REVIEW ARTICLE

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Effect of forest bathing ('shinrin-yoku') on human health – a literature review

Wpływ kąpieli leśnej (shinrin-yoku) na ludzkie zdrowie – przegląd literatury

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Abstract

Introduction and Objective. In contemporary times, stress is an inherent part of human life which can contribute to the development of many lifestyle diseases. Therefore, methods of coping with stress and strategies for preventing stress-related diseases have been long the focus of interest in the medical community. In recent times, there has been a surge in interest regarding the practice of 'shinrin yoku', also known as forest bathing. This practice entails walking or immersing oneself in a forested environment, actively engaging all sensory modalities in the perception of the surroundings. The purpose of this study is to investigate the effects of forest bathing on human health.

Brief description of the state of knowledge. Forest bathing has been proven to have a positive impact on both mental and physical health. A decrease in cortisol levels in saliva and an increase in serotonin levels in the blood have been observed. Studies using a POMS questionnaire showed a reduction in levels of fatigue, tension, anger, and anxiety, along with increased vigour. Improvement in sleep quality was also noted. Forest bathing lowered blood pressure and heart rate while increasing Heart Rate Variability (HRV). The activity of NK cells in the immune system also increased.

Summary. Based on a review of studies, forest bathing has a positive impact on human health. This practice can be utilized to reduce stress levels, enhance overall well-being and support the functioning of the immune system. Taking into consideration an individual approach to the patient, forest bathing can be one of the methods of preventive medicine, especially in the context of cardiovascular diseases and mental disorders, and can also support pharmacological therapy for conditions such as hypertension, depression, and sleep disorders. However, further research into this topic is needed.

Key words

health, forest bathing, shinrin-yoku, cortisol, immunity, forest therapy

Streszczenie

Wprowadzenie i cel pracy. Nieodłącznym elementem życia współczesnego człowieka jest stres, który może przyczynić się do rozwoju wielu chorób cywilizacyjnych. Metody radzenia sobie ze stresem oraz strategie zapobiegania chorobom z nim związanym od dawna zatem stanowią przedmiot zainteresowania społeczności medycznej. W ostatnim czasie szczególnie wzrosło zainteresowanie praktyką shinrin-yoku, znanej również jako kąpiel leśna, która polega na spacerowaniu i„zanurzaniu się" w środowisku leśnym, przy aktywnym zaangażowaniu wszystkich zmysłów w percepcję otoczenia. Celem pracy była ocena wpływu kąpieli leśnej na ludzkie zdrowie.

Opis stanu wiedzy. Kąpiel leśna miała pozytywny wpływ zarówno na zdrowie psychiczne, jak i fizyczne człowieka. U osób ją praktykujących odnotowano obniżenie poziomu kortyzolu w ślinie oraz zwiększenie poziomu serotoniny we krwi. Badania przy użyciu kwestionariusza POMS wykazały również redukcję poziomu zmęczenia, napięcia, złości i lęku oraz zwiększenie wigoru. Zaobserwowano również poprawę jakości snu. Kąpiel leśna obniżała ciśnienie krwi oraz tętno, a także zwiększała zmienność częstości rytmu serca (HRV). Rosła także aktywność komórek NK układu odpornościowego.

Podsumowanie. Analiza badań sugeruje korzystny wpływ kąpieli leśnej na zdrowie człowieka. Praktyka ta może być wykorzystywana do redukcji poziomu stresu, poprawy ogólnego samopoczucia oraz wsparcia funkcjonowania układu odpornościowego. Ze względu na indywidualne podejście do pacjenta shinrin-yoku może być jedną z metod medycyny prewencyjnej, szczególnie w kontekście chorób sercowo-naczyniowych oraz zaburzeń psychicznych, a także może wspomagać terapię farmakologiczną takich chorób jak nadciśnienie tętnicze, depresja i zaburzenia snu. Konieczne jest jednak przeprowadzenie dalszych badań nad tym zagadnieniem.

Słowa kluczowe

zdrowie, kąpiel leśna, shinrin-yoku, kortyzol, odporność, terapia lasem

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INTRODUCTION

In contemporary times, stress has become a common phenomenon, influencing the mental and physical health of individuals. The term 'stress" describes environmental stimuli that threaten an organism's homeostasis. Research indicates that stress in daily life adversely affects multiple systems in the human body and may contribute to the development of lifestyle diseases. It impairs immune response, attenuates overall immunity, increases intestinal permeability, and promotes the development and worsening of diseases such as obesity [1], depression [2], cancer [3] and inflammatory bowel disease [4]. Chronic exposure to stress can cause hyperstimulation of sympathetic nerves and the HPA-Axis affecting the endocrine and nervous systems [5]. Moreover, stress causes a consistent elevation of blood pressure, thereby contributing to the development of hypertension [6]. Stress has also been implicated in increasing the risk of accelerating atherosclerosis and clinical cardiovascular events by precipitating myocardial infarction (MI) or causing myocardial injury and damage [7, 8].

Considering the influence of stress on human health, strategies for managing and alleviating stress continue to be of great importance.

One of the methods for coping with stress is forest bathing, also known as shinrin-yoku. Originating in Japan, in 1982 a national health programme for this practice was proposed by the Forest Agency of Japan for reducing stress in workers. Forest bathing is a practice encompassing the act of walking or spending time in a forested environment with an emphasis on silent observation of multi-sensory stimuli, derived from the natural surroundings [9]. The word 'shinrin' translates as 'forest', and 'yoku' as 'bath'. Consequently, the term 'shinrin-yoku' conveys the concept of immersing oneself in the forest environment. In 2004, the Japanese Society of Forest Therapy was founded to conduct evidence-based research regarding the impact of forest environments on human health [10]. Subsequently, further studies were conducted in Korea, China, and Europe. During the last decade, the practice has spread around the world, and this term is now used internationally.

Recent studies suggest that forest bathing may contribute to health promotion and disease prevention [11, 12].

Forest bathing has given rise to a new medical science known as Forest Medicine. It focuses on studying the impacts of forest environments on the overall well-being and functioning of the human body, encompassing physical, mental, and social aspects. This evidence-based discipline belongs to the categories of alternative medicine, environmental medicine, and preventive medicine. Forest bathing includes various healing elements, such as sunlight, landscape, temperature, phytoncides, food, sound and humidity.

The aim of this study was to investigate the benefits of forest bathing on the human body, mental-stress and overall well-being.

METHOD AND MATERIALS

The PubMed database was analyzed. Articles were searched in English using the following key words: 'forest bathing', 'shinrin-yoku', 'health'. Scientific articles published in the last seven years (2017–2023) were included in the search.

RESULTS

Salivary Cortisol concentration. Cortisol is a stress hormone produced by the adrenal glands. The study conducted by Kobayashi et al. investigated the effects of walking in a forest environment on salivary cortisol concentrations. The study included 74 Japanese male students. Each participant walked for 15 minutes in his determined forested or urban environment. Saliva samples were collected before and immediately after the walk. The studies demonstrated the beneficial impact of walking on cortisol levels both in urban and forest environments; however, walking in a forest environment had significantly more favourable effects (Fig. 1) [13]. The meta-analysis performed by Qiu et al. revealed the impact of forest therapy, involving activities such as walking and observation, on the salivary cortisol levels of the participants. It demonstrates a significant reduction in salivary cortisol concentration (SCC) compared with urban control group. However, the category of nature-based activity did not influence the cortisol response. Additionally, it was observed that interventions lasting 20 minutes or more elicited more significant changes in salivary cortisol levels, compared to those lasting less than 20 minutes. [14].

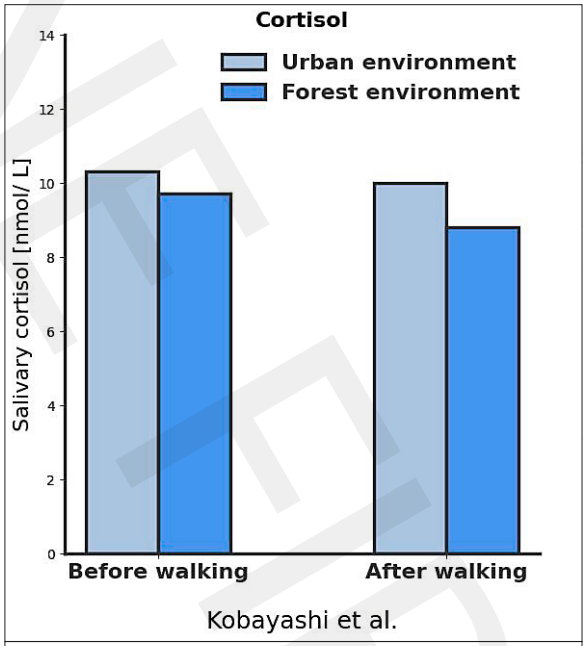

Figure 1. Figure was created based on data presented by Kobayashi et al. 'Combined effect of environment and walking on salivary cortisol concentrations.' Mean cortisol concentration after walking was significantly lower in forest environments than in urban environments ($p < 0.001$), walking in a forest environment significantly decreased salivary cortisol ($p < 0.001$), walking in an urban environment did not significantly change salivary cortisol ($p = 0.658$) [13]

Serotonin in serum levels. Serotonin, also known as 5-hydroxytryptamine (5-HT), is a neurotransmitter synthesized in both the central nervous system and mucosa of the gastrointestinal tract. In the brain, serotonin regulates mood and emotional well-being, and imbalances in its levels are linked to such conditions as depression and anxiety. Research suggests that serotonin levels below 100 µg/L may be associated with depressive syndromes, while in some studies elevated levels are correlated with a lower risk of suicide [15].

The current study involved 20 male subjects who did not suffer from any major depressive disorder, and demonstrated a significant elevation in serum serotonin levels following forest bathing, in contrast to urban walking, where serotonin levels also increased but without statistical significance [16].

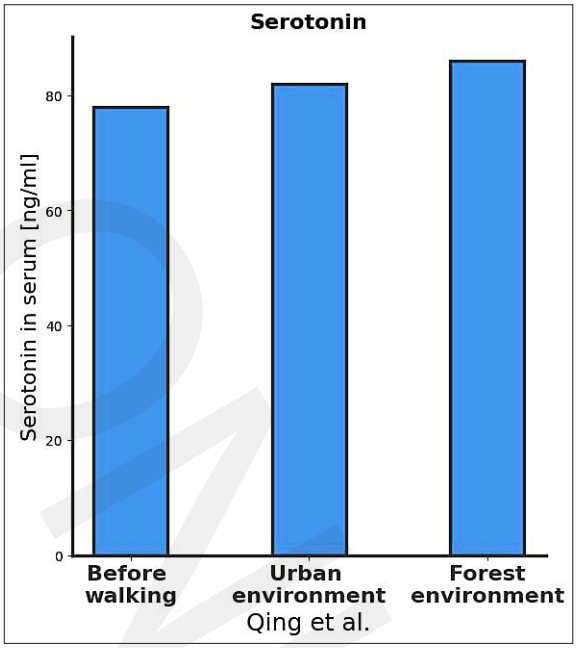

Figure 2. Figure was created based on data presented by Qing et al. 'Before walking' means before the walking in the urban area or before the forest bathing. 'Urban environment' means after walking in the urban area. 'Forest environment' means after walking in the forest (forest bathing) (p = 0.002) forest environment vs before walking(p = 0.048) forest environment vs urban environment (p = 0.185) urban environment vs before walking by paired t-test (n = 20) [16]

Psychological benefits. In various studies examining psychological aspects, researchers utilized the Profile of Mood States (POMS) questionnaire for the subjective assessment of participants. This questionnaire consists of 30 adjectives rated on a 0–4 scale, categorized into 6 primary dimensions: T-A – tension and anxiety, D – depression and dejection, A-H – anger and hostility, F – fatigue, C – confusion, and V – vigour. The presented findings suggest a significant decrease in fatigue levels and a simultaneous enhancement of vigour following forest bathing in young men [16]. Moreover, a significant reduction was observed in the subscales related to tension, depression, anger, and fatigue [11].

Song et al. conducted experiments in 52 forest and city areas of Japan. Each experiment included 12 male Japanese students. It was observed that walking in forested areas led to a reduction in negative moods associated with 'depression-dejection', 'tension-anxiety', 'anger-hostility', 'fatigue', and 'confusion', while simultaneously enhancing the participants' positive mood of 'vigour' compared to walking in urban environments. Additionally, participants gauged their anxiety levels using the psychometric tool State-Trait Anxiety Inventory (STAI), which assesses current anxiety levels and measures an individual's enduring tendency to experience anxiety. The results indicated a significant impact of forest bathing on reducing anxiety levels among the participants [17].

Another factor influenced by forest bathing is sleep. The cited study demonstrates a significantly positive impact of this practise on the subjective quality of sleep [16]. Using the Oguri-Shirakawa-Azumi sleep inventory MA version (OSA-MA) test, the effects of forest bathing and city walking on participants were assessed in terms of test components, such as sleepiness on rising, initiation and maintenance of sleep, frequent dreaming, feeling refreshed, and sleep length. Among the given factors, forest bathing had a significant impact on sleepiness on rising (which was decreased) and feeling refreshed (which was increased), with no effect on the other test components [16]. Kim H. et al. showed that forest bathing can be a non-pharmacological method for treating insomnia in post-menopausal women, as it increased sleep efficiency and reduced the frequency of interrupted sleep [18]. Similar results were observed in patients diagnosed with cancer [19].

Physiological Benefits. Many studies have found that forest bathing affects cardiovascular functions (CVFs). Yau and Loke revealed a significant impact of shinrin-yoku on reducing systolic blood pressure in all examined groups, including the walking group, non-walking group, group of young men, group of middle-aged men, group of older men, group of middle-aged women and group of older women, compared to the same groups exposed to a non-forest environment [20]. Heart rate variability (HRV), which is a marker of the autonomic nervous system activity, referring to the variation over time between successive heartbeats (RR intervals) in an ECG recording was also investigated. A higher HRV score indicates activation of the parasympathetic system and is observable in stress-free situations when the individual being examined is relaxed. The study demonstrates a significant impact of forest bathing on the increase of HRV in pre-hypertensive or hypertensive middle-aged adults [20].

Further studies have confirmed the impact on blood pressure by subjecting participants to forest therapy sessions, such as walking and observing. The results demonstrate a significant reduction in both systolic and diastolic blood pressure among the participants. Furthermore, a greater influence on lowering blood pressure was observed when forest therapy sessions exceeded 20 minutes, and when the participants were older or had initially higher blood pressure levels [14].

Tsao et al. included in their study brachial systolic blood pressure (SBP) and central systolic blood pressure (cSBP), both of which showed a significant decrease in the group subjected to forest bathing (either through observation or walking in woodland conditions). Additionally, there was a reduction in blood pressure (BP) in general, heart rate (HR), sympathetic nerve activity, and pulse pressure (PP), the latter being associated with higher mortality from cardiovascular diseases and serving as a risk factor for heart attack, even in individuals with normal blood pressure. Further indicators of cardiovascular function, such as the maximum rate of change of left ventricular pressure during systole (dP/dt max), a measure reflecting the heart's ability to contract and generate pressure, as well as left ventricular contractility, cardiac output (CO), and stroke volume (SV), all showed a significant decrease [21].

Immune system mobilization. The study results demonstrate a positive impact of residing in a forest environment on the human immune system. One of the defence mechanisms of cellular immunity is natural killer (NK) cells, which have a unique ability to kill virus-infected cells and cancer cells by releasing anti-cancer proteins, such as perforin, GRN, and

GrA/B. There is a significant increase in the activation of NK cells and in the immune response of NK cells in individuals exposed to the forest environment, especially in obese men with hyperglycaemia [22]. This effect may be caused by biogenic volatile organic compounds (VOCs), which are released by trees and then inhaled by humans. Certain volatile terpene compunds, such as β-pinene, a-pinene, D-limonene, α-terpineol and camphor, have been found to be effective in the treatment of respiratory inflammation diseases [23]. Forest bathing is also considered a beneficial practice against COVID-19 [24, 25, 26]. During the COVID-19 pandemic, a study conducted in Italy revealed that regions with higher rates of forest area *per capita* experienced lower mortality rates from COVID-19. The study suggests that forests play a role in the prevention and/or treatment of COVID-19 by emitting immune-modulating VOCs [27].

A detailed descriptions of the studies on the subject of forest bathing and their methodology are presented in Table 1.

SUMMARY

Analysis of the study indicates positive health benefits associated with forest bathing. It was observed that walking in a forest environment, as opposed to urban walking, significantly reduces salivary cortisol concentration. The study results also showed an elevation in serum serotonin levels following forest bathing. Research has further demonstrated that forest bathing improves mental health by lowering fatigue levels and simultaneously enhancing vigour. Additionally, a reduction in tension, depression, anger, and anxiety was observed. Shinrin-yoku has a significant impact on the quality of sleep, decreasing sleepiness upon rising and increasing the feeling of being refreshed. However, no effect was observed on the initiation and maintenance of sleep, frequent dreaming, and length of sleep. Forest bathing also influences the reduction of cardiovascular system functioning indicators such as SBP, cSBP, general

Table 1. Forest bathing effects based on different studies and their methodology

Author, year	Participants characteristics	Forest bathing intervention	Control/ comprarator	Outcome measurement	Results
Kobayashi et al., 2019 [13]	n=74 100% males, aged 20–29 years	Forest walking (15 min)	Urban walking (15 min)	SCC	There was a significant decrease in cortisol concentration after walking in forest environments than in urban environments ($p < 0.001$). Walking in a forest environment significantly decreased salivary cortisol ($p < 0.001$), whereas walking in an urban environment did not significantly change salivary cortisol ($p = 0.658$).
Li et al., 2022 [16]	n=20, 100% males, aged 41-69 years.	2.5 km for 120 min in the morning and afternoon, total 5.0 km per day in forest environment.	2.5 km for 120 min in the morning and afternoon, total 5.0 km per day in urban environment.	POMS, serotonin concentration in serum, lactic acid concentration in serum, OSA-MA.	No significant difference was noted in lactic acid concentrations between the forest bathing and walking in urban areas ($p = 0.08$). There was a significant increase in serotonin concentration in serum after forest bathing ($p = 0.002$), but this was not observed after walking in urban areas ($p = 0.185$). The score for vigour was significantly increased after the forest bathing ($p = 0.003$) and the score for fatigue was decreased ($p = 0.019$) in the POMS test. Sleepiness on rising ($p = 0.036$) and feeling refreshed (recovery from fatigue, $p = 0.002$) assessed by the OSA-MA were significantly improved after forest bathing, while urban walking did not improve the subjective sleep quality.
Song et al., 2018 [17]	n= 585 100% males, mean age 21.7 years.	Forest walking (15 min).	Urban walking (15 min).	POMS, STAI.	The score of the D subscale of POMS was significantly lower after forest walking than after urban walking ($p < 0.01$). There were also decreases in subscales: T-A ($p < 0.01$), A-H ($p < 0.01$), F ($p < 0.01$), and C (< 0.01), and in negative mood state after walking through forest areas. The score for vigour after walking through forest areas was significantly higher than after urban walking ($p < 0.01$). Participants with high anxiety trait levels showed a more pronounced reduction in the feeling of 'depression-dejection' after walking through forest areas, compared to those with normal and low anxiety trait levels.
Kim et al., 2020 [18]	n=35, 100% post-menopausal insomnia women, mean age 58.8 years.	6 days at the National Centre for Forest Activities in Hoengseong; various activities such as meditation, gymnastics, 30 min morning forest walks, 1-2 h afternoon trail walks, barefoot trekking, lying down in the forest, foot massage with cold groundwater.	NA	ESS, SSS, the Korean version of PSQI, insomnia severity index for measuring the severity of insomnia symptoms, the STOP-BANG, HADS, PSG, CBCs, glucose, AST, ALT, blood urine nitrogen, creatinine, sodium, potassium, chloride, CRP, interleukin 6, cortisol.	There was a significant reduction in cortisol levels. Levels of CRP and interleukin 6 did not exhibit significant changes. In the PSG results, sleep efficiency increased ($p< 0.01$), waking after sleep onset reduced ($p<0.01$), and total sleep time increased but was not statistically significant. The ESS, ISI and anxiety and depression index improved, but without statistical significance.

Author, year	Participants characteristics	Forest bathing intervention	Control/ comprarator	Outcome measurement	Results
Kim et al., 2019 [19]	n= 9, volunteers with gastrointestinal tract cancers, 11.1% males; mean age 53.6 years.	6 days of forest therapy in the Jang-Seong forest healing centre.	NA	PSG, Korean version of the PSQI, SSS, ESS, ISI, STOP-BANG, HADS.	In the PSG results after forest therapy, sleep efficiency increased (p = 0.027), on waking after sleep onset decreased (p=0,026), total sleep time also increased but without significant difference. There was no significant difference in the STOP-BANG score, PSQI scores, the results of the SSS and ESS, and depression and anxiety scores.
Tsao et al., 2022 [21]	n= 25 I = 14, 71.43% males, mean age 54.21 years C= 11, 72.73% males, mean age 42.36 years.	6-day/5-night forest walking exercise program in Xitou forest	Walking in urban parks (2 days).	Cardiovascular functions, such as: SBP, cSBP, PP, HR, LV dP/dt max, LV contractility, cardiac output, CI, SV, and SV index, SVC, BAR	Forest walking exercise resulted in significant decrease in SBP, cSBP, PP, HR, LV dP/dt max, LV contractility, CO, CI, SV, SV index and BAR. It also resulted in significant increase of SVC. Urban walking exercise did not result in a statistically significant difference in the measured indicators.
Tsao et al., 2018 [22]	n=90 forest staff members, 66.67% males, mean age 45.2 years n=110 urban staff members, 53.64% males, mean age 44.8 n=11 urban staff members who attended a forest trip, 27.3% males, mean age 60.4 years.	Forest trip (5-days/4-nights).	Urban staff members.	The percentage of NK cells, percentage of activating NK cells. Comparisons of NK cell and activating NK cell percentage among staff members residing in urban and forest environments.	There was a significantly higher percentage of NK cells in the forest staff members group, compared to the urban staff members group. The percentages of activating NK cells were not significantly higher in the forest staff members group. However, the percentage of activating NK cells significantly increased in the group of urban staff members who attended a forest trip (p=0.002), although there was no significant increase in the percentage of NK cells in this group after the forest trip.

SCC - salivary cortisol concentration; POMS - profile of mood states; OSA - MA Oguri-Shirakawa-Azumi sleep inventory MA version; STAI - State-Trait Anxiety Inventory; ESS -Epworth sleepiness scale; SSS - Stanford sleepiness scale; PSQI - Pittsburgh Sleep Questionnaire Index; HADS - Hospital Anxiety and Depression Scale; I - intervention; C -control; PSG - polysomnography; CBCs - common blood cells; AST - aspartate transaminase; ALT - alanine transaminase; CRP C - reactive protein; SBP - systolic blood pressure, cSBP -central end-cSBP; PP - pulse pressure; HR - heart rate; LV - dP/dt max maximum rate of left ventricular pressure rise; CI - cardiac index; SV - stroke volume; SVC - Systemic vascular compliance; BAR - Brachial artery resistance; NK - cells natural killer cells

BP, heart rate, sympathetic nerve activity, pulse pressure, as well as dP/dt max, CO, and SV. An increase was noted in the activation of NK cells and in the immune response of NK cells in individuals exposed to the forest environment.

It should also be emphasized that while the practice of forest bathing can bring many health benefits, there are also potential risks and challenges associated with it. In forested areas, there may be poisonous plants, wild animals, as well as insects, reptiles, and spiders that may be venomous or carry diseases. Additionally, uneven terrain, steep slopes associated with the risk of falling, and weather conditions, such as extreme temperatures, rainfall, storms, or strong winds pose a threat. Increasingly, environmental pollution by litter left by humans or chemical contamination is observed in forest environments. Individuals practicing forest bathing, especially caregivers of older adults and children, should be aware of potential hazards and take precautions, such as wearing suitable attire and footwear, maintaining a safe distance from wildlife, and choosing routes and areas that align with their physical capabilities. Therefore, forest therapy, like other forms of therapy, requires an individual approach by the patient.

In conclusion, forest bathing has proven to exert favourable effects on overall human well-being. However, further research exploring this topic is needed.

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