkers. However, findings remain heterogeneous and have not been comprehensively synthesized. **Objective:** To systematically evaluate and quantitatively synthesize the evidence on the effects of forest bathing on immune function and psychological and physiological stress outcomes in adults. **Methods:** A systematic review and meta-analysis will be conducted in accordance with the PRISMA 2020 guidelines. PubMed, Embase, Scopus, Web of Science, Cochrane CENTRAL, and PsycINFO will be searched from database inception. Randomized controlled trials, crossover trials, and controlled quasi-experimental studies investigating forest bathing or forest therapy interventions in adults will be included. Primary outcomes will comprise immune biomarkers (e.g., NK cell activity, cytokines, C-reactive protein) and stress-related measures (e.g., cortisol, Perceived Stress Scale, State–Trait Anxiety Inventory, Profile of Mood States, heart rate variability, blood pressure, and heart rate). Risk of bias will be assessed using the Cochrane RoB 2 and ROBINS-I tools. Random-effects meta-analyses will be performed using standardized mean differences with 95% confidence intervals. Heterogeneity, publication bias, sensitivity analyses, and subgroup analyses will be conducted where appropriate. **Outcomes:** This review will provide a comprehensive synthesis of current evidence on the effects of forest bathing on immune and stress-related outcomes. The findings are expected to clarify the magnitude and consistency of reported effects and identify factors influencing intervention effectiveness.

Keywords: forest bathing; Shinrin-yoku; forest therapy; immune function; stress; systematic review; meta-analysis.