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Proceeding Paper

Forest Exposure and Respiratory Function: A Literature Review †

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Abstract: Environmental health research has recently started to study the health effects of well-being-promoting practices based on forest exposure. This narrative review aims to understand whether forest exposure can directly improve respiratory function. PubMed, Cochrane Library and Google Scholar were screened, up until April 2021, for clinical studies about changes of respiratory function induced by forest exposure, preferably measured with spirometry. Relevant evidence was summarized and critically discussed. Five studies were included in this review (three trials, an observational study and a case report). Globally, forest exposure seems to be associated with improved forced expiratory volume (FEV), peak expiratory flow (PEF) and forced vital capacity (FVC). In most included studies, exposure time was at least 1 h, and sessions were repeated over time. Study participants were either healthy subjects or patients with respiratory diseases. The benefits were reported, even in terms of inflammatory markers, and were detected in children, adults and elderly individuals of both genders. The number of participants per study ranged from 1 to 65. Forest exposure coupled with light physical activity may result in short-term improvements of some respiratory function parameters (FEV1, FEV6, PEF, FVC). Autonomic responses to environmental stimuli and the inhalation of some volatile compounds detectable in the forest air seem to directly contribute to the overall effect, which may be enhanced around waterfalls and creeks due to water nebulization. However, current scientific evidence is limited, and high atmospheric levels of some plant-derived compounds, especially when reacting with air pollutants, may even worsen certain respiratory conditions. Further studies on the topic are recommended to better quantify the effect size of forest-based interventions, assess long-term benefits, ascertain potential health risks and identify any moderator variables or confounding factors.

Keywords: forest exposure; Shinrin-yoku; respiratory function; spirometry; environmental health; review

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1. Introduction

Environmental health research has recently started to study the health effects of well-being-promoting practices based on forest exposure in greater depth [1–3]. Among other benefits, the potential benefits for respiratory function have gained attention both within and outside the scientific community. With air pollution becoming a crucial health and environmental issue, the burden of chronic respiratory problems has risen worldwide [4–6]. As such, public health strategies, applicable to large populations in a sustainable way, have been investigated.

This study's aim was to evaluate if forest exposure can directly improve respiratory function.

2. Methods

A narrative review of the scientific literature was carried out to identify the most relevant studies measuring the effects of forest exposure on respiratory function. No limitations were posed in terms of publication date or article language. The following PICOS criteria were applied for the inclusion and exclusion of screened articles:

P (population): healthy subjects or patients with chronic respiratory diseases.
I (intervention): forest exposure.
C (comparator): any type, including no control.
O (outcomes): changes in spirometric indices or, in case of patients with respiratory diseases, even variations in inflammatory markers.
S (study design): both observational and interventional studies; laboratory experiments were excluded.

PubMed, Cochrane Library and Google Scholar were searched from inception up until 29 April 2021 with the following keywords: "forest", "Shinrin-yoku", "nature therapy", "pulmonary", "respiratory", "spirometry", "inflammation" and "obstructive".

Relevant data (characteristics of study participants, intervention, comparator, analyzed outcomes and results) were extracted manually from included trials. Then, scientific evidence was summarized and briefly discussed.

3. Results

After a database search, five studies matched our PICOS criteria [7–11], and their results are reported in Table 1. In particular, three randomized controlled trials (RCTs) [7,9,11], an observational study with a pre−post design [10] and a case report [8] were selected for inclusion. The number of study participants ranged from 1 to 65, and trial populations were quite heterogeneous in terms of individual characteristics, ranging from healthy adults and children to elderly subjects with chronic respiratory disorders (chronic obstructive pulmonary disease or bronchial asthma).

Table 1. Summary of evidence from included studies.

Population	Intervention (*N*) and Forest Site Altitude	Forest Type	Comparative (*N*)	Outcomes *	Pre−Post Test Results	Study Design	Reference
60 elderly women	A single session of forest walking (40)—1 h. Alt.: 150 mt a.s.l.	A Japanese cypress forest located in Janghung (Republic of Korea)	Walking in an urban area (20)	↑ FEV1 ↑ FEV6	FEV1 (L): from 1.54 ± 0.49 to 1.73 ± 0.42 (forest) * from 1.71 ± 0.39 to 1.72 ± 0.41 (city) (ns) FEV6 (L): from 2.03 ± 0.59 to 2.26 ± 0.51 (forest) * from 2.16 ± 0.51 to 2.19 ± 0.55 (city) (ns)	RCT	[7]
65 stressed adults	A 7-day forest trip—1 h/day spent in a forest with WF (33). Alt.: 1000 mt a.s.l.	An alpine forest with waterfalls located in Carinthia (Austria)	Forest exposure (32) or no intervention (26)	↑ PEF (only significant for the forest + WF combination)	PEF (L/s): from 8.7 ± 2.0 to 9.0 ± 1.9 (forest + WF) * from 8.5 ± 1.5 to 8.9 ± 1.7 (forest without WF) (ns) from 8.6 ± 2.1 to 8.6 ± 1.8 (control) (ns)	RCT	[9]

Table 1. *Cont.*

Population	Intervention (N) and Forest Site Altitude	Forest Type	Comparative (N)	Outcomes *	Pre−Post Test Results	Study Design	Reference
20 elderly patients with COPD	Forest bathing (10). Alt.: >1000 mt a.s.l.	A broad-leaved evergreen forest in the Zhejiang Province (China)	Walking in an urban area (10)	↓ inflammatory and stress markers (no spirometry)	Data only displayed graphically (IL-6 *, IL-8 *, IFN-γ *, IL-1β *, TNF-α and C-reactive protein *)	RCT	[11]
21 children with asthma	A 4-day forest trip—2 h/day (21). Alt.: 333 mt a.s.l.	A fir tree forest located in the northeast part of the Korean peninsula (Republic of Korea)	None (0)	↑ FVC = FEV1 ↓ FeNO	FVC (% predicted): from 92.0 ± 11.3 to 95.8 ± 13.3 * FEV1 (% predicted): from 91.2 ± 9.9 to 92.9 ± 11.0 (ns) FeNO (ppb): from 23.7 (14.2–39.5) to 16.4 (9.1–29.4) *	Pre−post study design	[10]
A 57-year-old male with asthma and occupational exposures to air pollutants	A 5-month program with regular light exercises in forest areas (1). Alt.: ?	Different deciduous or coniferous forests in British Columbia (Canada)	None (0)	↑ FVC ↑ sleep quality ↓ symptoms	FVC (L): Baseline: 4.64 After the program: 5.46 *	Case report	[8]

* Significant changes in favor of intervention ($p < 0.05$); a.s.l.: above sea level; COPD: chronic obstructive pulmonary disease; FeNO: fractional exhaled nitric oxide; FEV1: forced expiratory volume in the first second; FEV6: forced expiratory volume in the sixth second; FVC: forced vital capacity; ns: not statistically significant; PEF: peak expiratory flow; RCT: randomized controlled trial; WF: waterfalls; ↑: significant increase; ↓: significant decrease.

Study interventions always combined forest exposure with light physical activity, such as walking in the forest [7] or breathing exercises (forest bathing) [11]. In the majority of studies, exposure time was at least 1 h, and sessions were repeated over time. Forest characteristics differed across the included studies, but several forest sites had an elevation of 1000 mt or less above sea level. In one case, study participants reached a forest area with waterfalls [9]. Controlled groups were mostly sent to walk in an urban area (Table 1).

Globally, forest-based interventions seemed to be associated with improved forced expiratory volume (FEV), peak expiratory flow (PEF) and forced vital capacity (FVC). Benefits were also reported in terms of inflammatory markers and were detected in children, adults and elderly individuals of both genders. Outcome-related changes from baseline are summarized in a specific column to provide a rough estimate of the effect size of forest- and city-based interventions (Table 1).

4. Discussion

Forest exposure coupled with light physical activity may result in short-term improvements of some respiratory function parameters (FEV1, FEV6, PEF, FVC). Autonomic responses to environmental stimuli and the detectable inhalation of some volatile compounds with anti-inflammatory and antioxidant properties seem to directly contribute to the overall effect [12], which may be enhanced around waterfalls and creeks due to water nebulization [9]. Additionally, recent studies suggest that high altitude climate exposure may reduce acute exacerbations of asthma [13], and respiratory rehabilitation programs set in mountainous environments can be useful for the improvement of health-related quality of life and exercise capacity in patients with chronic bronchitis [14]. However, current scientific evidence is limited, and seasonal atmospheric levels of some plant-derived compounds, especially when reacting with air pollutants, may even worsen certain respiratory conditions [15].

In light of what is stated above, the purported benefits of forest exposure on respiratory function can be summarized in the following key points (Figure 1): inhalation of volatile organic and inorganic forest compounds (plant-derived substances, nebulized water, ions) (a); psychophysical relaxation and autonomic responses induced by forest exposure (b); light physical activity (walking in the forest and, in the case of forest bathing, even performing breathing exercises) (c). However, many factors can play a role in contributing to the health effects associated with forest activities, ranging from environmental features (climate, location, altitude, phytoncides, air quality, prevalent tree species, presence of waterfalls or running water) to individual characteristics (lifestyle habits, types of activity, diseases and medicinal drugs).

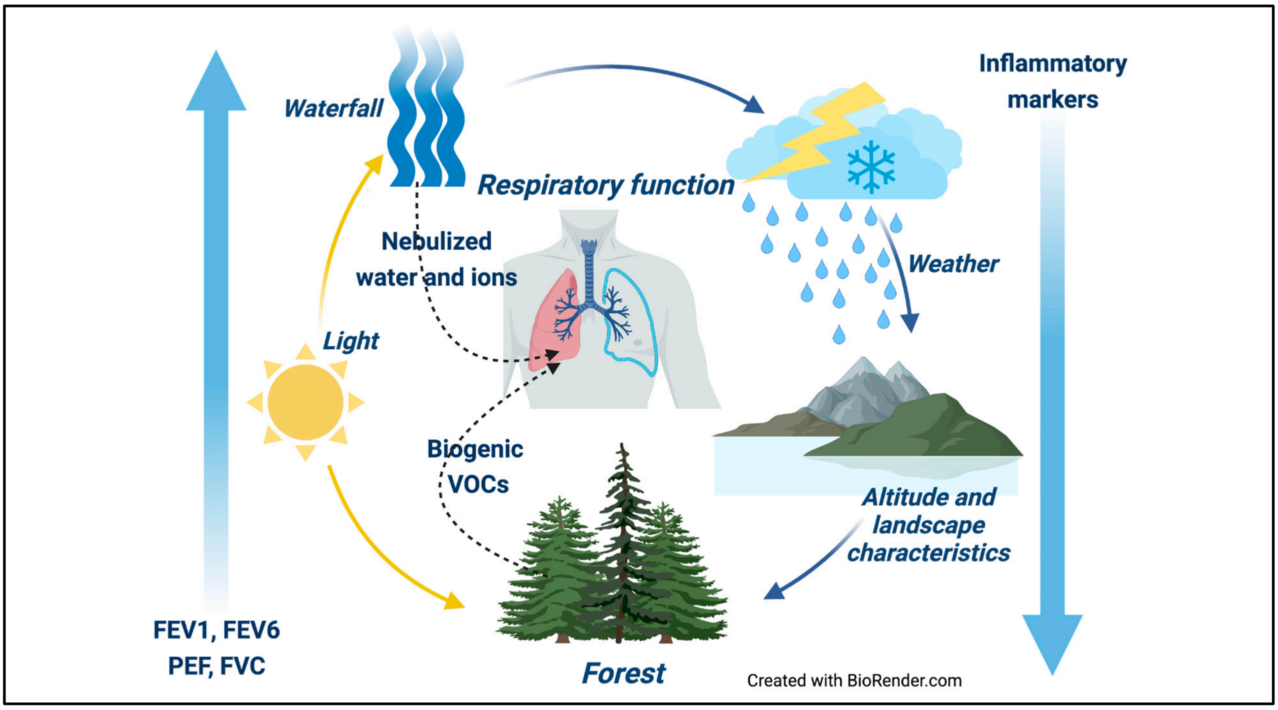

Figure 1. Forest exposure and respiratory function.

In conclusion, forest exposure coupled with light physical activity may result in short-term improvements of some respiratory function parameters. Further studies on the topic are recommended to better quantify the effect size of forest-based interventions, assess long-term benefits, ascertain potential health risks and identify any moderator variables or confounding factors. For example, it would be important to measure the exact beneficial contribution of forest exposure when compared with low-impact aerobic exercises performed in natural environments other than forests.

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