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Effects of moderate mountain hiking and balneotherapy on community-dwelling older people: A randomized controlled trial

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ABSTRACT

Background: Population aging is one of the greatest socio-economic challenges of the 21st century, as aging is a well-known risk factor for the development of chronic diseases and functional disabilities. A sedentary life-style promotes the progression of chronic diseases and impaired mobility in older people. Therefore, physical activity is essential for healthy aging. The optimal exercise program for older persons, which covers fall prevention as well as endurance and strength, still remains unclear.
Methods: We performed a longitudinal, randomized, controlled intervention study to investigate the combined effects of moderate mountain hiking and balneotherapy on gait, balance, body composition and quality of life on high-functioning people aged 65–85 years. The intervention group ($n = 106$) participated in a seven-day holiday with mountain hiking tours. In addition, balneotherapy was applied. The control group ($n = 33$) spent a typical seven-day cultural holiday with sightseeing. Medical examinations were performed before (day 0) and after the intervention week (day 7), after two months (day 60) and after half a year (day 180). Statistical analysis was done by fully nonparametric analysis of variance-type testing.
Results: An improvement of static balance was observed in the intervention group (treatment effect $p = 0.02$). No significant changes were found in dynamic balance, measured as center of pressure, gait parameters and self-assessed balance confidence. Only for gait speed, a short-term effect was observed (treatment $p = 0.03$). The gait speed increased in the intervention group. Although quality of life improved significantly in both groups, a sustainable effect until day 60 is only visible in the intervention group (interaction effect for treatment and day-60 $p = 0.02$). Significant interaction effects of treatment and time were found for total body water ($p = 0.04$), appendicular muscle mass (p = 0.04) and fat free mass index ($p = 0.03$), all indicating an increase of these variables in the intervention group.
Conclusions: A seven-day intervention with moderate mountain hiking in combination with balneotherapy is an effective training for highly functioning older persons, inducing short-term improvements in static balance and quality of life.

1. Introduction

The world's population is growing old (United Nations et al., 2017). Aging is a well-known risk factor for the development of chronic diseases, and is characterized by the accumulation of molecular and cellular damages, which lead to structural and functional aberrancies (López-Otín et al., 2013). Especially low-grade inflammatory processes are under suspicion of playing a central role in the development of

Abbreviations: ABC scale, Activity Specific Balance Confidence Scale; GDS, Geriatric Depression Scale; BIA, Bio-impedance analysis; DSST, Digit Symbol Substitution Test; MFT, Multifunktionale Trainingsgeräte (Multifunctional Training Equipment); nparLD, nonparametric longitudinal data analysis; F1-LD-F1 Model, Model for longitudinal data with one whole-plot and one sub-plot factor; IV, independent variable; DV, dependent variable; RTE, relative treatment effect; Rz, resistance; T0, T1, T1, T3, Time point 0 (day 0), time point 1 (day 7), time point 2 (day 60), time point 3 (day 180); TSH, Thyroid Stimulating Hormone; Xc, reactance; % GCT, percentage of gait cycle time

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chronic diseases (Giunta et al., 2008; Lencel and Magne, 2011; Libby, 2006). Another hallmark of aging is an altered body composition, which is mainly characterized by the loss of muscle mass and the accumulation of body fat (Falsarella et al., 2015). The reduction of skeletal muscle mass is very frequent among older people and is responsible for functional disabilities, as mobility, strength and balance depend to some extent on the skeletal muscle tissue (Janssen et al., 2002). Loss of muscle strength and proprioceptive feedback, cognitive impairment, changes in acuity of vision or postural hypotension increase the risk of falls in advanced age (Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society, 2011). Beside the direct consequences of falls for mobility and health status, fear of falling is a serious problem. It leads to activity avoidance and further loss of muscle mass and balance (Evitt and Quigley, 2004). In addition to the loss of muscle mass, the aerobic capacity of aged people declines. It is a vicious circle – decline in aerobic capacity or fear of falling causes further avoidance of physical activity and further loss of muscle mass and strength (Fleg et al., 2005). Falls are one of the leading causes of poor health status among people aged 65 years or older (Stevens et al., 2008). Therefore, fall prevention and healthy aging are relevant public health issues, as loss of function is associated with high health care costs, not only in terms of hospitalization and increasing demand for health care services, but also regarding its long-term consequences like depression and a reduced quality of life (Kumar et al., 2016; Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society, 2011).

There is growing evidence that physical exercise, in contrast to a sedentary lifestyle, prevents the progression of chronic diseases and mobility limitation in older persons. Exercise cannot stop the processes of aging, but it supports healthy aging (American College of Sports Medicine et al., 2009). Recommendations for fall prevention and aerobic training include a variety of interventions reaching from multifactorial interventions addressing balance, gait, endurance, resistance and strength trainings for older people (Bouaziz et al., 2017; Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society, 2011). However, the optimal training program for these still remains unclear.

Mountain hiking is a very popular leisure time activity among aged people. More than 6 million people older than 60 years undertake mountain activities in the Alps every year (Burtscher, 2004). Unfortunately, such hiking activities are very often restricted to one tour per week. Hiking at moderate intensity once a week does not improve cardiovascular risk factors in healthy aged persons (Gatterer et al., 2015). To trigger sustainable health effects, regular physical activity is necessary. However, an active vacation at moderate altitude (1.500–2.500 m) is known to induce positive and sustainable health effects on adults: It improves the quality of sleep, well-being, and physical recovery (Schobersberger et al., 2010). Furthermore, physical activity in natural environments like forests, meadows or alpine pastures, which is also known as "green exercise" promotes positive effects on mental well-being in comparison to indoor sports (Barton et al., 2012). Greater enjoyment and less negative feelings like frustration and even a greater intent to repeat the exercise are experienced when training outdoors in natural environments (Niedermeier et al., 2017; Thompson Coon et al., 2011). Yet, valid data concerning the specific effects of mountain hiking on gait pattern and balance in aged persons are still missing.

Furthermore, little is known about potential health effects of balneotherapy in older people and whether it can represent a complementary intervention to exercise training. Balneotherapy uses thermal waters or so-called healing waters to treat chronic diseases. Its beneficial effects on various systems of the body are widely used to treat musculoskeletal diseases, to improve immunity and to relieve pain (Mooventhan and Nivethitha, 2014). Bathing in thermal water triggers several physiological responses like vasodilation, gate control mechanism, elevation of beta-endorphin levels and muscle relaxation (Onat et al., 2014), which could positively affect regeneration after exercise like e.g. mountain hiking.

With a growing life expectancy, it has become more and more important what proportion of life is spent in good health. Although life expectancy is increasing, disability-free life expectancy, which is focusing on life years spent in healthy state, is not. The gap between life expectancy and healthy life expectancy is even growing (Liotta et al., 2018). Therefore, interventions to prolong disability free life expectancy are a relevant public health issue. The beneficial effects of physical activity on mobility and chronic diseases in older people are well known. However, little is known about the specific effects of moderate mountain hiking on the balance of aged community-dwelling people. In addition, there is little evidence concerning the beneficial effects of balneotherapy as a complementary intervention to exercise training. From this background, we performed a randomized, controlled clinical trial to investigate the combined effects of moderate mountain hiking and balneotherapy on balance and gait parameters of community-dwelling people in the age of 65–85 years. Beside specific gait and balance parameters, quality of life, balance confidence and cognitive performance were assessed.

2. Materials and methods

2.1. Study design and setting

The presented data is part of a larger longitudinal, randomized, controlled intervention study (BERG-Study, ISRCTN-18092043), which investigates the combined effects of exercise and balneotherapy on relevant markers of immunosenescence and balance in aged persons. This work focuses on balance and gait parameters. The intervention group participated in a seven-day balneotherapy and mountain hiking program. The intervention group was further subdivided into three different subgroups, each bathing in another type of water. In contrast, the control group spent a classic seven-day holiday with sightseeing. Allocation ratio for the three intervention groups and the control group was set at equal sample size. The study protocol was approved by the Ethics Committee of Salzburg (E1987/5-2016) and conducted in the Tegernsee Valley (Germany), Bad Reichenhall (Germany) and Abtenau (Austria) between April and July 2016.

2.2. Participants

Eligible participants were community-dwelling people between 65 and 85 years with at least one typical aging-associated disease, like osteoporosis, hypertension or diabetes type 2. Participants were recruited all over Austria and Germany through advertisements in newspapers and communication via web page between February and April 2016. Written informed consent was obtained from all study members. Inclusion/exclusion criteria were defined using an adapted version of the SENIEUR protocol (Ligthart et al., 1984). Inclusion criteria were as follows: age between 65 and 85 years, community-dwelling, stable chronic non-immunologically condition and normal range of reference laboratory parameters. The physical ability to participate in 3–5 h moderate mountain hiking tours with a difference of 200–500 m in altitude. Exclusion criteria were as follows: cognitive impairment (Folstein Mini Mental State < 23), depression (Geriatric Depression Scale ≥ 6), poorly controlled hypertension (systolic blood pressure ≥ 180 mm Hg), renal insufficiency (serum creatinine ≥ 2.0), elevated glucose (non-fasting > 200 mg/dl), malnutrition (serum albumin < 3.2 g/l; total lymphocyte count $< 1500/ml^3$), anemia (hematocrit $< 30\%$), TSH (< 0.3, > 4.0 mU/l), immunologically mediated chronic conditions, immunodeficiency, severe respiratory disorders, psychiatric disorders, arteriosclerotic event during 2 weeks before enrollment, cardiac insufficiency, malignancies and lymphoproliferative disorders, history of alcoholism, current drug abuse, currently smoking > 10 cigarettes/d and contraindications for balneotherapy.

2.3. Intervention

The participants of the intervention and control groups spent a seven-day holiday either in Bad Reichenhall (Germany, GPS: 47° 43′ 49.21″ N 12° 52′ 53.717″ E) located 473 m above sea level, Bad Wiessee (Germany, GPS: 47° 43′ 0.676″ N 11° 43′ 11.845″ E) located 740 m above sea level or Abtenau (Austria, GPS: 47° 33′ 58.457″ N 13° 20′ 59.219″ E) located 714 m above sea level. All participants were hosted in local hotels and received the same meals. The exercise program for the intervention groups was identical in all three regions and was composed of five guided GPS-monitored mountain hiking tours (Garmin Fenix 1, Garmin Ltd., Swiss) and one resting day (day 4). All tours were guided by at least two tour guides. The tour guide at the head of the group limited the pace to an appropriate level, so that everybody could follow the group. All participants were instructed to keep up with the group, but not to overextend their fitness level. All participants completed the tours without relevant time differences. Daily average difference in altitude was 305 m and 10 km in distance. The duration of the hiking program ranged between 3 and 5 h, depending on the difficulty and length of the tour. The intervention group of Bad Reichenhall received five sole-baths (12% Sole, 36 °C). The participants of Bad Wiessee bathed three times in Iodine-Sulfur-Na-Cl-water (36 °C, total mineralization 32,315 mg/l: Cl 18.42%, Na 15.16%, iodine 0.12%, HS 0.24%; H_2S: 77 mg/l). The intervention group of Abtenau received five baths in highly mineralized Na-Ca-Cl-SO_4-water (36 °C, total mineralization 6080 mg/l: Na 49.7%, Ca 38.3%, Cl 51.3%, SO_4 43.3%). The difference in the bathing frequency resulted from the individual medical recommendations from the local health care providers. Each bathing session lasted 20 min, which was followed by a 30 min resting session. Due to the location-bound water types, no blinding of the treatments was performed.

The control group spent a classic cultural seven-day holiday and participated in six 2.5–6 h local sightseeing activities at the same time. These activities included a visit of a cheese diary, the local Casino, salt mine and museums, a bus tour to a local lake, a boat trip and an author's reading. The participants of the control group were hosted in the same hotels in Bad Reichenhall, Bad Wiessee and Abtenau, as the intervention groups. Hiking activities or physical training or bathing in the local wellness and balneotherapy facilities were not allowed for the control group. All transfers were made by buses. Follow up examinations were performed 60 days and 180 days after the intervention.

2.4. Data collection and outcomes

All medical examinations were performed at the Department of Geriatric Medicine, Salzburger Landeskliniken (Austria). Data were anonymized by four-digit-ID. Static balance was set as primary outcome. Secondary outcomes were dynamic balance including gait parameters, body composition, cognitive performance, self-reported quality of life, balance confidence and activity level, all assessed by validated questionnaires.

Assessments were performed at baseline (day 0; T0), after the intervention week (day 7; T1), two months after the intervention (day 60, T2) and after half a year (day 180; T3). Effects on day 7 are considered short-term effects and effects on day 180 are considered long-term effects. The study schedule is presented in Fig. 1. At each time point, 12 ml of forearm venous blood were collected in tubes (Vacuette®, Greiner Bio-One GmbH, Austria) according to manufactures guidelines. The analysis of the inclusion criteria serum albumin, cholesterol, serum creatinine, TSH and differential blood count was performed by the University Institute for Medical and Chemical Laboratory Diagnostics of the Paracelsus Medical University Salzburg (Salzburg, Austria). The German version of WHO-5 Well-Being Index (Bonsignore et al., 2001) and the activity specific Balance Confidence (ABC) scale (Powell and Myers, 1995) were handed out for completion on T0, T1, T2 and T3. The German PAQ-50+ Questionnaire (Huy and Schneider, 2008), assessing the activity level of persons older than 50 years was handed out on T0, T2 and T3. Activities of the intervention and control group were monitored via Fitbit Charge HR™ activity wristbands (Fitbit, Inc. San Francisco, USA) between T0-T1.

2.5. Measurements of gait and balance

Gait analysis was performed using Zebris FDM semiautomatic gait analysis (Donath et al., 2016) mat 300 × 60 cm (Zebris Medical GmbH, Germany). Data were collected with a minimum number of 20 steps for each individual. All individuals were instructed to walk barefoot at a self-selected speed. The following temporal and spatial gait parameters were evaluated: gait velocity (m/s), cadence (step/min), variation of velocity (%), stride width (cm), stance (% GCT), swing (% GCT), double support (% GCT), center of pressure of the anterior-posterior position (mm), anterior-posterior variation (mm), lateral center of pressure (mm) and variation of the lateral center of pressure (mm).

Static balance was assessed by MFT-S3 Check (Multifunctional Training Equipment - Bodywork, Trend Sport Trading GmbH, Großhöflein, Austria), which measures static balance in two-legged stand on a labile balance disc. Participants were instructed to enter the labile balance disc and to keep the disc centered. Within two measurement cycles, postural stability, body symmetry and sensorimotor function were assessed. The balance score of each individual is presented as percent of predicted, based on normative data, offered by the MFT-S3-Check (Raschner et al., 2008).

2.6. Bio-impedance-analysis

Resistance (Rz) and reactance (Xc) were measured on T0, T1, T2 and T3 under standardized conditions by a four-terminal impedance analyzer (BIA-101, RJL Systems; Detroit, USA) with two electrodes placed on the right hand and two on the right foot according to the standard procedure described elsewhere (Lukaski et al., 1986). According to manufactures manual the resolution for reactance and resistance are ± 0.1 Ω. Analysis of BIA data were performed with Bodygram PLUS software (Akern S.r.l; Pontassieve, Italy). The following variables were analyzed: total body water (l), fat mass index (kg/m^2), fat-free mass index (kg/m^2), body cell mass index (kg/m^2), muscle mass index (kg/m^2) and appendicular muscle mass index (kg/m^2).

2.7. Digit Symbol Substitution Test

The Digit Symbol Substitution Test (DSST) is a simple pencil and paper test, assessing psychomotor performance, incidental memory (ability to filter relevant information) and selective attention (Kaufman, 1983). The subject is given a key grid of numbers and matching symbols and a test section with numbers and empty boxes. The test consists of filling as many empty boxes as possible in 90 s. DSST was performed on T0, T1, T2 and T3.

2.8. Randomization and sample size

Randomization was performed using an open-source add-in (Daniel's XL Toolbox, Ver. 7.2.7) for the Microsoft Excel® spreadsheet software, with gender, age and sample size as allocation criteria (Kraus, 2014). The maximal allowed group difference was set as 4. As allocation method Kullback-Leibler Divergence method was used. Recruitment of eligible participants, randomization and assignment to treatments were performed by the same researcher. The allocation to the treatments was concealed.

The sample size for the study was calculated with G*Power (G*Power Ver. 3.0.10, Franz Faul, Universität Kiel, Germany) statistical

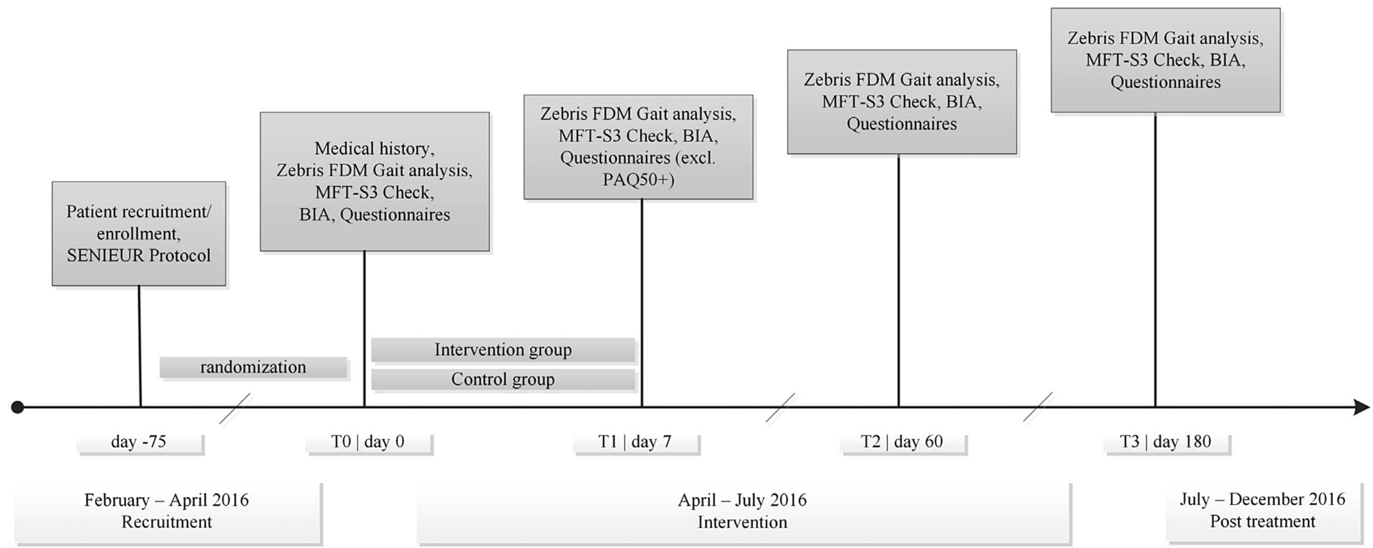

Fig. 1. Study schedule. Timetable of the study.

packages. Effect size for the power analysis was derived from a former clinical trial measuring salivary IgA (Grafetstätter et al., 2017). The required group size for getting a power of 85%, type I error (α) of 0.05 and effect size (f) of 0.38 was calculated as 32. Dropout rate was anticipated as 10%.

2.9. Statistical analysis

All statistical analyses were performed using the R-GNU software environment (General Public License, R Foundation for Statistical Computing, Vienna, Austria, version 3.4.4). Statistical significance was set at the level of a < 0.05 for all tests. All variables are expressed as mean ± standard deviation (SD) unless otherwise indicated. Randomly missing values were replaced using the standard procedure last outcome carried forward.

Longitudinal data analysis were performed using the nparLD-package (Noguchi et al., 2012), which offers a fully nonparametric analysis of variance-type testing. For all tests we used ANOVA-Type Statistics. In a first F1-LD-F1 Model we included the water-type (Iodine-Sulfur vs. Sole vs. Mineral) as whole-plot-factor and time as a sub-plot-factor (T0, T1, T2 and T3) to test the hypothesis of no different water effects. In a second F1-LD-F1 Model we included the treatment (hiking & bathing vs. sightseeing) as whole plot factor and time as sub-plot factor (T0, T1, T2 and T3). Post hoc tests were applied in case of a significant main effect for time. For this, we also used nparLD (F1-LD-F1) and corrected the *P*-values according to Holm-Bonferroni. As a measure of effect, we used the relative treatment effect (RTE). The RTE is a number between 0 and 1 and can be interpreted as follows: A RTE of 0.5 means no effect. A RTE > 0.5 means a tendency for subjects in a subgroup to score at least as high as a randomly chosen subject from the whole sample. A RTE of 0.7 for a subgroup means that the probability of a randomly chosen person from the subset having a higher score than a person randomly chosen from the whole data set is estimated to be 70%. A RTE of 0.2 for a subgroup means that the probability of a randomly chosen person from the whole subset having a lower score than a randomly chosen person from the subset is estimated to be 20%.

Multiple regression analysis was performed using the data from time point 0 (T0, day 0). The following gait parameters were set as dependent variables (DV): velocity (m/s), cadence (step/min), variation of velocity (%), stride width (cm), stance (%), swing (%), double support (%), center of pressure of the anterior-posterior position (mm) and lateral center of pressure (mm). Independent variables (IV) were data from inclusion/exclusion criteria, balance, gait, questionnaires, DSST and BIA-Analysis. All dependent and independent variables were checked for correlation and collinearity. Only significant variables were kept in the model.

3. Results

3.1. Study participants and baseline characteristics

Out of 204 potential participants, 139 eligible persons were enrolled and invited for the intervention week. Seven persons declined to participate due to personal reasons ($n = 2$ control, $n = 5$ intervention) after enrollment. Within the intervention groups, three persons discontinued the study because they could not keep up with the exercise level. One person from the control and one from the intervention group were lost during the follow-ups for personal reasons. Four participants of the intervention group were excluded from the analysis because they did not meet the inclusion criteria any more. One participant developed a leukemia, another participant presented himself with constantly decreasing cognitive performance and two participants showed symptoms of depression.

For the per protocol analysis 93 participants of the intervention groups and 30 participants of the control group (Fig. 2) were included. Baseline characteristics do not show relevant differences between the study groups (Table 1). The exercise, balneotherapy and sightseeing program was well tolerated by all participants. All participants of the exercise group were able to finish the different tours, without meaningful time differences. One participant tripped over his hiking sticks during a hike and sprained his wrist. Another participant hurt his knee. Both persons were able to complete the study. No further harms or unintended effects like injuries or severe cardiorespiratory events were observed.

3.2. Activity by Fitbit Charge HR™

The activities of the control and the intervention group were monitored throughout the intervention week with FitBit Charge HR™ wristbands. The intervention group made on average 20.784 ± 2.395 steps/day. The control group had on average 11.721 ± 3.165 steps/day. Thus, the intervention group made significantly more steps per day than the control group (Mann-Whitney *U* Test $p < 0.001$). All hiking tours were additionally tracked via GPS watches (Garmin Fenix 1, Garmin Ltd., Swiss) to verify the accuracy of the FitBit wristbands (see Table 2). With 305 ± 146 m in altitude/day, the intervention group

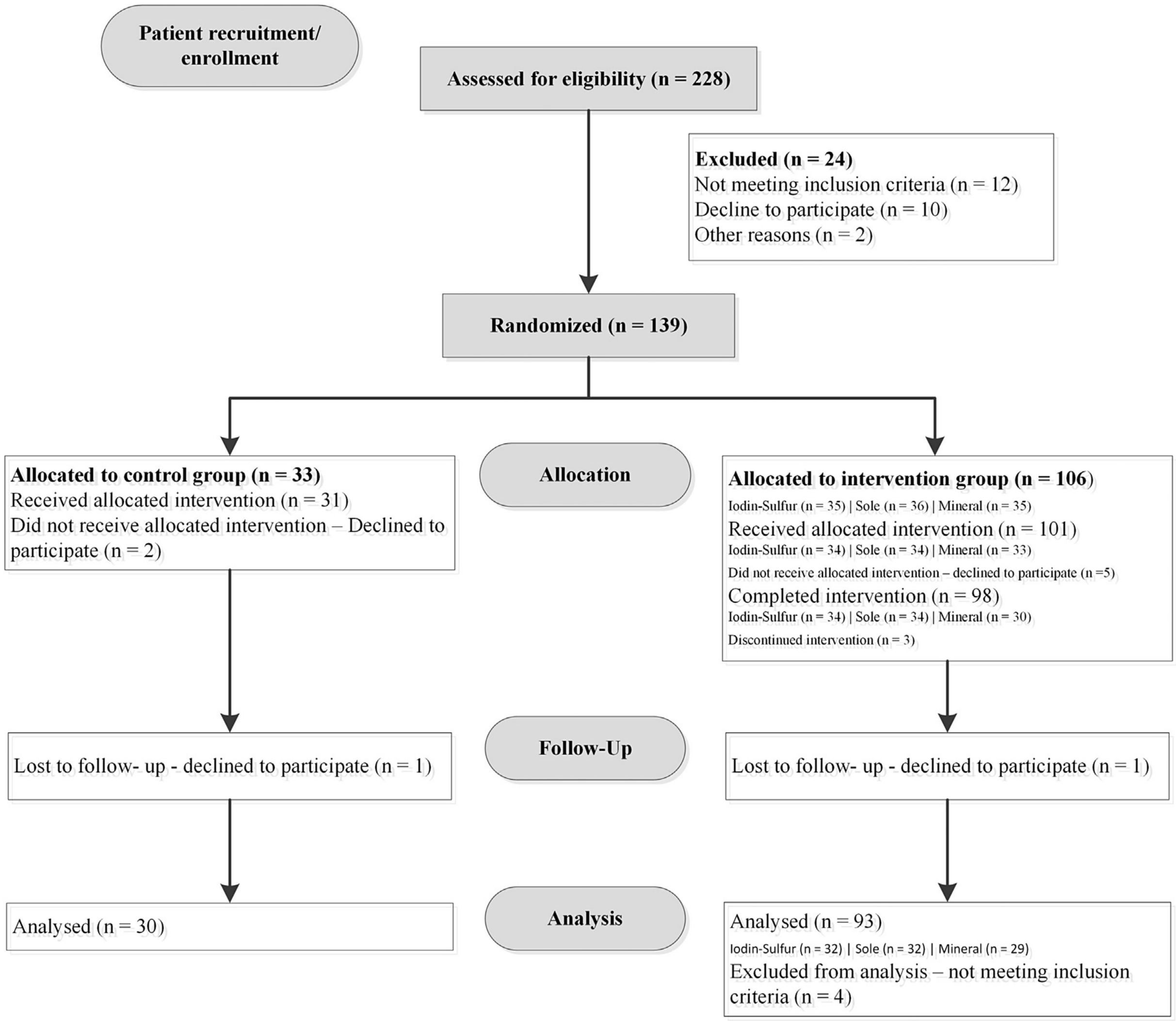

Fig. 2. Study Flow-chart of included and excluded patients.

Table 1
Baseline characteristics of the study participants.

	Control	Intervention			
		Iodine-Sulfur	Alpensole	Mineral	Balneo
Number	30 (33)	32 (35)	32 (36)	29 (35)	93 (106)
Sex -male	13	14	16	16	46
Sex- female	17	18	16	13	47
Hypertension|Osteoporosis[a]	43%|11%	34%|23%	46%|10%	39%|7%	40%|13%
Arthrosis|Diabetes type 2[a]	40%|9%	34%|9%	41%|3%	49%|5%	42%|5%
Age (years)	71.20 ± 5.08	71.09 ± 5.04	72.44 ± 3.87	71.97 ± 4.27	71.83 ± 4.41
Height (m)	1.67 ± 0.087	1.66 ± 0.086	1.69 ± 0.091	1.69 ± 0.092	1.68 ± 0.090
Weight (kg)	81.97 ± 16.10	74.78 ± 16.20	75.30 ± 15.74	77.21 ± 15.16	75.72 ± 15.59
BP-Systole (mm Hg)	140.87 ± 15.64	145.19 ± 17.31	145.12 ± 21.98	146.03 ± 15.01	145.43 ± 18.23
BP-Diastole (mm Hg)	78.40 ± 9.94	80.84 ± 10.33	79.62 ± 10.56	81.34 ± 7.44	80.58 ± 9.53
Mini Mental State	28.43 ± 1.36	28.00 ± 1.30	28.34 ± 1.36	28.03 ± 1.21	28.13 ± 1.29
GDS	0.77 ± 0.94	1.12 ± 1.43	1.00 ± 1.27	1.21 ± 1.45	1.11 ± 1.37
ABC (%)	91.86 ± 10.37	92.07 ± 7.17	91.59 ± 10.32	93.12 ± 7.59	92.23 ± 8.43
Albumin (g/l)	4.44 ± 0.18	4.52 ± 0.27	4.47 ± 0.18	4.48 ± 0.17	4.49 ± 0.21
Creatinine (mg/dl)	0.91 ± 0.27	0.88 ± 0.18	0.97 ± 0.20	0.94 ± 0.17	0.93 ± 0.19
TSH (mU/l)	1.46 ± 0.75	1.56 ± 0.83	1.23 ± 0.75	1.71 ± 0.74	1.49 ± 0.79

Data are presented as the mean ± SD; No significant baseline differences were found; Balneo includes all three intervention groups, *GDS* Geriatric Depression Scale, *ABC* Activity Specific Balance Confidence Scale, *TSH* Thyroid Stimulating Hormone.

[a] Frequencies of age related diseases among the participants.

Table 2
Characteristics of the mountain hiking program.

Tour	Altitude	Distance
Tour 1	114.5 ± 13.4 m	10.7 ± 1.7 km
Tour 2	231.7 ± 13.6 m	9.3 ± 1.9 km
Tour 3	301.0 ± 8.5 m	9.4 ± 0.8 km
Tour 4	280.0 ± 13.2 m	13.2 ± 0.5 km
Tour 5	523.0 ± 8.9 m	6.8 ± 1.6 km
Average	304.6 ± 145.7 m	9.6 ± 2.5 km

Data are presented as the mean ± SD of the belonging tours in all three regions.

made more meters in altitude/day than the control group with 54 ± 36 m in altitude/day (Mann-Whitney U Test $p < 0.001$).

3.3. Longitudinal data analysis

No significant effects regarding the water type were found for the selected parameters. Therefore, the results from the first F1-LD-F1 model with the water type as whole plot factor are not shown. For the second F1-LD-F1 model, all three intervention groups were analyzed together as one intervention group (balneo group). This work represents only a subset of a larger study, which also investigated possible effects of the intervention on immunosenescence. As the three water types are characterized by a unique composition, different effects on inflammatory and immunosenescence parameters are expected.

3.3.1. PAQ-50 Questionnaire

The analysis of variance type test of the subscale "Energy consumption" in the PAQ-50+ questionnaire revealed no significant effects for treatment ($F_{(1,\ \infty)} = 2.01$, $p = 0.157$, RTE = 0.48 for intervention) and time ($F_{(1.9,\ \infty)} = 1.17$, $p = 0.308$, RTEs = 0.50, 0.54, 0.51 for T0, T2 and T3). Also, no significant interaction effect of treatment and time was found ($F_{(1.9,\ \infty)} = 0.99$, $p = 0.366$, RTEs = 0.49, 0.50, 0.46 for intervention at T0, T2 and T3), thus indicating, that the activity patterns of the participants did not change throughout the study.

3.3.2. Gait Analysis and center of pressure

Results from the F1-LD-F1 analysis of gait parameters and center of pressure are presented in Table 3. The analysis of variance type test for gait velocity revealed a significant main effect for treatment ($p = 0.025$). No significant time- or interaction effects were observed. For cadence, only a significant main effect for time was observed and post hoc test revealed no interaction effects at the single time points (T1, T2 or T3). Stride width, variation in velocity, double support, swing (left/right) and stance (left/right) are all presenting a significant baseline difference between the intervention and the control group. In addition, all these parameters show a significant main effect for treatment. Because of the flat and parallel RTE-profile in combination with a significant baseline difference, a significant effect of the intervention on these parameters can be excluded. No significant effects in the center of pressure of the lateral position, lateral variation, anterior-posterior position and the variation in the anterior-posterior position were found.

3.3.3. Regression Analysis of gait parameters

The majority of the variation in the selected gait parameters can be explained by gait parameters itself. The double stride time was identified as the only and most predictive variable for cadence ($F_{(1,\ 131)} = 9285$, $p < 0.001$, $R^2 = 0.99$). The participant's cadence is equal to 232.6–111.9 s (stride time). A significant regression equation was found for gait velocity ($F_{(2,\ 130)} = 7765$, $p < 0.001$), with a R^2 of 0.99. The gait velocity is equal to 4.31 + 0.03 cm (stride length) – 4.04 s (stride time). Both independent variables are highly significant ($p < 0.001$) predictors. The variation in gait velocity can be poorly explained by the available parameters ($F_{(2,\ 130)} = 28.3$, $p < 0.001$, R^2 of 0.30). The variation in velocity is equal to 4.85–0.06 cm (stride length) + 0.04 mm (ant.-post-position). Both, double stride length and anterior-posterior position were significant ($p < 0.001$) predictors. Also, the stride width can be poorly explained by the available variables ($F_{(2,\ 130)} = 22.37$, $p < 0.001$, $R^2 = 0.26$). The stride width is equal to 7.60 + 0.10 kg (muscle mass) – 0.03% (S3 - Stability Index). Both, muscle mass ($p < 0.001$) and stability index ($p = 0.004$) were significant predictors for the stride width. The variation in double support can be mainly explained by the swing left and swing right ($F_{(2,\ 130)} = 13{,}070$, $p < 0.001$) with an R^2 of 0.99, where both are significant predictors ($p < 0.001$). The double support is equal to 99.92–1.02% (swing left) – 0.98% (swing right). Swing left and swing right itself present with a perfect fit for each other. No other variable was found as a significant predictor.

A significant regression equation was found or the anterior posterior position of the center of pressure ($F_{(2,\ 130)} = 47.35$, $p < 0.001$, $R^2 = 0.42$), whereas 106.3 + 0.56 kg (muscle mass) + 1.35 mm (anterior-posterior variation) accounts for the anterior-posterior position. Both independent variables are highly significant predictors ($p < 0.001$). No significant regression equation was found for the lateral position of the center of pressure.

3.3.4. MFT-S3 Check Stability Index and ABC-Scale

As the MFT-S3 Check Stability Index is a combination of symmetry and sensorimotor function, only results from the Stability Index are presented. The analysis of variance type test for the Stability Index revealed a significant main effect for treatment ($p = 0.025$). No significant main effects for time- or interaction were observed (Table 4). Both, intervention- (92.23 ± 8.43%) and control group (91.86 ± 10.37%) are presenting with high baseline activity specific balance confidence. No significant main effects for treatment- or interaction were found for the ABC-Scale. Although a significant main effect for time ($p = 0.003$) was observed, post hoc test did not reveal any further effects (Table 4).

3.3.5. WHO-5 and Digit Symbol Substitution Test (DSST)

No significant main effect for treatment- or interaction was observed for the WHO-5 Well-Being index. A significant main effect for time was detected ($p < 0.001$) and post hoc test revealed a significant interaction effect at day 60 ($p = 0.017$), indicating a sustainable effect of the intervention (Table 4). The analysis of variance type test for the Digit-Symbol-Substitution Test revealed no significant main effects for treatment- or the interaction. A significant main effect for time ($p < 0.001$) was found and post hoc test did not reveal any interaction effects at the single time pints (Table 4).

3.3.6. Bio impedance analysis

The results from the F1-LD-F1 model of the BIA-analysis are presented in Table 4. No significant changes were found for the phase angle, the muscle mass- and body cell mass index (kg/m^2). For reactance and resistance significant main effects for time ($p < 0.001$), but not for treatment- or the interaction, were found. Post hoc test revealed no further effects. For total body water (l) a significant main effect for time ($p \leq 0.001$) and the interaction were found ($p = 0.035$). Post hoc test revealed no further effects. For the appendicular muscle mass index (kg/m^2), a significant main effect for time was found and post hoc test revealed a significant interaction effect on day 7 ($p = 0.019$). The analysis of the fat free mass index (kg/m^2) revealed a significant main effect for time ($p < 0.001$) and the interaction ($p = 0.034$). According to post hoc test, the interaction effect is also present on day 7 ($p = 0.023$).

The fat mass index (kg/m^2) presents with a significant baseline difference (Mann-Whitney *U* Test $p < 0.001$). The control group (9.06 ± 4.08 kg/m^2) is characterized by a higher fat mass index in comparison to the intervention group (6.58 ± 2.36 kg/m^2). The analysis of variance type test revealed a significant main effect for the

Table 3
Results from the F1-LD-F1 Model including relative treatment effects (RTE) for gait parameters.

Parameter	F1-LD-F1 Model			Relative treatment effects (RTE)							
		F	p-Value			Time		Interaction effects			
								Balneo		Control	
Gait velocity (m/s)	Treat	5.03 (1.00, ∞)	0.025*	Balneo	0.53	T0	0.45	Balneo × T0	0.49	Co × T0	0.41
	Time	1.31 (2.65, ∞)	0.271n.s.	Control	0.40	T1	0.48	Balneo × T1	0.55	Co × T1	0.42
	Treat × Time	1.48 (2.65, ∞)	0.223n.s.			T2	0.48	Balneo × T2	0.56	Co × T2	0.40
						T3	0.45	Balneo × T3	0.53	Co × T3	0.38
Cadence (steps/min)	Treat	1.53 (1.00, ∞)	0.216n.s.	Balneo	0.52	T0	0.45	Balneo × T0	0.47	Co × T0	0.42
	Time	3.56 (2.51, ∞)	0.019*	Control	0.45	T1	0.50	Balneo × T1	0.53	Co × T1	0.47
	Treat × Time	0.79 (2.51, ∞)	0.479n.s.			T2	0.49	Balneo × T2	0.52	Co × T2	0.46
						T3	0.50	Balneo × T3	0.55	Co × T3	0.45
Variation in velocity (%)	Treat	0.14 (1.00, ∞)	0.708n.s.	Balneo	0.50	T0	0.51	Balneo × T0	0.50	Co × T0	0.52
	Time	0.51 (2.53, ∞)	0.644n.s.	Control	0.51	T1	0.51	Balneo × T1	0.52	Co × T1	0.51
	Treat × Time	1.53 (2.53, ∞)	0.150n.s.			T2	0.51	Balneo × T2	0.46	Co × T2	0.55
						T3	0.49	Balneo × T3	0.49	Co × T3	0.48
Stride-width (cm)	Treat	6.16 (1.00, ∞)	0.013*	Balneo	0.47	T0	0.55	Balneo × T0	0.47	Co × T0	0.62
	Time	0.50 (2.39, ∞)	0.638n.s.	Control	0.60	T1	0.53	Balneo × T1	0.46	Co × T1	0.61
	Treat × Time	0.54 (2.39, ∞)	0.615n.s.			T2	0.53	Balneo × T2	0.45	Co × T2	0.60
						T3	0.53	Balneo × T3	0.48	Co × T3	0.58
Double support (%GCT)	Treat	12.94 (1.00, ∞)	< 0.001***	Balneo	0.45	T0	0.55	Balneo × T0	0.47	Co × T0	0.63
	Time	0.24 (2.62, ∞)	0.843n.s.	Control	0.65	T1	0.55	Balneo × T1	0.44	Co × T1	0.65
	Treat × Time	1.68 (2.62, ∞)	0.177n.s.			T2	0.56	Balneo × T2	0.45	Co × T2	0.67
						T3	0.55	Balneo × T3	0.45	Co × T3	0.65
Swing left (%GCT)	Treat	14.07 (1.00, ∞)	< 0.001***	Balneo	0.55	T0	0.45	Balneo × T0	0.54	Co × T0	0.37
	Time	1.00 (2.86, ∞)	0.389n.s.	Control	0.35	T1	0.46	Balneo × T1	0.56	Co × T1	0.36
	Treat × Time	1.13 (2.86, ∞)	0.334n.s.			T2	0.43	Balneo × T2	0.55	Co × T2	0.31
						T3	0.45	Balneo × T3	0.55	Co × T3	0.35
Swing right (%GCT)	Treat	7.78 (1.00, ∞)	0.005**	Balneo	0.54	T0	0.45	Balneo × T0	0.51	Co × T0	0.40
	Time	0.13 (2.81, ∞)	0.937n.s.	Control	0.38	T1	0.46	Balneo × T1	0.56	Co × T1	0.37
	Treat × Time	1.44 (2.81, ∞)	0.232n.s.			T2	0.46	Balneo × T2	0.54	Co × T2	0.37
						T3	0.46	Balneo × T3	0.54	Co × T3	0.39
Stance left (%GCT)	Treat	14.07 (1.00, ∞)	< 0.001***	Balneo	0.45	T0	0.55	Balneo × T0	0.46	Co × T0	0.63
	Time	1.00 (2.86, ∞)	0.389n.s.	Control	0.65	T1	0.54	Balneo × T1	0.44	Co × T1	0.64
	Treat × Time	1.13 (2.86, ∞)	0.334n.s.			T2	0.57	Balneo × T2	0.45	Co × T2	0.69
						T3	0.55	Balneo × T3	0.45	Co × T3	0.65
Stance right (%GCT)	Treat	7.78 (1.00, ∞)	0.005**	Balneo	0.46	T0	0.55	Balneo × T0	0.49	Co × T0	0.60
	Time	0.13 (2.81, ∞)	0.937n.s.	Control	0.62	T1	0.54	Balneo × T1	0.44	Co × T1	0.63
	Treat × Time	1.44 (2.81, ∞)	0.232n.s.			T2	0.54	Balneo × T2	0.46	Co × T2	0.63
						T3	0.54	Balneo × T3	0.46	Co × T3	0.61
Anterior-posterior position (mm)	Treat	0.29 (1.00, ∞)	0.588n.s.	Balneo	0.49	T0	0.52	Balneo × T0	0.50	Co × T0	0.54
	Time	1.17 (2.27, ∞)	0.315n.s.	Control	0.52	T1	0.49	Balneo × T1	0.49	Co × T1	0.50
	Treat × Time	0.69 (2.27, ∞)	0.519n.s.			T2	0.51	Balneo × T2	0.49	Co × T2	0.54
						T3	0.50	Balneo × T3	0.49	Co × T3	0.52
Anterior-posterior variation (mm)	Treat	0.15 (1.00, ∞)	0.700n.s.	Balneo	0.50	T0	0.52	Balneo × T0	0.52	Co × T0	0.53
	Time	2.23 (2.84, ∞)	0.087	Control	0.49	T1	0.46	Balneo × T1	0.51	Co × T1	0.41
	Treat × Time	2.16 (2.84, ∞)	0.095			T2	0.53	Balneo × T2	0.50	Co × T2	0.56
						T3	0.47	Balneo × T3	0.49	Co × T3	0.46
Lateral position (mm)	Treat	0.09 (1.00, ∞)	0.768n.s.	Balneo	0.50	T0	0.52	Balneo × T0	0.50	Co × T0	0.54
	Time	0.80 (2.65, ∞)	0.483n.s.	Control	0.51	T1	0.52	Balneo × T1	0.51	Co × T1	0.53
	Treat × Time	0.44 (2.65, ∞)	0.699n.s.			T2	0.49	Balneo × T2	0.50	Co × T2	0.48
						T3	0.49	Balneo × T3	0.47	Co × T3	0.50
Lateral variation (mm)	Treat	2.22 (1.00, ∞)	0.136n.s.	Balneo	0.48	T0	0.53	Balneo × T0	0.47	Co × T0	0.59
	Time	0.56 (2.89, ∞)	0.636n.s.	Control	0.55	T1	0.50	Balneo × T1	0.49	Co × T1	0.50
	Treat × Time	1.27 (2.89, ∞)	0.284n.s.			T2	0.53	Balneo × T2	0.48	Co × T2	0.58
						T3	0.51	Balneo × T3	0.50	Co × T3	0.51

F1-LD-F1 model with time and treatment and the interaction of treatment and time (Treat × Time); *%GCT* percentage of gait cycle time, *Treat* treatment (balneo or control), *balneo* includes all three intervention groups, *Co* control group.
T0, T1, T2 and T3 time points T0 = day 0, T1 = day 7, T2 = day 60, T3 = day 180.
*** < 0.001, ** < 0.01,* < 0.005, < 0.1, n.s. not significant.

treatment ($p < 0.001$) and for time ($p < 0.001$). No significant interaction effect was found. Because of the significant baseline difference and the flat and parallel RTE-profile, a significant treatment effect can be excluded.

4. Discussion

The aim of the presented study was to assess the combined effects of moderate mountain hiking and balneotherapy on balance, gait, body composition, quality of life and cognitive performance in high-functioning community-dwelling people aged 65–85 years. Among these parameters, no water type-specific effects were found. Therefore, all three intervention groups were pooled into one intervention group. We observed significant effects on static balance, gait speed, body composition and quality of life. In addition, significant changes over time were observed for cognitive performance.

There is growing evidence supporting that physical activity prevents the progression of chronic diseases and improves mobility in aged persons (American College of Sports Medicine et al., 2009). A simple way to track physical activity is to monitor steps taken per day via

Table 4
Results from the F1-LD-F1 Model for balance, BIA, quality of life and cognitive performance.

Parameter	F1-LD-F1 model			Relative treatment effects (RTE)							
		F	p-Value			Time		Interaction effects			
								Balneo		Control	
Stability Index (%)	Treat	5.03 (1.00, ∞)	0.025*	Balneo	0.53	T0	0.46	Balneo × T0	0.50	Co × T0	0.42
	Time	1.52 (2.77, ∞)	0.210n.s.	Control	0.41	T1	0.50	Balneo × T1	0.59	Co × T1	0.42
	Treat × Time	0.94 (2.77, ∞)	0.414n.s.			T2	0.45	Balneo × T2	0.51	Co × T2	0.39
						T3	0.47	Balneo × T3	0.51	Co × T3	0.43
ABC-Scale	Treat	0.03 (1.00, ∞)	0.860n.s.	Balneo	0.50	T0	0.49	Balneo × T0	0.47	Co × T0	0.50
	Time	5.36 (2.37, ∞)	0.003**	Control	0.51	T1	0.54	Balneo × T1	0.53	Co × T1	0.54
	Treat × Time	0.42 (2.37, ∞)	0.694n.s.			T2	0.51	Balneo × T2	0.52	Co × T2	0.51
						T3	0.47	Balneo × T3	0.47	Co × T3	0.47
WHO-5	Treat	0.20 (1.00, ∞)	0.657n.s.	Balneo	0.51	T0	0.44	Balneo × T0	0.38	Co × T0	0.42
	Time	50.83 (2.76, ∞)	< 0.001***	Control	0.48	T1	0.70	Balneo × T1	0.71	Co × T1	0.69
	Treat × Time	1.57 (2.76, ∞)	0.198n.s.			T2	0.47	Balneo × T2	0.51	Co × T2	0.43
	Treat × T2	7.61 (1.00, ∞)	0.017*			T3	0.41	Balneo × T3	0.41	Co × T3	0.40
DSST	Treat	0.33 (1.00, ∞)	0.567n.s.	Balneo	0.49	T0	0.42	Balneo × T0	0.41	Co × T0	0.43
	Time	26.36 (2.35, ∞)	< 0.001***	Control	0.52	T1	0.49	Balneo × T1	0.47	Co × T1	0.52
	Treat × Time	0.21 (2.35, ∞)	0.845n.s.			T2	0.52	Balneo × T2	0.51	Co × T2	0.54
						T3	0.59	Balneo × T3	0.58	Co × T3	0.60
Reactance (Ω)	Treat	0.21 (1.00, ∞)	0.647n.s.	Balneo	0.51	T0	0.49	Balneo × T0	0.50	Co × T0	0.49
	Time	5.83 (2.72, ∞)	< 0.001***	Control	0.48	T1	0.46	Balneo × T1	0.46	Co × T1	0.46
	Treat × Time	1.07 (2.72, ∞)	0.357n.s.			T2	0.49	Balneo × T2	0.52	Co × T2	0.46
						T3	0.53	Balneo × T3	0.55	Co × T3	0.51
Resistance (Ω)	Treat	0.01 (1.00, ∞)	0.934n.s.	Balneo	0.50	T0	0.49	Balneo × T0	0.49	Co × T0	0.49
	Time	16.37 (2.72, ∞)	< 0.001***	Control	0.50	T1	0.47	Balneo × T1	0.46	Co × T1	0.49
	Treat × Time	1.31 (2.72, ∞)	0.272n.s.			T2	0.50	Balneo × T2	0.50	Co × T2	0.550
						T3	0.54	Balneo × T3	0.54	Co × T3	0.53
Phase angle (°)	Treat	0.18 (1.00, ∞)	0.672n.s.	Balneo	0.51	T0	0.50	Balneo × T0	0.50	Co × T0	0.50
	Time	0.31 (2.44, ∞)	0.774n.s.	Control	0.48	T1	0.49	Balneo × T1	0.49	Co × T1	0.49
	Treat × Time	0.67 (2.44, ∞)	0.541n.s.			T2	0.48	Balneo × T2	0.51	Co × T2	0.46
						T3	0.50	Balneo × T3	0.52	Co × T3	0.48
Total body water (l)	Treat	0.01 (1.00, ∞)	0.946n.s.	Balneo	0.50	T0	0.50	Balneo × T0	0.50	Co × T0	0.50
	Time	14.47 (2.80, ∞)	< 0.001***	Control	0.50	T1	0.51	Balneo × T1	0.52	Co × T1	0.50
	Treat × Time	2.94 (2.80, ∞)	0.035*			T2	0.50	Balneo × T2	0.50	Co × T2	0.50
						T3	0.48	Balneo × T3	0.48	Co × T3	0.49
Fat mass index (kg/m^2)	Treat	8.55 (1.00, ∞)	0.003**	Balneo	0.46	T0	0.54	Balneo × T0	0.45	Co × T0	0.63
	Time	12.32 (2.59, ∞)	< 0.001***	Control	0.64	T1	0.54	Balneo × T1	0.44	Co × T1	0.63
	Treat × Time	0.84 (2.59, ∞)	0.460n.s.			T2	0.54	Balneo × T2	0.45	Co × T2	0.63
						T3	0.57	Balneo × T3	0.48	Co × T3	0.65
Fat free mass index (kg/m^2)	Treat	0.44 (1.00, ∞)	0.509n.s.	Balneo	0.49	T0	0.51	Balneo × T0	0.49	Co × T0	0.54
	Time	14.71 (2.84, ∞)	< 0.001***	Control	0.53	T1	0.53	Balneo × T1	0.52	Co × T1	0.54
	Treat × Time	2.95 (2.84, ∞)	0.034*			T2	0.51	Balneo × T2	0.49	Co × T2	0.53
	Treat × T1	7.12 (1.00, ∞)	0.023*			T3	0.49	Balneo × T3	0.47	Co × T3	0.51
Body cell mass index (kg/m^2)	Treat	0.15 (1.00, ∞)	0.698n.s.	Balneo	0.49	T0	0.51	Balneo × T0	0.49	Co × T0	0.52
	Time	1.55 (2.02, ∞)	0.212n.s.	Control	0.52	T1	0.52	Balneo × T1	0.52	Co × T1	0.52
	Treat × Time	0.74 (2.02, ∞)	0.478n.s.			T2	0.50	Balneo × T2	0.49	Co × T2	0.51
						T3	0.50	Balneo × T3	0.48	Co × T3	0.51
Muscle mass index (kg/m^2)	Treat	0.18 (1.00, ∞)	0.670n.s.	Balneo	0.49	T0	0.51	Balneo × T0	0.49	Co × T0	0.53
	Time	2.13 (2.05, ∞)	0.117n.s.	Control	0.52	T1	0.52	Balneo × T1	0.52	Co × T1	0.52
	Treat × Time	0.95 (2.05, ∞)	0.388n.s.			T2	0.50	Balneo × T2	0.49	Co × T2	0.51
						T3	0.50	Balneo × T3	0.48	Co × T3	0.51
Appendicular muscle mass (kg/m^2)	Treat	0.92 (1.00, ∞)	0.338n.s.	Balneo	0.49	T0	0.52	Balneo × T0	0.49	Co × T0	0.55
	Time	6.34 (2.79, ∞)	< 0.001***	Control	0.54	T1	0.53	Balneo × T1	0.51	Co × T1	0.54
	Treat × Time	2.65 (2.79, ∞)	0.051			T2	0.51	Balneo × T2	0.48	Co × T2	0.54
	Treat × T1	7.49 (1.00, ∞)	0.019*			T3	0.50	Balneo × T3	0.47	Co × T3	0.53

F1-LD-F1 model with time and treatment and the interaction of treatment and time (Treat × Time); *ABC* activity specific confidence balance scale, *WHO-5* WHO Well-Being Index, *DSST* Digit Symbol Substitution Test, *Treat* treatment (balneo or control), *balneo* includes all three intervention groups, *Co* control group; T0, T1, T2 and T3 time points T0 = day 0, T1 = day 7, T2 = day 60, T3 = day 180; *** < 0.001, ** < 0.01,* < 0.005, < 0.1, n.s. not significant.

activity wristbands, but such devices sometimes lack accuracy. Therefore, all hiking tours were tracked via GPS-watches. The outcomes from the FitBit wristbands and the GPS-watches were quite consistent. Healthy older adults take an average of 2000 to 9000 steps/day (Tudor-Locke et al., 2011). The participants of the control group walked on average 11,721 ± 3165 steps/day during their sightseeing vacation. In contrast, the intervention group walked on average 20,784 ± 2395 steps/day. Although the intervention group walked significantly more steps per day, both groups had a highly active lifestyle during the intervention week compared to normative data.

A seven-day intervention with mountain hiking and balneotherapy improves static balance in high-functioning elderly people significantly in comparison to the control group. The relative treatment effects indicate a short-term improvement of static balance in the intervention group. This outcome shows clearly that not only the number of steps/day is important to improve physical abilities, but also the type of exercise is critical. Mountain hiking affects people in a variety of ways by exercising in natural terrain. Due to changing soil conditions, proprioceptive inputs are changing constantly. Each step requires a different motor response (step length, stride width, gait speed etc.). Changing environmental conditions like slope of the path, stony or narrower passages, altitude, weather conditions, ascending and descanting sections, promote diversification of gait pattern and balance response (James, 2014). In contrast, the control group walked almost exclusively on paved roads during their sightseeing program. Walking in urban environments with flat and level roads, offers less proprioceptive input. This might explain why there's no detectable improvement in the static balance in the control group.

Despite the improvements of static balance, no significant changes of dynamic balance, measured as center of pressure, were detected. A common phenomenon especially after intensive exercise training and muscle fatigue, is an impaired proprioception, which can be a critical factor in reducing dynamic balance (Röijezon et al., 2015). No changes in the dynamic balance were observed in the study population between day 0 and day 7. This indicates, that the chosen exercise intensity did not overextend the participants' exercise capacity. A too intensive hiking program would have led to muscular fatigue, which could have been seen directly in the increase of the center of pressure. However, dynamic balance control and good sensorimotor control are especially important for mountaineering, due to physical demands of this activity.

The results from the activity specific balance scale on which the participants rated their balance confidence for different tasks between 0 and 100% clearly show, that loss of balance confidence is not yet a relevant issue for such highly functioning older people. Both the intervention and control group are presenting with high balance confidence > 90% at baseline. The results from the self-assessed balance confidence appear to be consistent with the findings from the balance and gait analysis. Gait pattern and stability index are comparable with available normative data and do not show abnormalities or pathologies (McKay et al., 2016; Raschner et al., 2008). To exclude a significant gender effect, a multiple regression analysis was performed. Like Frimenko et al. we did not observe any significant influences from sex differences with regard to gait parameters (Frimenko et al., 2015). The majority of variation in the gait parameters can be explained by gait parameters themselves.

Interestingly, stride width, variation in velocity, double support, swing (left/right) and stance (left/right) are all presenting with a significant baseline difference between the intervention and the control group. However, with exception of the observed short-term increase in gait speed, no significant changes in the gait pattern were found. Gait speed - also called walking speed - is a simple and reliable measure for assessing and monitoring functional status and overall health, as walking is the fundament for daily activities and independent life. Walking speed is rightly considered as the sixth vital sign as a decrease in walking speed as small as 0.1 m/s has been linked to difficulties in performing daily tasks (Judge et al., 1996). One week of moderate mountain hiking and balneotherapy significantly improves the walking speed of older people. The relative treatment effects indicate even a sustainable improvement until day 60.

As no significant influences from water types were observed, it seems that the general physical and thermal effects, rather than the specific water constitution, are the critical factors in this case. The well-known thermal effects of balneotherapy including vasodilation, increased blood flow or reduced vascular spasm are leading to a faster deportation of nociceptive elements and free oxygen radicals (Nasermoaddeli and Kagamimori, 2005). Balneotherapy is also used to improve the range of joint movements, relieving muscle spasm and enhancing functional mobility (Pittler et al., 2006). In this context, it is possible, that balneotherapy promotes regeneration after mountain hiking. However, as no intervention group without balneotherapy was included in this study, no specific effects from balneotherapy alone can be derived.

A hallmark of aging is an altered body composition, which is mainly characterized by the reduction of muscle mass. Loss of muscle mass is highly associated with functional impairment and disability (Janssen et al., 2002). Short-term improvements in fat-free mass index (kg/m^2), total body water (liter) and appendicular muscle mass (kg) were only observed in the intervention group. Because increase in appendicular muscle mass is mainly associated with strength training, it seems like walking in rough terrain already offers some kind of strength training for older people. BIA-measurements are sensitive to any body fluid change. Regular hiking and bathing can lead to dehydration, which is a well-known confounder in the measurement of body composition. Within our study population no signs of dehydration were observed - the total body water even increased in the intervention group. Therefore we can exclude any bias in the BIA-results from dehydration, but other confounders like previous food or drink intake were not controlled. Although, a seven-day holiday with moderate mountain hiking and balneotherapy induces significant changes in these parameters, the relative treatment effect is low. A seven-day intervention is probably too short to induce clinically relevant changes in body composition. Although both study groups had a highly active lifestyle during the intervention weeks, changes in the body composition are only visible in the intervention group. Despite the random allocation to the treatment groups, the control group presents a significantly higher fat mass index (kg/m^2).

Short-term memory, visuomotor coordination, selective attention and the ability to filter out relevant information are critical cognitive abilities required for daily living and can be easily measured with the DSST-Test. A low DSST-Score (< 25 points) is strongly associated with mortality (Swindell et al., 2012). In both groups the DSST-scores increase constantly throughout the study. In older highly functioning people cognitive performance can be improved over time when trained. The parallel profile of the relative treatment effects shows clearly, that both groups improved their score over time similarly. Performing a DSST-Test itself is an intervention, improving cognitive performance via a learning effect.

Vacations are well known to improve mood and quality of life in aged persons (Kim et al., 2015). However, this positive effect may not apply for all types of vacation and all subgroups, as people have different needs. Both an active vacation with hiking and balneotherapy and a classic sightseeing vacation improve quality of life immediately. Interestingly, sustainable effects were only found in the intervention group. Both groups stayed at the same hotels and the only difference was their daily activities. Instead of exercising in a natural environment, the control group had only a limited visual impression of natural environments, as they were sent to urban areas or participated in sedentary activities (e.g. boat trip, visit of a chees diary, salt mine). This type of “classic cultural” vacation alone improves the quality of life in high-functioning elderly people, but long-lasting effects cannot be observed. Exercise in natural environments is known to have a positive influence on physiological and psychological parameters (Bowler et al., 2010; Thompson Coon et al., 2011). The steady movement during hiking in green space, the exposure to natural sunlight and the self-selected pace seem to be more health promoting than walking through noisy urban areas with crowded spaces (Gladwell et al., 2013) or participating in sedentary activities. The combination of exercising in natural environments induces sustainable improvements in quality of life until day 60 in high-functioning elderly people.

Beside the sustainable effect on quality of life until day 60, no long-term effects were observed. Body composition and static balance present with short-term improvements. Furthermore, a significant main treatment effect for gait speed was found. Although, the relative treatment effects indicate a sustainable effect for gait speed until day 60, no significant interaction effects were found for this time point. The results from the PAQ50+ Questionnaire, show clearly that the activity level of the participants did not change after the intervention. To induce long-term improvements in body composition, gait speed and static balance or to maintain such changes, regular physical exercise is required. As the intervention time was rather short and no psychoeducational elements were included, sustainable life style changes cannot be expected.

5. Limitations

Aging is a complex process with a broad spectrum of physical and cognitive disabilities with varying severity. Only older people in good general condition with high balance confidence and good cognitive performance were included in this study. Therefore, the results are limited to this specific target group. In addition, this study is focused on the combined effects of balneotherapy and mountain hiking. The specific effects of balneotherapy and moderate mountain hiking alone were not evaluated. No placebo-control for the balneotherapy was implemented. With this study design no specific remarks about mountain hiking or balneotherapy alone can be made. Further, the calculated sample size ($n = 32$) was not met in all subgroups and a per-protocol analysis was performed. To exclude a bias from baseline body composition, weight or BMI should be implemented as allocation criteria in further studies. BIA-measurements can be influenced by various confounders, not only by dehydration. Although the BIA-assessment schedule was standardized, other factors like previous activity level, associated sweating or food and drink intake, were not controlled.

In clinical intervention studies like this, other factors than the intervention, like social interactions, group dynamics or individually perceived exercise intensity as well as the holiday atmosphere itself, may play a critical role. The individual exercise intensity (e.g. measured via heart rate) was not controlled, therefore further studies are needed to determine dose-response-relationships. The intervention time of seven days was too short to induce sustainable physiological changes in this study population. Further studies with larger sample sizes and longer intervention periods are needed to evaluate the effects of mountain hiking and balneotherapy on promoting healthy aging and fall prevention.

6. Conclusions

A one-week holiday with moderate mountain hiking and balneotherapy improves static balance, quality of life, body composition and gait speed in high-functioning aged persons without gait-abnormalities and high balance confidence. In comparison to a classic sightseeing vacation, which induces short-time improvements of quality of life, moderate mountain hiking and balneotherapy induce sustainable improvements in quality of life until day 60. Only short-term improvements of static balance, body composition and gait speed were induced. Further research is needed to assess the impact of such intervention on healthy aging and fall prevention.

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Author contributions

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Conflicts of interest

The authors declare no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.exger.2019.04.006.

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