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# Forest Exposure and Respiratory Function: A Literature Review †

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**Abstract:** Environmental health research has recently started to study the effects on health 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 to April 2021 for clinical studies about changes of respiratory function induced by forest exposure and 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 hour and sessions were repeated over time. Study participants were either healthy subjects or patients with respiratory diseases. 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 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 some 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 in more depth the effects on health of well-being promoting practices based on forest exposure [1–3]. Among others, 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 aim is to evaluate if forest exposure can directly improve respiratory function.

## 2. Methods

It was decided to carry out a narrative review of the scientific literature 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 to April 29th, 2021 with the following keywords: "forest", "shinrin yoku", "nature therapy", "pulmonary", "respiratory", "spirometry", "inflammation", "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 database search, five studies matched our PICOS criteria [7–11] and their results were 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 to children or elderly subjects with chronic respiratory disorders (chronic obstructive pulmonary disease or bronchial asthma).

Study interventions always combined forest exposure with light physical activity, like walking in the forest [7] or breathing exercises (forest bathing) [11]. In the majority of studies, exposure time was at least 1 hour and sessions were repeated over time. Forest characteristics differed across included studies, but several forest sites had an elevation of 1000 mt or less above the 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 were summarized in a specific column to provide a rough estimate of the effect size of forest- and city-based interventions (Table 1).

**Table 1.** Summary of evidence from included studies.

| Population | Intervention (n) and forest site altitude | Comparator (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. | Walking in an urban area (20) | ↑ FEV1<br>↑ FEV6 | FEV1 (L):<br>from 1.54 ± 0.49 to 1.73 ± 0.42 (forest)*<br>from 1.71 ± 0.39 to 1.72 ± 0.41 (city) (ns)<br><br>FEV6 (L):<br>from 2.03 ± 0.59 to 2.26 ± 0.51 (forest)*<br>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. | Forest exposure (32) or no intervention (26) | ↑ PEF (only significant for the forest+WF combination) | PEF (L/sec):<br>from 8.7 ± 2.0 to 9.0 ± 1.9 (forest+WF)*<br>from 8.5 ± 1.5 to 8.9 ± 1.7 (forest without WF) (ns)<br>from 8.6 ± 2.1 to 8.6 ± 1.8 (control) (ns) | RCT | [9] |
| 20 elderly patients with COPD | Forest bathing (10). Alt.: >1000 mt a.s.l. | Walking in an urban area (10) | ↓ inflammatory and stress markers (no spirometry) | Data only displayed graphically (IL-6*, IL-8*, IFN-$\gamma$*, IL-1$\beta$*, TNF-$\alpha$, 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. | None (0) | ↑ FVC<br>= FEV1<br>↓ FeNO | FVC (% predicted):<br>from 92.0 ± 11.3 to 95.8 ± 13.3*<br><br>FEV1 (% predicted):<br>from 91.2 ± 9.9 to 92.9 ± 11.0 (ns)<br><br>FeNO (ppb):<br>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.: ? | None (0) | ↑ FVC<br>↑ sleep quality<br>↓ symptoms | FVC (L):<br>Baseline: 4.64<br>After the program: 5.46* | Case report | [8] |

* Significant changes in favor of intervention (**$p<0.05$**); A.s.l.: above the sea level; COPD: Chronic Obstructive Pulmonary Disease; FeNO: Fractional exhaled Nitric Oxide; FEV1: Forced Expiratory Volume in the 1st second; FEV6: Forced Expiratory Volume in the 6th second; FVC: Forced Vital Capacity; ns: not statistically significant; PEF: Peak Expiratory Flow; RCT: Randomized Controlled Trial; WF: Waterfalls.

## 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 inhalation of some volatile compounds with anti-inflammatory and antioxidant properties detectable in the forest air 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 mountain environments can be useful to improve 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 some respiratory conditions [15].

In view of what stated above, purported benefits for respiratory function of forest exposure can be summarized in the following key points (Figure 1): inhalation of forest volatile organic and inorganic 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 case of forest bathing, even doing breathing exercises) (c).

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.

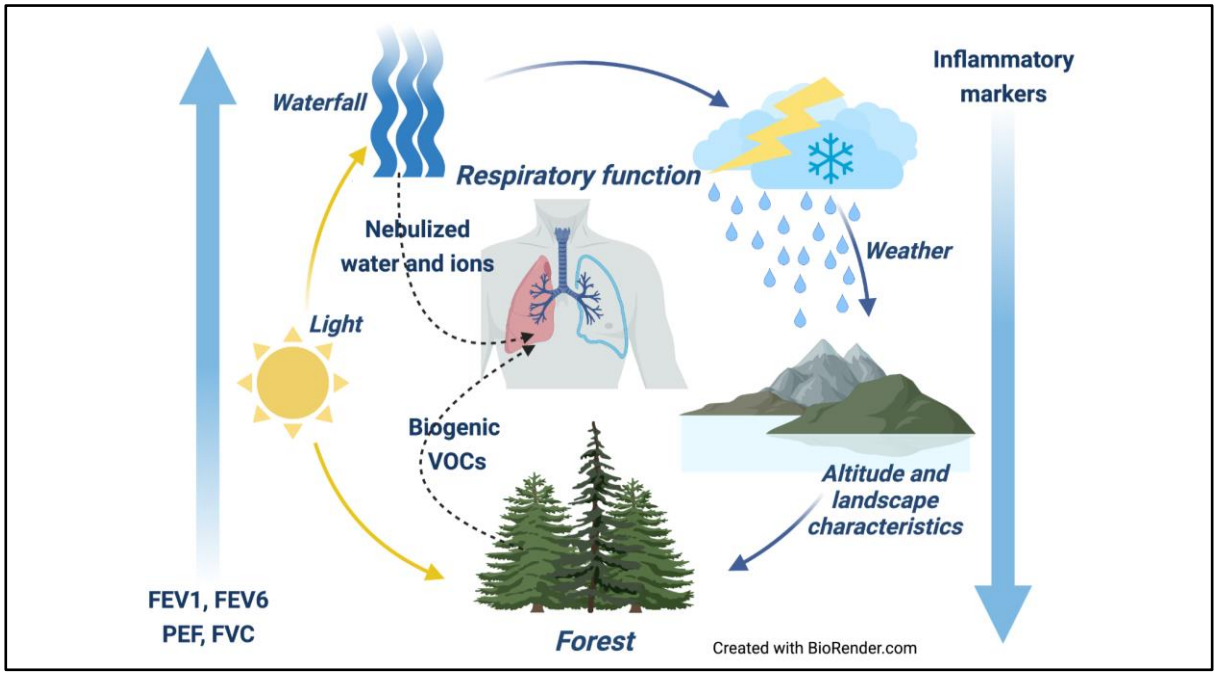


**Figure 1.** Forest exposure and respiratory function.

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## References


1. Antonelli, M.; Donelli, D.; Carlone, L.; Maggini, V.; Firenzuoli, F.; Bedeschi, E. Effects of Forest Bathing (shinrin-Yoku) on Individual Well-Being: An Umbrella Review. *Int. J. Environ. Health Res.* **2021**, 1–26, doi:10.1080/09603123.2021.1919293.
2. Hansen, M.M.; Jones, R.; Tocchini, K. Shinrin-Yoku (Forest Bathing) and Nature Therapy: A State-of-the-Art Review. *Int. J. Environ. Res. Public Health* **2017**, *14*, doi:10.3390/ijerph14080851.
3. Wen, Y.; Yan, Q.; Pan, Y.; Gu, X.; Liu, Y. Medical Empirical Research on Forest Bathing (Shinrin-Yoku): A Systematic Review. *Environ. Health Prev. Med.* **2019**, *24*, 70, doi:10.1186/s12199-019-0822-8.
4. D'Amato, G.; Baena-Cagnani, C.E.; Cecchi, L.; Annesi-Maesano, I.; Nunes, C.; Ansotegui, I.; D'Amato, M.; Liccardi, G.; Sofia, M.; Canonica, W.G. Climate Change, Air Pollution and Extreme Events Leading to Increasing Prevalence of Allergic Respiratory Diseases. *Multidiscip. Respir. Med.* **2013**, *8*, 12, doi:10.1186/2049-6958-8-12.
5. Ferkol, T.; Schraufnagel, D. The Global Burden of Respiratory Disease. *Ann. Am. Thorac. Soc.* **2014**, *11*, 404–406, doi:10.1513/AnnalsATS.201311-405PS.
6. Requia, W.J.; Adams, M.D.; Arain, A.; Papatheodorou, S.; Koutrakis, P.; Mahmoud, M. Global Association of Air Pollution and Cardiorespiratory Diseases: A Systematic Review, Meta-Analysis, and Investigation of Modifier Variables. *Am. J. Public Health* **2018**, *108*, S123–S130, doi:10.2105/AJPH.2017.303839.
7. Lee, J.-Y.; Lee, D.-C. Cardiac and Pulmonary Benefits of Forest Walking versus City Walking in Elderly Women: A Randomised, Controlled, Open-Label Trial. *European Journal of Integrative Medicine* 2014, *6*, 5–11.
8. Edwards, A.; Woods, V. Forest-Based Therapy: Research Letter of a Novel Regime for Improved Respiratory Health. *Integr. Med.* **2018**, *17*, 58–60.
9. Grafetstätter, C.; Gaisberger, M.; Prossegger, J.; Ritter, M.; Kolarž, P.; Pichler, C.; Thalhamer, J.; Hartl, A. Does Waterfall Aerosol Influence Mucosal Immunity and Chronic Stress? A Randomized Controlled Clinical Trial. *J. Physiol. Anthropol.* **2017**, *36*, 10, doi:10.1186/s40101-016-0117-3.
10. Seo, S.C.; Park, S.J.; Park, C.-W.; Yoon, W.S.; Choung, J.T.; Yoo, Y. Clinical and Immunological Effects of a Forest Trip in Children with Asthma and Atopic Dermatitis. *Iran. J. Allergy Asthma Immunol.* **2015**, 28–36.
11. Jia, B.B.; Yang, Z.X.; Mao, G.X.; Lyu, Y.D.; Wen, X.L.; Xu, W.H.; Lyu, X.L.; Cao, Y.B.; Wang, G.F. Health Effect of Forest Bathing Trip on Elderly Patients with Chronic Obstructive Pulmonary Disease. *Biomed. Environ. Sci.* **2016**, *29*, 212–218, doi:10.3967/bes2016.026.
12. Antonelli, M.; Donelli, D.; Barbieri, G.; Valussi, M.; Maggini, V.; Firenzuoli, F. Forest Volatile Organic Compounds and Their Effects on Human Health: A State-of-the-Art Review. *Int. J. Environ. Res. Public Health* **2020**, *17*, doi:10.3390/ijerph17186506.
13. Fieten, K.B.; Rijssenbeek-Nouwens, L.H.; Hashimoto, S.; Bel, E.H.; Weersink, E.J. Less Exacerbations and Sustained Asthma Control 12 Months after High Altitude Climate Treatment for Severe Asthma. *Allergy* **2019**, *74*, 628–630, doi:10.1111/all.13664.
14. Kubincová, A.; Takáč, P.; Kendrová, L.; Joppa, P.; Mikuľáková, W. The Effect of Pulmonary Rehabilitation in Mountain Environment on Exercise Capacity and Quality of Life in Patients with Chronic Obstructive Pulmonary Disease (COPD) and Chronic Bronchitis. *Med. Sci. Monit.* **2018**, *24*, 6375–6386, doi:10.12659/MSM.909777.
15. Gibbs, J.E. Essential Oils, Asthma, Thunderstorms, and Plant Gases: A Prospective Study of Respiratory Response to Ambient Biogenic Volatile Organic Compounds (BVOCs). *J. Asthma Allergy* **2019**, *12*, 169–182, doi:10.2147/JAA.S193211.