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Benefits of Thalassotherapy with Sleep Management on Mood States and Well-being, and Cognitive and Physical Capacities in Healthy Workers

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Abstract

Objective: Thalassotherapy, which combines seawater hydrotherapy and the marine climate, improves mood, fatigue, general well-being, and physical capacities in the working population, but little is known on the interest to add sleep management to cares. We investigated effects of three days of thalassotherapy cares combined with sleep management on psychological and physical capacities using subjective and objective tests in healthy workers.

Methods: Cares were undertaken in the morning after tests (10:15-12:15) and in the afternoon (14:15-16:15). Participants were asked to go to sleep from 22:30 to 07:00. Tests were performed at 09:00 before arriving to the resort (T0), the day after arrival (T1), the days following cares (T2, T3, T4), the day after week-end at home (T5) and after three days working (T6).

Results: Polysomnographic sleep analysis showed that Total Sleep Time was significantly higher (+6%) the second night compared to the first, indicating an immediate positive effect of hydrotherapy cares. Self-reported mood states and health outcomes scores were improved at T2 in comparison with T1 (-67% for total mood disturbances, -17% for anxiety, -71% for fatigue, +23% for general well-being), as was daytime sleepiness (-26%). The number of lapses in the Psychomotor Vigilance Test (as objective marker of sustained attention) was significantly lower (-59%) at T2 compared to T1, whereas a delayed increase of lower limb flexibility was observed at T4 compared to T1 (+38%).

Conclusion: Three days of thalassotherapy combined to sleep management have immediate beneficial effects on self-reported mood states, anxiety, fatigue, well-being and daytime sleepiness, as well as on the objective evaluation of sustained attention, in healthy workers. Beneficial effects on lower limb flexibility are observed after 3 days of cares. Positive effects were still observed after the weekend back home and after 3 days of return to work.

Keywords: Thalassotherapy; Sleep; Psychological state; Sustained attention; Flexibility

Introduction

In western countries, professionally active populations (e.g. health care professions, drivers, soldiers) are prone to sleep loss with daytime sleepiness, fatigue, mood disorder, and cognitive deficits [1,2]. Several approaches are available for improving sleep and general well-being and fatigue, and there has been a growing interest in this last decade for treatments in health thalassotherapy resorts both in healthy subjects with non-specific disorders and in patients with defined health conditions [3]. Thalassotherapy is a therapy that is linked to the sea and is one of the most important of the climatotherapeutic methods. It refers to a combination of different techniques, including hydrotherapy (pool, baths, showers, and saunas), balneotherapy, spas, aquatic exercises, massages supervised by physiotherapists [3]. The duration of the sessions and the temperature of the water may vary between treatments [4,5].

The cares in health resorts can be applied to different groups of people, e.g. healthy subjects, persons with non-specific disorders and patients with defined health conditions [3]. Stays in thalassotherapy resorts are currently proposed with a limited number of cares (healthcare) selected for their specific actions. Thus, it has been evidenced that sea water exercises bring more advantages related to emotional aspects when compared to water pool in women with fibromyalgia [6]. Moreover, the warmth and buoyancy of water reduces pressure on the bones, joints and muscles which may facilitate movement and may block nociception by acting on thermal receptors and mechanoreceptors [7]. Warm water causes peripheral vasodilatation, a reduction in vascular resistance, enhances cardiac output and stroke volume which may dissipate algogenic chemicals and facilitate muscle relaxation [8]. In accordance with these principles, it has been shown that in the case of various pathologies or aging, thalassotherapy can improve flexibility, postural control, and articular amplitude, contribute to tissues detoxification, which may last for several weeks [3].

Relative to the interest of hydrotherapy for sleep, Horne, et al. [9] evidenced, using EEG recording, an increase of sleepiness at bed-time, and increases of N3, N4 and reduction of REM sleep after 90 min of passive body heating in a warm bath (41°C) in young healthy women. The spa resort and balneotherapy use are also beneficial for health-related quality of life, sleep, sickness absence, and fatigue in the working population [10-12] but this has been reported mainly after several weeks of cares. Frequent spa resort users (a large population of 3341 employees) were more likely to have better quality of sleep, and better physical and mental health [10]. Vitorino et al. [13] also already reported, using sleep logs data, an improvement in TST (by at least 1 hour) and quality of life in fibromyalgia patients after three weeks of hydrotherapy care (60 min per day, three times per week). Recently, a 12-day balneotherapy programme was found to improve significantly pain, mood state, sleep and depression (all through questionnaires and VAS scales) in healthy elderly [14]. A 3-week resort-based spa therapy was found to improve quality of sleep, fatigue, distress, reduced motivation, in working individuals with mild burnout (i.e. increased emotional exhaustion) and individuals with a full burnout syndrome (i.e. increased exhaustion plus social detachment and/or performance dissatisfaction) [15]. However, polysomnographic sleep and cognitive capacities have been only weakly studied. Being constantly exposed to professional and family constraints, workers may suffer from insufficient rest and reduced daily sleep time [16]. This chronic sleep debt and repeated sleep/wake cycle disturbances induced behavioral changes (diurnal sleepiness, anxiety, fatigue) and impairments of cognitive and physical capacities (decreases of sustained attention and physical capacity, increase of mistakes, fatigue, pain, etc) [17,18]. Implementing a sleep extension programme was recently shown to improve sleep and sustained attention with beneficial changes in stress hormone expression among professional athletes [19].

The aim of this study was to evaluate the effects of 3 days of thalassotherapy cares combined with sleep management in a thalassotherapy resort (Saint-Malo, North Brittany, France, Les Thermes Marins) on objective and subjective measures of sleep, mood states, well-being, health outcomes and cognitive (sustained attention) and physical capacities in healthy middle-aged workers.

Subjects and Methods

Subjects

After being informed of the procedures, 11 healthy workers (7 men and 4 women; age: 41.1 ± 11.9 years) were volunteer to take part in the experiment. They all signed an informed consent before being included in this study which is conformed to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. The study was reviewed and approved by the local Institutional Review Board of the medical committee.

Exclusion criteria were as follows: to not present an extreme chronotype (moderately morning=4, intermediate=3, moderately evening=3) based on the Horne and Östberg questionnaire (1976) [20] nor any sleep troubles (PSQI scores<6) [21], to not suffer from excessive diurnal sleepiness (Epworth scores<11) [22], and to not use nap during the day. Participants were nonsmokers, had no medical treatment, and did not suffer from an articular or functional disease (rheumatoid arthritis, osteoarthritis…).

Protocol Design

After the inclusion visit, participants remained working during 2 weeks. During this period, they wore a wrist activity monitor (Actiwatch7, CamNtech2008®, Cambridge Neurotechnology, Cambridge, Cambridgeshire, UK) and filled out a sleep diary to control sleep/wake activity rhythm. At the end of this period (Thursday), they come to the laboratory to spend one night with electrophysiological recording of nocturnal sleep (Night 0 as a baseline night) followed the day after, between 9:00 to 10:00, by the first testing (T0 as baseline) (detailed further) (corresponding to D-3, 3 days before the transfer to the thalassotherapy resort). Then, participants spend the weekend at home, and on Monday (D1) they moved for thalassotherapy cares (3 days) in Saint-Malo, North Brittany, France (Les Thermes Marins). Participants arrived in the afternoon at the resort and spent the first night (Night 1) without having received any cares. The day after and during 3 days (D2, D3 and D4), they were submitted to the test battery (T1, T2, and T3) (from 9:00 to 10:00) followed by hydrotherapy cares (detailed further) (H1, H2, and H3) from 10:15 to 12:15 and from 14:15 to 16:15. After the fourth night (Night 4) and after completion of the last test session (T4) in the morning, participants returned to their home for the week-end and came back next day to the laboratory (D8) for tests in the morning (T5). Then, after working 3 days (D9 to D11), participants had to complete the last morning tests session (T6) at D12. During the four nights in the resort, the participants were instructed to have sleep opportunity by staying in bed between 22:30 and 07:00 (510 min). From living the thalassotherapy resort to D12, participants wore a wrist activity monitor and filled out a sleep diary (Figure 1).

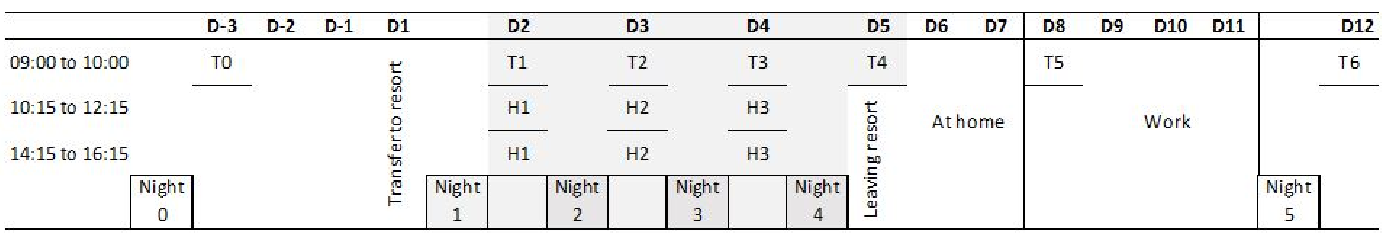

Figure 1: Protocol design. D-3 is the baseline day (3 days before transfer to the thalassotherapy resort); D1 is day of transfer; D2 to D4 are days with cares; D5 day leaving the resort; D6 and D7 are week-end at home; D9 to D11 working days; and D12 the last day with tests. T0 to T6: tests between 09:00 and 10:00; H1 to H3: hydrotherapy cares between 10:15 and 12:15 and between 14:15 and 16:15. The stay in the resort is in gray

During the two weeks of work before beginning the protocol, and during returning at home and working after the thalassotherapy stay, the mean of the total sleep time (according to wrist actigraphy and sleep diaries) of the participants was 347 ± 57 min and 345 ± 67 min.

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Hydrotherapy treatments

During the three days of treatments, the participants received 4 different cares each day, determined by the technical staff. Thalassotherapy treatments in the Saint-Malo resort involve hydrotherapy treatments with warm seawater (31°C-34°C). On H1, they had a marine draining (12 min), underwater showerheads, pool with lombar jets (15 min) and modelling under affusions (25 min). On H2, the participants had a jets bath with essential oils (20 min), dynamic affusions (15 min), seaweed body wrap (25 min), aquarelaxing. On H3, they had a marine draining, underwater showerheads (15 min), pool with cervical jets (15 min) and modelling under affusions. In addition, during the half-day of cares, the participants had an unlimited open access to an aquatonic® pool, hammam, sauna and a sea mist room.

Measurements

Nocturnal sleep: Sleep parameters were analyzed by polysomnographic (EEG, EMG, EOG and EKG) recordings [23] using miniaturized multi-channel ambulatory devices (Actiwave®, CamNtech Ltd England) during the baseline night (Night 0), the four nights in the resort (Nights 1, 2, 3, 4), and the night after 3 days of recovery and 3 days of work (Night 5). Bio-electrical signals were digitized at a sampling frequency of 200 Hz with a 16-bit quantization between −500 and 500 µV, within a bandwidth of 0-48 Hz. All the data were stored into computer files using the standard EDF data format.

Daytime sleepiness: The subjective feeling of diurnal sleepiness was measured by the Karolinska Sleepiness Scale (KSS) [24]. The dependent measure was the subject's sleepiness rating. This scale was completed during test sessions at T0, T1, T2, T3, T4, T5, and T6.

Mood states and fatigue assessment: The POMS-f (French version) is a 65-item questionnaire measuring six mood states (Tension, Depression, Anger, Vigor, Fatigue, Confusion) on a 5-point Likert scale, in relation to the context [25]. The Total Mood Disturbance [(Tension+Depression+Anger+Fatigue+Confusion)−Vigor] was calculated. In addition, the raw scores for each item were analyzed to further investigate changes in mood states.

The subjective feeling of fatigue was measured using the Pichot's questionnaire which consisted in 8 items rated from 0 (not at all) to 4 (extremely) [26]. The sum of the different items was retained for analysis.

Anxiety and depression: The Hospital Anxiety and Depression (HAD) questionnaire was used which comprised 14 items, 7 items related to anxiety and 7 related to depression [27]. Each item of the questionnaire is scored from 0 to 3. The summed score for each symptom was retained for analysis.

Visual analog scales: Relaxation, perceived soreness, well-being were evaluated using visual analog scales [6]. Participants had to estimate these 3 dimensions by placing a cursor on a 10 cm line. Each scale was defined with an adjective at each extremity (0 cm=Not at all; 10 cm=extremely). The higher the scores for relaxation and well-being, the better for health. In contrast, the lower the scores for perceived soreness, the better for health.

Sustained attention: The 3-min Psychomotor Vigilance Task (PVT-Brief version) [28] was performed at T0, T1, T2, T3, T4, T5, and T6. The inter-stimulus intervals varied randomly from 1-4 sec. Subjects were instructed to press the response button as soon as each stimulus appeared, in order to keep RT as low as possible, but not to press the button too soon (which yielded a false start warning on the display). An auditory signal was given after a 30-sec period without response. Lapse definition for the 3-min PVT was adjusted from the standard ≥ 500 ms definition to ≥ 355 ms. The number of lapses was considered as the primary PVT outcome metric.

Flexibility: The lower-limb posterior chain flexibility was measured through the sit-and-reach test [29]. The subjects were requested to carry out a maximal flexion of the spine so as to push the cursor located on a graduated scale on the top of the box as far as possible, using the index finger of each hand. The scale was graded from -20 to 30 cm with 0 corresponding to foot level and -20 cm corresponding to the maximal level of flexibility. The final position was to be maintained for at least 2 sec so that the measurement could be validated.

Vertical jump capacity: It was determined using the counter-movement jump (CMJ) test [30]. Flight time and jump height were measured using an Optojump® device (Microgate, Bolzano, Italy). The participants had to perform jumps from an upright standing position while performing a countermovement to reach a knee angle of about 90°. 3 trials were realized with the hands positioned on the waist and with a 20 sec pause between successive trials. The highest of the 3 jumps was selected for analysis.

Statistical analysis

The different scores at the questionnaires and scales (KSS, Pichot, HAD, POMS, VAS), the parameters for sustained attention, flexibility and vertical jump were analyzed using a Friedman ANOVA with repeated measures as were the nocturnal sleep parameters. In case of significance, a Wilcoxon test was performed to evidence pairwise differences. To examine the relationships between parameters, the Spearman's rank correlation coefficient was used. Results are described as means ± SEM for each assessment. All statistical differences were considered as significant for a p-value<0.05. All statistical analysis was performed using Statistica software® v.10 (Statsoft Inc, France).

Results

Nocturnal sleep

Significant increases for time in bed (TIB) ($\chi 2$=26.79; p<0.001), sleep period time (SPT) ($\chi 2$=26.85; p<0.001), and total sleep time (TST) ($\chi 2$=29.55; p<0.001) were observed (20% for TST during the first night at the resort (Night 1 compared to Night 0) and 6% more during the second night following hydrotherapy cares (Night 2 compared to Night 1) (Table 1).

Considering sleep stages (Table 1), N2 sleep duration significantly increased ($\chi 2$=14.71; p<0.05) in Night 1 (Z=2.59; p<0.01) and Night 2 (Z=2.80; p<0.01) in comparison with Night 0. N3 sleep duration also increased ($\chi 2$=18.63; p<0.01) in Night 2 (Z=2.19; p<0.05), Night 3 (Z=2.39; p<0.05) and Night 4 (Z=1.99; p<0.05) compared with Night 0. In contrast, no significant effect was observed on Sleep onset latency (SOL) ($\chi 2$=5.29; p=0.38), N1 sleep duration ($\chi 2$=4.14; p=0.53) and Rapid eye movement (REM) sleep ($\chi 2$=8.04; p=0.15). In addition, these changes appeared without any modification of sleep architecture as no significant effect was observed on sleep stages percent [N1 sleep percent ($\chi 2$=4.14; p=0.53), N2 sleep percent ($\chi 2$=6.20; p=0.29), N3 sleep percent ($\chi 2$=6.40; p=0.27), REM sleep percent ($\chi 2$=2.48; p=0.78)].

	Night 0	Night 1	Night 2	Night 3	Night 4	Night 5
TIB (min)	416 ± 19	475 ± 9*	497± 8*§	486 ± 11*	477 ± 9*	447 ± 9§
SPT (min)	405 ± 19	463 ± 10*	488 ± 10*§	477 ± 11*	465 ± 10	438 ± 11
TST (min)	358 ± 15	428 ± 13*	455 ± 11*§	443 ± 12*	429 ± 11*	391 ± 19§
SOL (min)	10.5 ± 1.9	11.8 ± 2.1	8.1 ± 2.7	9.1 ± 1.5	11.3 ± 5.2	8.8 ± 2.3
WASO (min)	48 ± 11	35 ± 8	33 ± 6	34 ± 8	36 ± 9	47 ± 12
SEI (%)	87 ± 3	90 ± 2	92 ± 1	91 ± 2	90 ± 2	87 ± 3
N1 (min)	25 ± 5	22 ± 3	25 ± 3	27 ± 4	22 ± 4	21 ± 2
(% TST)	5.8 ± 0.9	4.6 ± 0.7	5.0 ± 0.6	5.5 ± 0.8	4.6 ± 0.8	4.6 ± 0.5
N2 (min)	166 ± 15	217 ± 10*	214 ± 11*	200 ± 12	198 ± 13	191 ± 11
(% TST)	46 ± 3	51 ± 2	47 ± 2	45 ± 2	46 ± 3	49 ± 2
N3 (min)	77 ± 7	97 ± 11	99 ± 9*	104 ± 9*	102 ± 9*	78 ± 9
(% TST)	22 ± 3	23 ± 2	22 ± 2	23 ± 2	24 ± 2	20 ± 2
REM (min)	91 ± 7	92 ± 9	117 ± 10	113 ± 7	107 ± 9	102 ± 12
(% TST)	25 ± 2	21 ± 2	26 ± 2	25 ± 2	25 ± 2	25 ± 2

Table 1: Sleep parameters. At baseline (Night 0), the first night in the thalassotherapy resort (Night 1), the first, second, and third night after hydrotherapy cares (Nights 2, 3 and 4) and the night after week-end at home followed by three days at work (Night 5). TIB: time in bed, SPT: sleep period time, TST: total sleep time, SOL: sleep-onset latency, WASO: wake after sleep onset, SEI: sleep efficiency index, N1, N2, N3, REM (non-rapid eye movement and rapid eye movement) sleep stages. * p<0.05): significant difference with Night 0; § p<0.05: significant difference with Night 1. N=11, Means ± SEM. Nights in the resort are in gray.

Daytime sleepiness

Daytime subjective sleepiness was significantly influenced by the thalassotherapy stay ($\chi 2$=29.94; p<0.001). More precisely, KSS scores decreased at T3 and T4 (Z=2.37; p<0.05 and Z=2.52; p<0.05, respectively) and were still reduced at T5 (Z=2.80; p<0.01), and T6 (Z=2.66; p<0.01) in comparison with T0 (Table 2). Moreover, the participants felt less sleepy at T2, T3, T4, T5 and T6 compared with T1 (p<0.05) (26% less at T2).

Mood states and fatigue

The total mood disturbance (TMD) score obtained in the POMS questionnaire significantly improved throughout the stay in the thalassotherapy resort ($\chi 2$=40.58; p<0.001) (Table 2). We observed a progressive and persistent improvement in TMD until T6 in comparison with T0 (p<0.05) and T1 (-67% at T2 compared to T1). Until T6, negative items Confusion, Anger, Depression and Fatigue were lower than T0 (p<0.001) (Table 2). The scores for Confusion were also significantly lower at T3 (Z=2.66; p<0.01) and T4 (Z=2.24; p<0.05) than at T1. The scores for Depression were lower at T2 (Z=2.80; p<0.01), T3 (Z=2.37; p<0.05), T4 (Z=2.31; p<0.05) and T5 (Z=2.66; p<0.01) than at T1. The scores for Anger were also lower at from T2 (Z=2.10; p<0.05), T3 (Z=2.66; p<0.01), T4 (Z=2.66; p<0.01), T5 (Z=2.38; p<0.05) and T6 (Z=2.43; p<0.05) than at T1. The scores for Fatigue were significantly lower at T3 (Z=2.65; p<0.01), T4 (Z=2.37; p<0.05), T5 (Z=2.70; p<0.01), T6 (Z=2.84; p<0.01). As for vigor (Z=20.61; p<0.01), an improvement was observed at T3 (Z=2.24; p<0.05) and T5 (Z=2.93; p<0.01) in comparison with T0. Moreover, vigor scores were improved from T2 (Z=2.45; p<0.05) to T6 (Z=2.04; p<0.05) in comparison with T1.

The scores obtained in the fatigue Pichot questionnaire were significantly influenced by the thalassotherapy stay ($\chi 2$=28.32; p<0.001). More precisely, post-hoc comparisons indicated that the participants felt less tired since T2 until T6 in comparison with T0 (p<0.05) (Table 2). Moreover, the scores at T2 (Z=2.44; p<0.05), T3 (Z=2.93; p<0.01), T4 (Z=2.70; p<0.01), T5 (Z=2.80; p<0.01), T6 (Z=2.80; p<0.01) were significantly lower than at T1 (-71% at T2).

Anxiety and depression

The scores for anxiety obtained in the HAD questionnaire were significantly changed by the stay in the thalassotherapy resort ($\chi 2$=15.21; p<0.05) (Table 2). Post-hoc comparisons indicated that anxiety was reduced from T2 to T6 in comparison with T0 (p<0.05). Moreover, anxiety was also reduced at T2 (Z=2.03; p<0.05), T3 (Z=2.07; p<0.05), T5 (Z=2.19; p<0.05), T6 (Z=2.19; p<0.05) in comparison with T1 (-17% for T2). Depression scores were also significantly impacted by the thalassotherapy stay ($\chi 2$=18.64; p<0.01). The Wilcoxon comparisons reported that depression scores were lower at T4 (Z=2.07; p<0.05), T5 (Z=2.49; p<0.05) and T6 (Z=2.24; p<0.05) in comparison with T1.

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		T0	T1	T2	T3	T4	T5	T6
KSS	Daytime sleepiness	5.1 ± 0.5	5.3 ± 0.7	3.9 ± 0.6 §	3.8 ± 0.4* §	3.6 ± 0.4* §	3.2 ± 0.5* §	3.6 ± 0.4* §
POMS	Confusion	6.5 ± 0.7	4.9 ± 0.6*	3.8 ± 0.4*	3.3 ± 0.3* §	3.5 ± 0.5* §	3.6 ± 0.3*	3.5 ± 0.5*
	Anger	11.5 ± 2.3	8.8 ± 1.7*	4.6 ± 0.9* §	3.6 ± 0.7* §	4.6 ± 1.0* §	4.5 ± 1.1* §	5.0 ± 1.3* §
	Depression	3.8 ± 1.1	4.0 ± 1.2	1.4 ± 0.5* §	1.4 ± 0.4* §	1.2 ± 0.4* §	1.4 ± 0.4* §	1.9 ± 0.9*
	Fatigue	11.2 ± 1.3	8.7 ± 1.4	6.4 ± 1.6*	3.5 ± 0.5* §	3.1 ± 0.8* §	1.9 ± 0.7* §	2.0 ± 0.4* §
	Tension	8.1 ± 1.3	6.4 ± 0.8	5.3 ± 0.8	5.4 ± 0.5	5.4 ± 0.6	5.4 ± 1.2	4.7 ± 0.7
	Vigor	14.6 ± 1.1	13.6 ± 1.3	15.2 ± 1.5 §	17.7 ± 1.0* §	17.7 ± 1.1 §	18.8 ± 1.1* §	17.6 ± 1.8 §
	Total mood disturbances	26.5 ± 4.8	19.2 ± 4.5*	6.3 ± 4.0* §	-0.7 ± 1.3* §	0.0 ± 2.6* §	-2 ± 2.5* §	-0.5 ± 3.5* §
PICHOT	Fatigue	6.8 ± 0.8	5.3 ± 0.8	3.1 ± 1.0* §	1.7 ± 0.5* §	2.1 ± 0.7* §	1.5 ± 0.7* §	1.7 ± 0.5* §
HADS	Anxiety	6.3 ± 0.8	5.8 ± 0.8	4.8 ± 0.8* §	4.5 ± 0.7* §	4.4 ± 0.9*	4.3 ± 1.0* §	3.7 ± 0.7* §
	Depression	3.2 ± 0.6	3.9 ± 0.8	2.9 ± 0.8	2.8 ± 0.7	2.4 ± 0.7 §	2.0 ± 0.7 §	2.3 ± 0.7 §
VAS	General well-being	57 ± 5	55 ± 5	71 ± 4* §	76 ± 4* §	75 ± 5* §	76 ± 4* §	73 ± 4* §
	Soreness	39 ± 11	32 ± 10	23 ± 8	32 ± 11	18 ± 8*	14 ± 7* §	18 ± 9*
	Relaxation	38 ± 8	43 ± 7	65 ± 6* §	76 ± 4* §	72 ± 6* §	68 ± 7* §	74 ± 3* §

Table 2: Psychological parameters; Scores at baseline (T0), the first, second, third and fourth days in the thalassotherapy resort (T1, T2, T3, T4), after week-end at home (T5) and after week-end at home followed by three days at work (T6). *p<0.05): significant difference with Night 0; §p<0.05: significant difference with Night 1. N=11, Means ± SEM. Nights in the resort are in gray.

General well-being, relaxation and perceived soreness

The general level of well-being of the participants obtained using VAS scales was influenced by the thalassotherapy stay ($\chi 2$=25.67; p<0.001). They felt significantly better (p<0.05) since T2, which lasted until T6 in comparison with T0 and T1 (Table 2) (+23% at T2 compared to T1). They also felt more relaxed ($\chi 2$=32.53; p<0.001) and this, more precisely from T2 to T6 in comparison with T0 and T1 (p<0.05). Finally, the subjective level of soreness ($\chi 2$=22.49; p<0.001) were significantly lower at T4 compared to T0, and stay lower until T6 (p<0.05). Moreover, perceived soreness scores were also lower at T5 than at T1 (Z=2.31; p<0.05).

Sustained attention

The number of lapses observed in the PVT-B test was significantly influenced by the thalassotherapy stay ($\chi 2$=24.66; p<0.001). Post-hoc comparisons indicated that the participants had less lapses from T2 to T6, in comparison with T0 and T1 (p<0.05) (Table 3). The participants had less lapses at T2 compared to T1 (-59%).

	T0	T1	T2	T3	T4	T5	T6
PVT Number of lapses	7.4 ± 1.8	9.4 ± 1.7	3.9 ± 1.1*§	2.9 ± 0.6*§	3.7 ± 1.4*§	4.2 ± 1.0*§	4.4 ± 1.3*§
Lower limb flexibility cm	-5.2 ± 2.9	-6.2 ± 3.1	-6.9 ± 3.1*	-9.1 ± 2.8*	-10.0 ± 2.9*§	-10.1 ± 2.5*§	-11.2 ± 2.5*§
Vertical jump cm	26 ± 3	25 ± 3*	26 ± 3	26 ± 3	27 ± 3	27 ± 3	27 ± 2§

Table 3: Cognitive (sustained attention through the Psychomotor vigilance test, PVT) and physical parameters. At baseline (T0), the first, second, third and fourth days in the thalassotherapy resort (T1, T2, T3, T4), after week-end at home (T5), and after week-end at home followed by three days at work (T6). *p<0.05): significant difference with Night 0; §p<0.05: significant difference with Night 1. N=11, Means ± SEM. Nights in the resort are in gray.

Lower-limb flexibility

The level of dorsal flexion of the participants, measured using the Sit-and-reach test, was significantly impacted by the days of experiment ($\chi 2$=34.86; p<0.001). In comparison with T0 and T1, our results indicated a flexibility improvement particularly at T4, T5 and T6 (p<0.05) (Table 3). The participants were 38% more flexible at T4 compared to T1.

Vertical jump capacity

The level of vertical jump varied throughout our experiment (χ^2=14.03; p=0.03). The participants performed better at T1 compared to T0 (Z=2,09; p<0.05) (Table 3).

Correlation analysis between parameters

The change of TMD between T0 and T4 was positively correlated with the change of the number of lapses (r=0.68). The more TMD score in the POMS decreases, the more important was the decrease in the number of lapses. The evolution of the self-reported general well-being between T0 and T4 was positively associated with the vertical jump capacity (r=0.83). The change of perceived soreness between T0 and T4 was positively associated with the change of fatigue in the Pichot's questionnaire (r=0.77). The more important was the decrease in subjective soreness, the more important was the decrease in fatigue complaint. No other significant correlation was observed.

Discussion

This study showed for the first time that three days of thalassotherapy combined to sleep management have immediate and delayed beneficial effects in healthy workers. Sleep management consisted of asking participants to increase the opportunity to sleep while staying in bed between 22:30 and 07:00 during the four nights in the resort.

We showed that TST was significantly higher during the four nights in the resort compared to the baseline night (Night 0) and we also showed an additional effect of cares the second night compared to the first. This additional effect was not observed at nights 3 and 4, probably because subjects get used to the care or because their need for sleep has lessened. The TST increase during the four nights in comparison with the baseline night was mainly associated to an increase duration of N2 sleep stage during the first two nights (1 and 2) and to an increase of N3 duration at nights 2, 3 and 4 (by nearly 30%), while the REM paradoxical sleep as well as the sleep architecture were unchanged. Other sleep parameters such as sleep-onset latency (SOL) and duration of brief bouts of wake, known as Wake after Sleep Onset (WASO), and sleep efficiency have not been statistically changed. The N3 sleep, also known as slow-wave sleep, represents the deepest sleep stage of non-REM sleep, and has been proven vital for health and well-being, as well as cognitive functions and brain plasticity [31].

In our study, the higher TST at the first night at the resort (Night 1 compared to Night 0) was not followed by reduced daytime sleepiness (i.e., KSS scores) the day after (at T1 compared to T0). However, when TST was at its highest level (at Night 2) because of the combined effect of beginning cares during the day and night-time sleep opportunity, the subsequent daytime sleepiness (at T2 testing) dropped and are further decreased at T3 and T4. Beneficial effects of the thalassotherapy stay including cares on daytime sleepiness were always present at T5 and T6 (after returning home for the weekend home and after 3 days of work).

The thalassotherapy stay including cares and higher opportunity of sleep significantly improved the total mood disturbance (TMD) score in the Profile of mood states (POMS-f) questionnaire, and this was maintained back to home and work. The POMS has been developed to quickly and reliably define and evaluate situational and short-term changes in mood states [25]. For example, there is evidence suggesting a consistent decline in mood states during sleep restriction or during high level athletic competition [32]. As regards to POMS subscales, anger, depression and fatigue scores, there was significant lowering effect of thalassotherapy conditions including cares but also the increase of night-time sleep opportunity, at the third and fourth days (T3 and T4) and the third day back to home. The subjective fatigue score was significantly lowered when assessed both by the POMS questionnaire and the Pichot scale. Additional beneficial effects of the thalassotherapy stay and cares were observed on self-reported anxiety, general well-being and relaxation respectively. The beneficial effects of balneotherapy on mood, well-being, motivation, fatigue, and quality of life have been repeatedly reported in healthy subjects [3,10,12]. In actively working seamen, Rapolienė, et al. [11] reported that two weeks and five times a week of balneotherapy decreased the number and intensity of stress-related symptoms, and pain and general, physical, and mental fatigue, and improved stress-related symptoms management, mood, activation, motivation, and cognitive functions. For these authors, the beneficial effects on relaxation, a sense of well-being, and a reduction of stress are likely related to changes in hormones like cortisol or the neurotransmitter serotonin system [33,34].

The daily cares combined with sleep management improved the cognitive capacity assessed through sustained attention as number of lapses were significantly lower at T2, T3 and T4 (compared to T0 and T1), and remained lower after week-end at home (T5) and after three days of consecutive work (T6). Adding night-time sleep opportunity (sleep intervention) was previously shown effective in improving alertness and performance in sustained attention using the PVT test in short sleeper workers [19,35]. Our results are the first to show that hydrotherapy cares have a beneficial effect on the sustained attention the very next day, which persisted the week after leaving the resort, while the TST returned to the baseline level. The PVT test has previously emerged as the dominant assay of vigilant attention in paradigms of sleep deprivation, as well as intervention with psychoactive, wake-promoting drugs, and finally, the test shows very minor learning effects making it suitable for regular repeated administration over the course of hours or days [36,37]. In addition, it has been evidenced that optimal performance (i.e., the fastest RTs) during the PVT is related to greater activation of a network of subcortical and cortical brain regions in well-rested individuals [38]. Interestingly, changes in the scores of sustained attention and TMD are positively correlated.

Beneficial effects of the thalassotherapy stay with sleep management are present on lower limb flexibility after three days of cares (T4) and were maintained at the fifth (T5) and sixth tests sessions (T6) back to home and then to work. Thalassotherapy cares involved hydrotherapy cares and manual modelling under affusions of the entire body. The sit-and-reach test is widespread use for the evaluation of physical flexibility in the sport and clinical environments. It evaluates hamstring flexibility, rather the whole-body motion, and represents a simple reproducible procedure easy to administer, requires minimal skills training and is particularly useful in large scale [29]. Among the objective physical parameters, the vertical jump was only significantly different at T6 (back to home and work) in comparison with T1. In untrained healthy men, 45 minutes of leg immersion in warm water (44°C) before a stretch-shortening exercise reduced the creatine kinase activity (indirect blood marker of exercise-induced muscle damage) and prevent prolonged decreases in jump height and maximal voluntary muscular force [39]. The limited effect of hydrotherapy cares on the jump capacity in our participants is probably related to the fact that we did not specifically explore it in response to an exercise protocol. In our study, the beneficial effect of thalassotherapy cares was mainly observed on muscle flexibility after three days cares and is interestingly maintained the week after, underlying a delayed beneficial response to muscular mobilization. This may be related in part to thermal water effects that promotes dilation of blood vessels, and increases blood oxygenation and metabolic rate [5]. These effects would increase oxygen supply to the skeletal muscles, which would facilitate muscular improvement such as flexibility of the musculotendinous unit. Nevertheless in our study, we assessed eleven healthy and actively working individuals, a relatively small number of subjects, thus these results deserve to be confirmed in a larger number of subjects. Future research should aim to replicate these findings adding a control condition and preferably with a crossover design.

This study's multiple approaches, using objective and subjective tools, was challenging and allowed new insights into the beneficial effects of 3 days of thalassotherapy cares combined with sleep management for mood states, well-being, health outcomes, and cognitive and physical capacities in the general working population. We suggested that hydrotherapy cares (3 days with two 2-hours sessions of cares) and sleep management resulting in increased total sleep time (TST) in the second night may explain immediate positive effects on self-reported psychological outcomes and objectively measured vigilance attention but also delayed positive effects on lower limb flexibility. It also would be interesting to evaluate interest of thalassotherapy in the prevention or management of professional burnout that we previously described as associated with anxiety and sleep disorders [40].

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Authors Contributions

The authors have made substantial contributions: conception and design of the study: Mounir Chennaoui, Clément Bougard and Didier Lagarde; acquisition, analysis and interpretation of data: Mounir Chennaoui, Clément Bougard, Pascal Van Beers, Mathias Guillard, Catherine Drogou; manuscript writing: Mounir Chennaoui, Danielle Gomez-Merino, Clément Bougard; final approval of the version to be submitted: all authors.

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Competing Interests

None.

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