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Audio-guided and mindfulness-based forest bathing in moderately affected Long/Post-COVID patients: A pre-post pilot-study

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ABSTRACT

Objective: Long/Post-COVID patients are in urgent need of specialized treatment. Forest bathing has shown to promote health and well-being, and thus may be an appropriate treatment option. This pilot study aimed to investigate both the feasibility of a two-week audio-guided and mindfulness-based forest bathing intervention and pre-to-post symptom changes in Long/Post-COVID patients.
Methods: A repeated-measures design was employed to collect self-reported data on Long/Post-COVID symptoms, fatigue, well-being and stress-coping strategies from moderately affected Long/Post-COVID patients ($N = 46$, $N = 36$ included; recruited through media) prior to and following participation in the forest bathing program. Pulse rate was monitored through smartwatches. Feasibility was assessed by analysis of dropout rates.
Results: The dropout rate was 22 % due to physical and environmental conditions. We observed decreased overall Long/Post-COVID symptoms ($p < .001$) and fatigue ($p < .001$), increased well-being ($p < .001$) and a more adaptive use of stress-coping strategies ($p < .01$) over time. Participants` pulse rate fell within the normal range after a forest "walk" ($p < .001$).
Conclusion: Our results suggest that further research on audio-guided and mindfulness-based forest bathing is warranted, since this approach may offer a feasible and cost-effective method for the complementary treatment of moderate Long/Post-COVID.

1. Introduction

The pandemic coronavirus disease 2019 (COVID-19) has so far caused over 770 million infections with the severe acute respiratory syndrome coronavirus type 2 (SARS-CoV-2) and is estimated to be responsible for over 6.9 million deaths worldwide (Hoffmann et al., 2020; Sun et al., 2022; World Health Organization, 2023). The clinical manifestations of SARS-CoV-2 infection range from asymptomatic or mild to more severe courses and symptoms (Ellul et al., 2020; Mao et al., 2020; Varatharaj et al., 2020; Wang et al., 2020). Approximately 10 to 20 % of SARS-CoV-2 patients suffer from Long-COVID, which includes physical, neurological and mental symptoms that persist for at least four weeks after an acute infection with SARS-CoV-2 (Antoniou et al., 2022; Chen et al., 2022; Ladds et al., 2020; Rajan et al., 2021; Seeßle et al., 2022; Sudre et al., 2021; Thompson et al., 2022). Some of the patients were diagnosed with Post-COVID, i.e., when symptoms persisted for more than 12 weeks after the infection (Koczulla et al., 2022). Following the suggestion from Koczulla et al. (2022), we will use the term Long/Post-COVID to indicate that no explicit distinction was made between Long- and Post-COVID. Prominent symptoms of Long/Post-COVID include fatigue, breathlessness, pain, anxiety, depression, cognitive impairments or sleeping disturbances (Aiyegbusi et al., 2021; Lopez-Leon et al., 2021; Woo et al., 2020). These symptoms can occur in isolation or in combination. They can vary in persistence, severity and duration, and have a broad impact on patients` functional status and well-being (McEwan et al., 2022; Rajan et al., 2021; Seeßle et al., 2022). Potential risk factors contributing to Long/Post-COVID are still rather unknown, but sex (women are more likely to be affected than men; Chen et al., 2022; Thompson et al., 2022), a high body mass index (BMI), the severity of previous infections, and pre-pandemic or accompanying (infection-independent) health conditions were recently identified (Aiyegbusi et al., 2021; Evans et al., 2021; Goërtz et al., 2020;

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Nittas et al., 2022; Righi et al., 2022; Serafini et al., 2021; Sudre et al., 2021; Tenforde et al., 2020; Thompson et al., 2022). In contrast, it is hypothesized that SARS-CoV-2 vaccine reduces the risk of Long/Post-COVID (Antonelli et al., 2022; Català et al., 2024).

The high prevalence of Long/Post-COVID and its impact on patients` functional status and well-being poses a significant and growing burden on healthcare services (Arnold et al., 2021; Crook et al., 2021; Davis et al., 2021), highlighting the urgent need for specialized treatment and rehabilitation within complementary medicine for various Long/Post-COVID populations (Hawke et al., 2022). However, the intervention research on Long/Post-COVID is still in its infancy (Hawke et al., 2022). In addition to physical and (neuro-)psychological interventions (e.g., Chandan et al., 2022; del Corral et al., 2022; Estebanez-Pérez et al., 2022; Fowler-Davis et al., 2021; Prabawa et al., 2022; Robbins et al., 2021), nature-based interventions could be a feasible complementary treatment option for Long-Post-COVID. A recent review reported positive effects of nature-based therapy on physical (e.g., cardiovascular) and mental health (e.g., depression and anxiety; Nguyen et al., 2023), both of which can be impaired in Long/Post-COVID. Forest bathing – as part of forest therapy – appears to be a cost-effective nature-based intervention for people suffering from Long/Post-COVID (McEwan et al. 2022). Forest bathing originated from Japan (where it is called *'Shinrin-yoku'*; Miyazaki, 2018; Miyazaki, Ikei, & Song, 2014) and draws upon techniques derived from the field of forest therapy, which involves a deep immersion in the forest's environment using all the senses (Ensinger, 2016). There are various approaches for implementing forest bathing, including group interventions and individual walks. These can be self-guided or guided (either on-site or remotely), and may be experienced in nature or virtual (e.g., by watching videos). While forest bathing is already an integral health-promoting approach in Asian countries (Tsunetsugu et al., 2010), it has not yet gained widespread acceptance in Western countries (Stier-Jarmer et al., 2021) despite the increasing use of mindfulness-based techniques in psychotherapeutic settings (Grossman & Reddemann, 2016). Forest bathing has been shown to be effective in improving physical health (Wen et al., 2019), fatigue (Lee et al., 2018; Muro et al., 2023), stress-related outcomes (Annerstedt et al., 2013; Antonelli et al., 2019; Morita et al., 2007; Park et al., 2007, 2010), and psychological well-being (Bang et al., 2017; Bielinis et al., 2018; Komori et al., 2017; McEwan et al., 2021; Muro et al., 2023). Jimenez et al. (2021) found evidence for associations between nature exposure and improved cognitive function, brain activity (mainly related to emotion regulation), blood pressure, mental health, physical activity, and sleep. At least some of the health-promoting effects of forest bathing may be due to various features of forest landscapes (e.g., plants, flowers, trees, various woods, water bodies; Dayawansa et al. 2003; Glass et al., 2014; Olson et al., 2020; Schuh & Immich, 2022), including the effects of phytoncides (the essential wood oils contained in coniferous forest aerosols) which have been shown to modulate immunological, cardiovascular, pulmonary and psychological processes (Cheng et al., 2009; Donelli et al., 2023; Ideno et al., 2017; Kawakami et al., 2004; Komori et al., 2017; Lee et al., 2011; Lee & Lee, 2014; Li, 2010; Li et al., 2006, 2009, 2011; Oh et al., 2017; Song et al., 2015; Tsunetsugu et al., 2010; Wen et al., 2019). Overall, on-site forest bathing is suggested to be an appropriate treatment for respiratory or psychiatric symptoms (Hansen et al., 2017; Oh et al., 2017; Roviello et al., 2021; Stier-Jarmer et al., 2021) and could therefore be of particular relevance for the treatment of Long/Post-COVID. However, these patients typically experience low energy and a fear of re-infection, why outdoor self-guided forest bathing could be demanding for this group (McEwan et al., 2022; Reese et al., 2022). However, there is evidence that people spent more time in nature during the pandemic than before and that these people (even those who were less connected to nature) experienced a benefit to their well-being (Desrochers et al., 2022; Muro et al., 2023; Sundara Rajoo et al., 2021). In particular, the integration of mindfulness and forest bathing during uncertain circumstances as COVID-19 is thought to be beneficial to at-risk groups, including those with high levels of stress or mental health conditions (Olson et al., 2020). Exposure to nature may be a contributing factor in this regard (Dzhambov et al., 2021; Markwell & Gladwin, 2020).

Relevant to the current study, a recent pilot study (McEwan et al., 2022) examined the feasibility (retention rates, reasons for absence, and written feedback) and outcomes of four weekly online forest bathing sessions, using a waitlist controlled, repeated-measures design, in female Long/Post-COVID patients ($N = 22$ at baseline, $N = 16$ post intervention) recruited via social media advertisements. The intervention consisted of four 60-minute online sessions including visual, listening, smell, and touch activities, as well as a sitting nature observation and a shared circle between participants. The sessions were led by qualified forest therapy guides and comprised groups of three to 12 participants. They had the option of carrying out the intervention from outside or inside (with the use of photographs or videos of nature) depending on their specific needs. It has been demonstrated that this method of online forest bathing was a feasible approach with the potential to significantly reduce the severity of Long/Post-COVID symptoms and psychological variables (measured by online surveys), e.g., anxiety, rumination, and social connectedness (McEwan et al., 2022). In contrast with the aforementioned pilot study, the objective of the present study is to collect pilot data on the feasibility of an individually and in a real forest environment conducted audio-guided and mindfulness-based forest bathing program, as well as to observe potential pre-to-post changes in Long/Post-COVID symptoms and well-being in moderately affected Long/Post-COVID patients. Our program comprised a total of four 60-minute sessions ("walks") conducted over a two-week period (with two "walks" per week separated by at least two consecutive days), thus fitting well within the standard four-week approval period for the rehabilitation of Long/Post-COVID in Germany (DRV, 2023).

2. Methods

2.1. Study design and participants

This pilot study used a pre-post design without a control group. Given the purpose of the study to assess the feasibility (i.e., dropout rate and reasons for dropout) of a two-week audio-guided and mindfulness-based forest bathing intervention and pre-to-post changes in health measures, a formal sample size calculation was not warranted. As many participants as possible were recruited through newspaper, support groups, social media platforms, or the university's website. Recruitment information included a brief description of the forest bathing program and was designed to motivate potential participants to contribute to research into specialized treatment and rehabilitation methods for Long/Post-COVID patients.

A total of $N = 46$ moderately affected Long/Post-COVID patients (Sex: 44 females, 2 males, Age: $M_{age} = 41.85 \pm 1.92$ *S.E.*, Age range: 20 to 71 years) from Germany and Switzerland participated in our study. All participants were novices in the practice of forest bathing and suffered from at least four weeks of persistent symptoms after a SARS-CoV-2 infection (assessed by self-reported PCR-test result). Exclusion criteria included severe limitations in sensory perception or motor function, as well as addictive behavior or substance abuse. The prerequisite for fulfilled participation in the study was the completion of all forest bathing sessions and all questionnaires (see sections 2.2 and 2.3). Participating students received course credits, but no monetary compensation was provided. All participants gave their written informed consent in accordance with the Declaration of Helsinki before participation in the study. This study was conducted in accordance with the recommendations of the German Psychological Society. The research protocol was approved by the local ethics committee of the University of Hildesheim, FB-1 (Educational and Social Sciences), in Germany (Reference Number: 222/2022).

2.2. Audio-guided and mindfulness-based forest bathing program

The mindfulness-based forest bathing program consisted of four 60-minute sessions ("walks") conducted within two consecutive weeks (with two "walks" per week separated by at least two consecutive days) and was designed as an audio-guided intervention. All "walks" followed a standardized step-by-step procedure (see Table 1) and were performed independently by all participants (i.e., without the accompaniment of a professional forest bathing guide). The participants have been invited to hold the sessions in a nearby forest. During their "walks" the participants were guided by 60-minute audio files providing standardized instructions and exercises that allow for an immersive multisensory experience, even for people with limited physical abilities (see Table 1).

The sessions and audio files were developed and recorded by an Association of Nature and Forest Therapy (ANFT) trained Forest Therapy Guide and trained Forest Therapist. Forest Therapy Guides complete an extensive professional training and offer forest bathing as a health-promoting or preventive approach, while Forest Therapists are therapeutic personnel trained in nature-based interventions for various indications.

All exercises guided by the audio files were based on the mindfulness-based stress reduction (MBSR) program (Kabat-Zinn, 2013) and ecotherapy interventions (Clifford, 2021; Huppertz & Schatanek, 2021; Schuh & Immich, 2022). They were adapted to the requirements of this study. For patients with low cardiorespiratory fitness, such as Long/Post-COVID patients, formal and informal nature-adapted immersive mindfulness exercises appear to be key elements. Each forest bathing session (see Table 1) started with an awareness exercise noticing the current individual state when entering the forest, followed by a breathing exercise to stimulate the parasympathetic nerve system. Subsequently, a mindfulness stimulation of the five senses was introduced as a fundamental component of the sensory integration in each session. This was followed by various mindfulness exercises to promote mental and physiological relaxation and foster a connection with the natural environment. Finally, participants were encouraged to find a 'sit-spot' for a sitting meditation before leaving the forest. In order to maintain auditory experience, participants were instructed to wear a single in-ear headphone in one of their ears. In addition, the audio files incorporated sufficient silent pauses to facilitate a profound immersion in the forest environment.

2.3. Instruments

2.3.1. Questionnaires

Immediately before and after the two-week forest bathing intervention, participants were instructed to complete a total of four standardized questionnaires in a quiet environment (at the university or at home). First, an adapted version of the *Covid-19 Yorkshire Rehabilitation Scale* (*C19-YRS*; Sivan et al., 2020) containing eight (from originally 19) prominent Long/Post-COVID symptoms was employed. These symptoms included physical (breathlessness, laryngeal/airway complications, pain/discomfort, and mobility impairment), cognitive (cognition and communication impairment), and affective (anxiety and depression) symptoms.

Second, participants completed an adapted version of the Fatigue Assessment Questionnaire (*FAQ*; Glaus & Müller, 2001) to assess physical, cognitive and affective fatigue. The adapted FAQ consisted of 20 items, but unlike the original, participants were asked about symptoms that had occurred within a period covering the last two weeks (originally: last week). Third, participants completed the German version of the *Short-Form Health Survey* (*SF-36*; Morfeld et al., 2011), which includes eight subscales and 36 items related to physical and mental health, summarized into physical and mental component sum scores (PCS vs. MCS). Finally, the German Stress-Coping Questionnaire ("*Stressverarbeitungsfragebogen-120", SVF-120*; Erdmann & Janke, 2008) was used to assess participants` coping behavior in stressful situations. The *SVF-120* contains 120 items and measures 20 coping strategies which are grouped into positive (adaptive) and negative (maladaptive) strategies.

All questionnaires took approximately 45 minutes to complete. If necessary, participants were allowed to take a break and continue answering the questions afterwards.

2.3.2. Physiological measures

In addition to the use of questionnaires, physiological measurements of pulse rate were taken one hour before, during, and two hours after each forest "walk". Data were collected using the smartwatch "Mi Watch Lite" (BHR4357GL, Xiaomi, Beijing, China) which continuously records the pulse rate and provides an average value sampled over a 30-minutes interval (bin). Due to technical limitation, pulse rate data could only be collected from a subsample of participants who were able to pick up the smartwatch at the university. To ensure reliable baseline data, participants were instructed not to engage in any physical activity for one hour before and two hours after each forest "walk".

2.4. Statistical analyses

Descriptive statistics were calculated and presented as mean and standard error (*S.E.*). Pearson's *Chi-Square* (χ^2) tests were used to examine categorical data. Repeated-measures *analysis of variances*

Table 1
Basic structure of consecutive forest "walks" guided by four 60-minute audio files allowing for an intense multisensory experience and deep immersion into the forest's environment.

Time	Basic structure	Walk 1	Walk 2	Walk 3	Walk 4
5 min	**Entry into the forest**	Wardrobe exercise		Threshold exercise	
5-10 min				**Relaxation and Attentive Breathing**	
		(10 *min*)	(5 *min*)	(5 *min*)	(5 *min*)
5-20 min			**Five-senses exercise**		
		(20 *min*)	(5 *min*)	(10 *min*)	
10-30 min	**Mindful-ness-based perception & Imagination**	Mindfulness-based walking (10 *min*)	90° exercise, Nature work of art & Fox exercise (25 *min*)	Gaze exercise & Mindfulness-based walking (20 *min*)	Body-Scan, Animal observation, Animal of the forest exercise, Snail exercise & Body journey with tree (30 *min*)
10-15 min				**Sitting meditation**	
		(10 *min*)	(15 *min*)	(15 *min*)	(15 *min*)
5 min				**Exit from the forest**	
∑ *60 min*					

The structure of consecutive forest "walks" follows a step-by-step procedure to intensify the sensory experience and to deepen the immersion into the forest's environment. All audio files followed the same sequence, but their content differed in intensity and difficulty of the employed exercises, which were adapted from the mindfulness-based stress reduction (MBSR) program (Kabat-Zinn, 2013) and from ecotherapy (Clifford, 2021; Huppertz & Schatanek, 2021; Schuh & Immich, 2022).
Abbreviations: Min = minutes.

(*ANOVAs*) served to examine main effects and interactions. Where appropriate, *post-hoc* (Bonferroni-corrected) pairwise comparisons and *Greenhouse-Geisser*-corrected *p*-values were applied. Specifically, *C19-YRS* data were analyzed using a *2 × 3* repeated-measures *ANOVA* with the within-subjects factors "time" (before and after participation in the forest bathing program) and "type of symptoms" (physical, cognitive and affective Long/Post-COVID symptoms). Similarly, *FAQ* data were analyzed using a *2 × 3* repeated-measures *ANOVA* with the within-subjects factors "time" and "type of fatigue" (physical, cognitive and affective fatigue). *SF-36* data were analyzed using a *2 × 2* repeated-measures *ANOVA* employing the within-subjects factors "time" and "type of well-being" (physical *vs*. mental well-being). *SVF-120* data were separately analyzed for adaptive and maladaptive strategies using repeated-measures *ANOVAs* with the within-subjects factor "time". To examine potential changes in participants´ pulse rate, a *3 × 4* repeated-measures *ANOVA* was conducted with the within-subjects factors "time" (one hour before, during and two hours after participation in a session) and "session" (forest "walks" 1 to 4). Results were considered significant if $p < .05$. All statistical analyses were performed using the Statistical Package for the Social Sciences (*SPSS*; version 27 and 28 for Mac, IBM, New York, USA).

3. Results

3.1. Participant characteristics and dropout

In total, $N = 48$ participants suffering from Long/Post-COVID have been recruited for this study. From this original sample, a total of $N = 10$ (22 %) Long/Post-COVID patients were excluded due to incomplete participation and withdrawal from the forest bathing program. Participants reported acute illness ($N = 2$), severe Long/Post-COVID symptoms during the intervention period ($N = 3$), bad weather ($N = 2$), or unknown reasons ($N = 3$) as reasons for dropout. Thus, the remaining sample comprising a total of $N = 36$ Long/Post-COVID patients with self-reported Long/Post-COVID symptoms (according to the National Institute for Health and Care Excellence, NICE; NICE, 2020) that persisted for at least four weeks after an initial SARS-CoV-2 infection (proven by a self-reported positive PCR-test). Important demographic and clinical characteristics of this sample are summarized in Table 2.

The mean time from SARS-CoV-2 infection to study entry was 52.26 weeks (*S.E.* = 6.03 weeks, *range:* 6 to 111 weeks). During acute illness $N = 30$ Long/Post-COVID patients (83.3 %) had a mild course of infection, four participants (11.1 %) developed pneumonia and were hospitalized, and two participants (5.6 %) required intensive care. Noteworthy, the sample included more female than male participants ($\chi^2(1) = 28.44$, $p < .001$). Vaccination status was not surveyed. With respect to the forest "walks", 55.6 % of participants performed all sessions in a deciduous forest, 2.8 % in a coniferous forest, and 41.7 % in a mixed forest.

The data regarding participants` Long/Post-COVID symptoms, fatigue, well-being, stress-coping strategies, and pulse rate – as they were measured at the two measurement time points (prior to and following participation in the audio-guided and mindfulness-based forest bathing program) – are summarized in Table 3.

Table 2
Demographic and clinical characteristics of Long/Post-COVID patients ($N = 36$).

	Long/Post-COVID patients
Sex (female/male)	34/2
Age ($mean_y \pm S.E.$)	41.44 ± 2.34
Age range (min_y to max_y)	20 to 71
Physical disease (yes/no)	21/15
Diagnosis of mental illness (yes/no)	14/22
Psychotropic drugs intake (yes/no)	6/30
Intake of other medication (yes/no)	19/17
Frequency of physical activity per week (*mean* ± *S.E.*)	1.57 ± 0.22
Body Mass Index (*mean* ± *S.E.*)	26.02 ± 1.14

COVID = *coronavirus disease*, *min* = minimum, *max* = maximum, *SARS-CoV-2* = severe acute respiratory syndrome coronavirus type 2, *S.E.* = standard error, *y* = years.

3.2. Long/Post-COVID symptoms

Using the *C19-YRS* (Sivan et al., 2020), participants rated their physical, cognitive and affective Long/Post-COVID symptoms on 10-point rating scales with higher values representing a higher extent of symptoms (values from 0 to 1 are considered as "low", from 1 to 3 as

Table 3
Summary of study outcomes as they were measured prior to (pre) and following (post) participation in the audio-guided and mindfulness-based forest bathing program.

Measures	Long/Post-COVID patients			
	Pre ($M \pm S.E.$)	*Post* ($M \pm S.E.$)	M_{Diff}	*p*
C19-YRS				
Physical symptoms	2.70 ± 0.38	2.29 ± 0.36	-0.41	< .01
• Breathlessness	2.96 ± 0.31	2.47 ± 0.34	-0.49	
• Laryngeal/airway complications	2.28 ± 0.35	2.11 ± 0.32	-0.17	
• Pain/discomfort	3.58 ± 0.37	2.75 ± 0.39	-0.83	
• Impaired mobility	1.97 ± 0.34	1.81 ± 0.31	-0.16	
Cognitive symptoms	3.67 ± 0.51	2.94 ± 0.46	-0.73	< .001
• Cognitive impairment	4.39 ± 0.44	3.31 ± 0.39	-1.08	
• Impaired communication	2.94 ± 0.40	2.58 ± 0.36	-0.36	
Affective symptoms	2.64 ± 0.46	2.17 ± 0.48	-0.47	< .05
• Anxiety	2.92 ± 0.44	2.36 ± 0.44	-0.56	
• Depression	2.36 ± 0.44	1.97 ± 0.42	-0.39	
FAQ	0.54 ± 0.04	0.39 ± 0.04	-0.15	< .001
• Physical fatigue	0.59 ± 0.04	0.44 ± 0.04	-0.15	< .001
• Cognitive fatigue	0.62 ± 0.06	0.42 ± 0.05	-0.20	< .001
• Affective fatigue	0.42 ± 0.04	0.31 ± 0.04	-0.11	< .01
SF-36	39.75 ± 1.17	42.70 ± 1.38	2.95	< .001
• Physical well-being	39.32 ± 2.07	42.65 ± 2.07	3.33	< .01
> • Mental well-being	40.18 ± 1.92	42.74 ± 1.86	2.56	< .05
SVF-120				
• POS stress-coping[1]	45.61 ± 1.62	48.22 ± 1.84	2.61	< .01
• NEG stress-coping[2]	53.94 ± 2.11	48.86 ± 1.86	-5.08	< .01
Pulse rate *(bpm)*	87.51 ± 1.78	78.85 ± 1.89	-8.66	< .001

C19-YRS = *COVID-19 Yorkshire Rehabilitation Scale* (Sivan et al., 2020): Higher values represent a higher extent of symptoms (range: 0 = "none of this symptom" to 10 = "extremely severe level or impact"; values from 0 to 1 are considered as "low", from 1 to 3 as "moderate", from 3 to 6 as "medium", and from 6 to 10 as "high"). *Abbreviations: FAQ* = *Fatigue Assessment Questionnaire* (Glaus & Müller, 2001): Values are given relative to the maximum sum value of the respective scale with higher values representing a higher degree of the corresponding symptom (values from 0 to 0.1 are considered as "low", from 0.1 to 0.3 as "moderate", from 0.3 to 0.6 as "medium", and from 0.6 to 1.0 as "high"); *SF-36* = *Short-Form Health Survey* (Morfeld et al., 2011): *T*-values are presented for physical and mental component summary scores; *SVF-120* = *German Stress-Coping Questionnaire-120* (Erdmann & Janke, 2008): [1] Higher *T*-values are associated with a positive effect on stress management. [2] Lower *T*-values are associated with a positive effect on stress management; *Pulse rate*: Data represent mean values (in *bpm*) before and after forest bathing measured across four "forest walks". *P*-values are shown for the comparisons that were statistically tested (see Section 2.4). *Further Abbreviations: bpm* = beats per minute, *COVID* = coronavirus disease, *M* = mean, M_{Diff} = mean difference, *SARS-CoV-2* = severe acute respiratory syndrome coronavirus type 2, *S.E.* = standard error.

"moderate", from 3 to 6 as "medium", and from 6 to 10 as "high"). The results are illustrated in Fig. 1 (shown as bold lines). Prior to participation in the forest bathing program, Long/Post-COVID patients reported moderate (for physical and affective symptoms) to medium (for cognitive symptoms) levels of Long/Post-COVID symptoms (see Table 3). A *2 × 3* repeated-measures *ANOVA* revealed significant main effects of "time" ($F(1, 35) = 17.33$, $p < .001$, $\eta^2_p = 0.33$) and "type of symptoms" ($F(1.64, 57.45) = 4.01$, $p < .05$, $\eta^2_p = 0.10$). Overall, Long/Post-COVID symptoms decreased from medium to moderate symptom severity from the first to the second measurement time point ($M_{PRE} = 3.00 \pm 0.39$ *S.E.*, $M_{POST} = 2.47 \pm 0.39$ *S.E.*, $p < .001$). In addition, *post-hoc* comparisons revealed that Long/Post-COVID patients showed (across the two measurement time points) more severe levels of cognitive ($M_{COGNITIVE} = 3.31 \pm 0.48$ *S.E.*) than physical ($M_{PHYSICAL} = 2.49 \pm 0.36$ *S.E.*; $p < .05$), but comparable levels of both affective ($M_{AFFECTIVE} = 2.40 \pm 0.45$ *S.E.*) and physical ($p > .05$), as well as affective and cognitive symptoms ($p > .05$).

3.3. Fatigue symptoms

Using the FAQ (Glaus & Müller, 2001), participants rated their physical, cognitive and affective fatigue symptoms on 4-point Likert scales. The results are illustrated in Fig. 1 (shown as bright lines), where values are given relative to the maximum sum value of the respective fatigue scale with higher values representing a higher degree of the corresponding symptom (values from 0 to 0.1 are considered as "low", from 0.1 to 0.3 as "moderate", from 0.3 to 0.6 as "medium", and from 0.6 to 1.0 as "high"). Prior to participation in the forest bathing program, Long/Post-COVID patients reported medium (physical and affective fatigue) to high (cognitive fatigue) levels of fatigue symptoms (see Table 3). A *2 × 3* repeated-measures *ANOVA* revealed significant main effects of "time" ($F(1, 35) = 22.67$, $p < .001$, $\eta^2_p = 0.39$) and "type of fatigue" ($F(2, 70) = 18.40$, $p < .001$, $\eta^2_p = 0.34$), as well as a significant interaction between "time" and "type of fatigue" ($F(1.65, 57.77) = 3.84$, $p < .05$, $\eta^2_p = 0.10$). *Post-hoc* comparisons revealed that the severity of all three types of fatigue (physical, cognitive and affective) symptoms decreased from the first to the second measurement time point (see Table 3). In addition, Long/Post-COVID patients showed comparable higher levels of physical and cognitive fatigue (at both time points $p > .05$), but a lower level of affective fatigue that significantly differed from physical (at both time points $p < .001$) and cognitive fatigue ($p_{PRE} < .001$, $p_{POST} < .01$) at both measurement time points.

3.4. Physical and mental well-being

Using the *SF-36* (Morfeld et al., 2011), participants rated their physical and mental well-being. Fig. 2 summarizes the *T*-values for physical and mental component summary scores for both measurement time points (shown as bold lines). According to Morfeld et al. (2011), well-being scores of $T < 40$ can be considered clinically relevant. Before participating in the forest bathing intervention, the *T*-values in Long/Post-COVID patients were in the range of clinical relevance or close to it (physical well-being: $T = 39.32$; mental well-being: $T = 40.18$; see Table 3). A *2 × 2* repeated-measures *ANOVA* revealed a significant main effect of "time" ($F(1, 35) = 20.63$, $p < .001$, $\eta^2_p = 0.37$), indicating an increase of overall (including physical and mental) well-being from the first to the second measurement time point ($M_{PRE} = 39.75 \pm 1.17$ *S.E.*, $M_{POST} = 42.70 \pm 1.38$ *S.E.*, $p < .001$). Specifically, both mental and physical well-being changed to the normal range ($T > 40$) from the first to the second measurement time point (see Table 3 and Fig. 2).

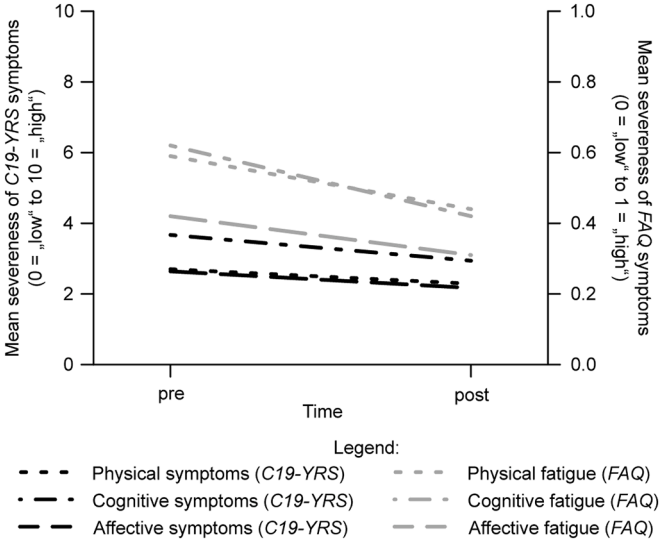

Fig. 1. Physical, cognitive, and affective symptoms (*C19-YRS*), as well as fatigue symptoms (*FAQ*) for Long/Post-COVID patients ($N = 36$). Data were shown prior to (pre) and following (post) participation in the audio-guided and mindfulness-based forest bathing. *Abbreviations: C19-YRS = COVID-19 Yorkshire Rehabilitation Scale (Sivan et al., 2020)*: Higher values represent a higher extent of symptoms (range: 0 = "none of this symptom" to 10 = "extremely severe level or impact"; values from 0 to 1 are considered as "low", from 1 to 3 as "moderate", from 3 to 6 as "medium", and from 6 to 10 as "high"); *FAQ = Fatigue Assessment Questionnaire (Glaus & Müller, 2001)*: Values are given relative to the maximum sum value of the respective scale with higher values representing a higher degree of the corresponding symptom (values from 0 to 0.1 are considered as "low", from 0.1 to 0.3 as "moderate", from 0.3 to 0.6 as "medium", and from 0.6 to 1.0 as "high"); *COVID* = coronavirus disease; *SARS-CoV-2* = severe acute respiratory syndrome coronavirus type 2.

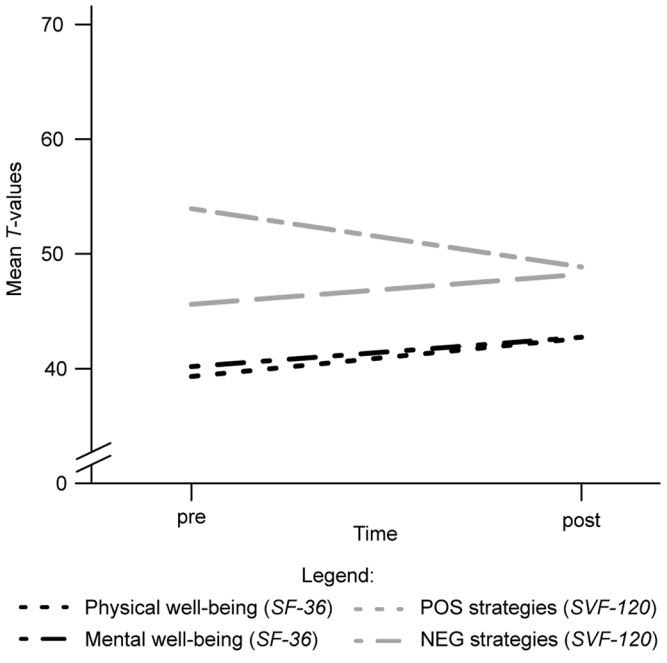

Fig. 2. Physical and mental well-being (*SF-36)* as well as coping strategies (*SVF-120)* for Long/Post-COVID patients ($N = 36$) as measured prior to (pre) and following (post) participation in the audio-guided and mindfulness-based forest bathing. *Abbreviations: SF-36 = Short-Form Health Survey (Morfeld et al., 2011)*: *T*-values are presented for physical and mental component summary scores; *SVF-120 = German Stress-Coping Questionnaire-120 (Erdmann & Janke, 2008)*: For positive strategies (POS), higher *T*-values, and for negative strategies (NEG), lower *T*-values are associated with more effective stress management; *Further Abbreviations: COVID* = coronavirus disease, *SARS-CoV-2* = severe acute respiratory syndrome coronavirus type 2.

3.5. Stress-coping strategies

Using the *SVF-120* (Erdmann & Janke, 2008), Long/Post-COVID patients` coping behavior in stressful situations were assessed. *T*-scores for adaptive (POS) and maladaptive (NEG) coping strategies are summarized in Fig. 2 (shown as bright lines). All *T*-scores were observed to fall within the normal range indicating no clinical relevance (see also descriptive data in Table 3), although the scores indicated an elaborated use of maladaptive (NEG) compared to adaptive (POS) coping strategies at the first measurement time point. A 2×2 repeated-measures *ANOVA* confirmed a significant main effect of "time" (POS: $F(1,35) = 9.62$, $p < .01$, $\eta_p^2 = 0.22$; NEG: $F(1,35) = 8.38$, $p < .01$, $\eta_p^2 = 0.19$), proving an increase in the use of adaptive coping mechanisms and a decrease in maladaptive coping strategies from the first to the second measurement time point (indicative of a more effective stress management).

3.6. Pulse rate

Due to limited availability of technical equipment, pulse rate data were recorded in a subsample of $N = 22$ (61 %) Long/Post-COVID patients (Sex: 20 females, 2 males; Age: $M_{age} = 40.55$ years $\pm$ 3.04 *S.E.*; Age-range: 20 to 67 years; BMI: $M_{BMI} = 25.78\ kg/m^2 \pm 1.69$ *S.E.;* Frequency of physical activity/week: 1.45 $\pm$ 0.19 *S.E.*). The temporal changes of participants` pulse rate are illustrated in Fig. 3. A 3×4 repeated-measures *ANOVA* revealed a significant main effect of "time" ($F(2, 42) = 33.33$, $p < .001$, $\eta_p^2 = 0.61$). *Post-hoc* comparisons showed that two hours after a forest bathing "walk" ($M_{POST} = 78.85\ bpm \pm 1.89$) Long/Post-COVID patients demonstrated a lower pulse rate within the normal range (60 to 80 *bpm)* compared to the pulse rate as measured during ($M_{DURING} = 91.33\ bpm \pm 2.10$ *S.E.;* $p < .001$) and one hour before a forest bathing "walk" ($M_{PRE} = 87.51\ bpm \pm 1.78$ *S.E.;* $p < .001$; see Fig. 3).

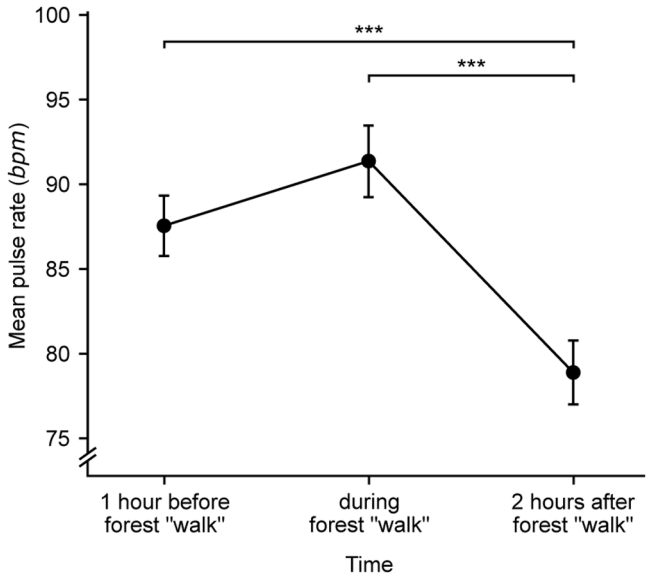

Fig. 3. Mean pulse rate *(bpm)* as measured one hour before, during and two hours after participation in the audio-guided and mindfulness-based forest bathing. For each timepoint data are averaged across four individual forest "walks" comprising the program. Error bars denote standard error. Data are assessed in a subsample of $N = 22$ Long/Post-COVID patients. *Abbreviations: bpm = beats per minute; SARS-CoV-2* = severe acute respiratory syndrome coronavirus type 2; *** $p < .001$, * $p < .05$.

4. Discussion

4.1. Long/Post-COVID symptoms and subjective well-being

Prior to participation in the forest bathing program, Long/Post-COVID patients predominantly reported moderate to medium levels of long-term physical, cognitive, and affective symptoms (including physical, cognitive, and affective fatigue) and an impaired level of physical well-being. Mental well-being was close to clinical relevance, while stress-coping strategies were inconspicuous, but showed an elaborated use of maladaptive (NEG) compared to adaptive (POS) coping strategies (indicative of a less effective stress management). These observations are in line with previous studies on Long/Post-COVID (Aiyegbusi et al., 2021; Chen et al., 2022; Lopez-Leon et al., 2021) and emphasize the high impact of even moderate to medium Long/Post-COVID symptom patterns on patient`s functional status and subjective well-being (Aiyegbusi et al., 2021; Halpin et al., 2021).

Given an increasing healthcare burden of Long/Post-COVID (Arnold et al., 2021; Crook et al., 2021; Davis et al., 2021), feasible and cost-effective adjunctive interventions are urgently required (Hawke et al., 2022). As previously described and also confirmed in this study, Long/Post-COVID can encompass a wide range of symptoms. In order to encounter both physical and mental symptoms, as well as well-being, multidisciplinary interventions combining physical and psychological methods are required (Aiyegbusi et al., 2021; Crook et al., 2021; Hawke et al., 2022; Sudre et al., 2021). Since nature-based methods are gaining popularity in support of sustainable health care (Nguyen et al., 2023), we employed a two-week audio-guided and mindfulness-based forest bathing program in moderately affected Long/Post-COVID patients and observed a significant pre-to-post decrease in physical, cognitive and affective Long/Post-COVID symptoms and fatigue symptoms. In addition, we not only observed a significant increase in overall (physical and mental) well-being (which was no longer within the range of clinical relevance at the second measurement time point), but also an increase in the use of adaptive stress-coping mechanisms (accompanied by a decrease in maladaptive strategies) from the first to the second measurement time point (being indicative of a more effective use of stress management strategies). Finally, two hours after a forest "walk", pulse rate of participants was observed to decrease to the normal range.

It is important to consider that our study design does not allow for any causal statements about the effectiveness of the employed forest bathing program. However, the observed pre-to-post changes were fairly consistent with improvements in Long/Post-COVID symptoms and psychological variables as they were already demonstrated for online forest bathing in a study employing a waitlist controlled, repeated-measures design (McEwan et al., 2022). In addition, previous studies have demonstrated that forest bathing is a suitable nature-based method to reduce negative affect (Komori et al., 2017; Sundara Rajoo et al., 2021) and symptoms of fatigue (Lee et al., 2018; Muro et al., 2023), improve cardiovascular parameters (Ideno et al., 2017; Komori et al., 2017; Lee et al., 2011; Lee & Lee, 2014; Li et al., 2011; Oh et al., 2017; Song et al., 2015; Tsunetsugu et al., 2010; Wen et al., 2019), enhance mindfulness states (Muro et al., 2023), reduce stress-related outcomes (Annerstedt et al., 2013; Antonelli et al., 2019; Morita et al., 2007; Park et al., 2007, 2010), and improve physical and mental well-being (Bang et al., 2017; Bielinis et al., 2018; McEwan et al., 2021).

4.2. Feasibility of the two-week audio-guided and mindfulness-based forest bathing

In our study, 34 out of 36 participants were female. The high proportion of women may highlight the fact that women are generally more affected by Long/Post-COVID (Muro et al., 2021; Sanabria-Mazo et al., 2021; Thompson et al., 2022). Alternatively, they might be more susceptible to nature-based interventions and/or more willing to participate in a research study. In light of the health challenges of

Long/Post-COVID patients, we observed a reasonable dropout rate of 22 %, which is fairly consistent with the rate of 27 % reported for online forest bathing in adult Long/Post-COVID patients (McEwan et al., 2022). In our study, participants reported acute illness and severe Long/Post-COVID symptoms as two important reasons for withdrawal. Our forest "walks" employed mindfulness-based exercises, which may have required high cognitive effort from the participants. Hence, our forest "walks" might have been too demanding for severely affected patients, especially those with more severe physical and cognitive symptoms. It should further be considered, that the completion of questionnaires – although our participants were allowed to take a break during their completion of questionnaires – might have been too burdensome for some of our Long/Post-COVID patients. Finally, bad weather conditions were reported as a reason for withdrawal. Compared to online interventions, outdoor interventions are more susceptible to physical restrictions (e.g., mobility restrictions and low energy) and environmental conditions (McEwan et al., 2022). However, face-to-face exposure to nature and the interweaving of mindfulness with forest bathing was previously suggested to be very effective in improving health and well-being (Dzhambov et al., 2021; Markwell & Gladwin, 2020).

According to McEwan et al. (2022), flexibility (i.e., the opportunity to effectively deal with diverse and evolving needs of patients), is a crucial factor in the development of feasible interventions in Long/Post-COVID. Both forest therapy and forest bathing, usually guided by an authentic forest therapy guide (who demonstrates the exercises and supports the patient with his or her nature-connected presence) are increasingly used as preventive, therapeutic and curative interventions (Schuh & Immich 2022), e.g., in recreational or healing forests worldwide (Immich & Robl 2023). The use of audio files to guide forest bathing allows more feasibility and flexibility of the intervention regardless of personal resources and individual time constraints, without significantly reducing the effectiveness of the program (Shin et al., 2023). Given the regular approval period for rehabilitation of Long/Post-COVID patients in Germany of four weeks (DRV, 2023), which corresponds to the median rehabilitation period in France (Ghanem et al., 2022), a two-week forest bathing intervention offers the possibility of delivering the intervention in an inpatient context even if a prior familiarization phase is taken into account.

4.3. Limitations & future studies

Our study employed a pre-post design without a control group. Thus, our study design does not allow for any causal statements about the effectiveness of the employed forest bathing program. In addition, our target population contained only a smaller sample of only moderately affected Long/Post-COVID patients, and predominantly women were recruited. With the exception of pulse rate, all data were self-reported and no objective tests or medical expertise were used to assess and confirm pre-existing health conditions and Long/Post-COVID symptoms. Unfortunately, physiological data were only collected in a subsample of Long/Post-COVID patients. Future studies should investigate potential effects of forest bathing on Long/Post-COVID symptoms using a randomized control group design, employing larger sample sizes, controlling for medication and diagnoses, and collecting more and detailed feasibility data, as well as follow-up data (for the examination of possible long-term intervention effects of forest bathing).

5. Conclusion

This pilot-study examined a two-week audio-guided and mindfulness-based forest bathing program using a pre-post design. Prior to participation in the forest bathing program, Long/Post-COVID patients predominantly reported moderate to medium levels of long-term physical, cognitive, and affective symptoms (including fatigue), and an impaired level of physical well-being. We observed a significant reduction in Long/Post-COVID symptoms and fatigue symptoms, an improvement in physical and mental well-being, an increased use of adaptive (instead of maladaptive) coping strategies, and a reduction of pulse rate. With respect to feasibility, 22 % of participants withdrew due to reasons of acute illness, severe Long/Post-COVID symptoms, demanding study conditions, or bad weather. However, the short duration of our intervention and the audio-guided approach enhance the feasibility and flexibility of this nature-based approach. Thus, audio-guided mindfulness-based forest bathing may offer a feasible, flexible and cost-effective method for the adjunctive treatment and rehabilitation of moderately affected Long/Post-COVID patients.

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Institutional review board statement

Ethical approval was obtained from the University of Hildesheim, FB-1 (Educational and Social Sciences) Ethics Committee (Reference Number: 222/2022).

Informed consent statement

Written informed consent was obtained from all participants involved in this study.

Data Availability Statement

Anonymized data are available on request from the corresponding author.

CRediT authorship contribution statement

Anna J. Torner: Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Anika Meißner:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Alicia Borchert:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Gisela Immich:** Writing – review & editing, Resources, Methodology, Conceptualization. **Kristian Folta-Schoofs:** Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors report no conflicts of interest.

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