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Effects of green exercise and waterfall aerosol on mucosal immunity and chronic stress
A randomized controlled clinical trial

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Abstract

Green exercise and the specific microclimate of alpine waterfalls with high levels of ionized water aerosols has been suggested to trigger beneficial health effects. In the present three-armed randomized controlled clinical trial (RCCT) we focused on import medical and physiological functions of human health: (i) immune reagibility, (ii) physiological stress response and (iii) stress-related psychological parameters.

Methods: 102 participants with increased stress levels were included in the present study. Two groups (n=65) spent an active sojourn with daily hiking tours in the National Park Hohe Tauern (AUT). One group was exposed to water aerosol of an alpine waterfall for 1 h/day (WF+, n=33), whereas the other group spent the same time at a distant site (WF-, n=32). A third arm (CO, n=26) had no intervention (except vaccination). The effect of the interventions on the immune system was tested by oral vaccination with an approved cholera vaccine and measuring salivary IgA antibody titers. Lung function was determined by peak expiratory flow measurement. Electric skin conductance, heart rate and adaption of respiration rate were assessed as physiological stress parameters. Psychological stress-related parameters were analyzed by questionnaires and scales.

Results: Compared to the CO group, both intervention groups (WF- and WF+) showed improvement of the lung function and of most physiological stress test parameters. Analysis of the mucosal immune response revealed a waterfall-specific beneficial effect with elevated IgA titers in the WF+ group. In line with these results, exposure to waterfall revealed an additional benefit concerning psychological parameters such as subjective stress perception (visual analog scale), the Global Severity Index (GSI) and the Positive Symptom Total (PST).

Conclusion: Our study provides new data that strongly supports a beneficial health effect of waterfall environment and green exercise on immune function, physiological and psychological stress parameters.

Keywords

Waterfall, Aerosol, Ions, High-altitude, Nature therapy, Chronic stress, Green exercise, Mucosal immunity, Hiking

Introduction

The specific microclimate of alpine waterfalls has been suggested to trigger beneficial immunological and psychological effects, for example for the treatment of allergic asthma (GAISBERGER et al. 2012). Waterfalls produce high levels of inhalable, negatively charged nano-water particles hovering in the air, while the positive-charged fragments sink to the ground (KOLARŽ et al. 2012). Negative air ions have been shown to influence psychologic well-being and increase serotonin levels (WU et al. 2011). Waterfalls also create a specific microbiological atmosphere, which may influence immunological parameters (CRAIG et al. 2016).

Chronic stress decreases sIgA expression and reduces the humoral immune response to a vaccination (GALLAGHER et al. 2008). Reduced IgA in turn weakens our immunity, as it is secreted in all mucosal surfaces and part of the first line of defense. The level of specific ABs in response to a vaccination is a proper model to monitor stress relief and immunity.
The present RCCT tests the hypothesis of a stronger vaccine-specific AB response due to waterfall exposition and stress relief, when combined with high-altitude climate therapy and physical activity.

Methods

Subjects

91 persons (age 19-61; 44 ♂/47 ♀) working in care professions (inclusion criterion: increased TICS score).

Intervention

Except for the control group (CO, n=26), all participants spent 1 week at Großkirchheim (Carinthia, A), hosted in hotels and receiving the same meals. For 1 h each day, the groups were separated for intervention into a waterfall- (WF+, n=33, waterfall exposition) and a “non-waterfall” group (WF-, n=32, no exposition). Individuals of the CO group stayed at home (no intervention except vaccination). Data Gartl Waterfall: 50 m drop height, water flow 0.6 m^3/s, 42660 neg. ions/cm^3.

Vaccination & sIgA

Mucosal immunity was tested by oral vaccination with DUKORAL® from SBL Vaccines, which was given on days 0 and 6 (Fig. 1). Saliva (2 ml) was collected on days 0, 6, 16, and 66 in the morning and DUKORAL® vaccine specific salivary IgA concentrations got determined.

Questionnaires & scales

Trier Inventory for the Assessment of Chronic Stress (TICS), Visual analog scale for subjective stress perception (VAS), Symptom Check List (SCL-90), Recovery-Stress Questionnaire (EBF), Maslach Burnout Inventory (MBI-D), List of complaints (Ksb-S BL) and the Mental state scale (Bf– S).

Lung function & stress physiology

A computer-guided stress test was performed to measure the heart rate, respiration rate, and the skin conductance during a 3-min baseline phase, a 1-min stressor phase (optical and acoustical stressor) and a 4-min post-stress recovery phase. To determine the training effect a lung function (peak expiratory flow (PEF)) was performed.

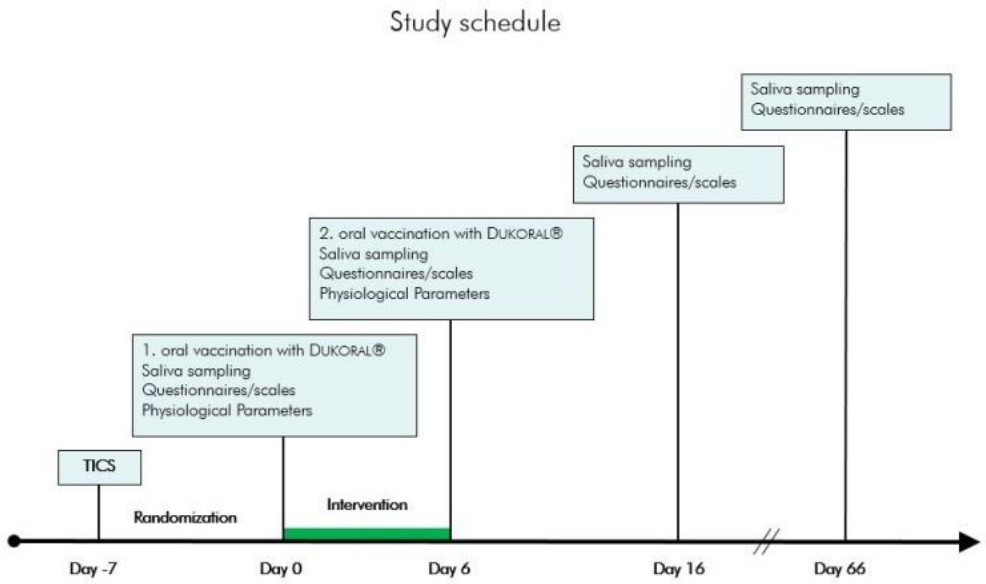

Figure 1: Study schedule. Schematic chronological process of the controlled clinical trial

Results

Specific sIgA

A comparison of IgA titers of both intervention groups (WF+ and WF–) with the non-intervention control group with a linear mixed model (LMM1) shows a strong statistical trend (p = 0.055) on day 16 of the WF+ group, compared to that of the CO group (Fig. 2). The strongest percentage increase at all time points can be found in the WF+ group. The specific impact of the waterfall ionosol was evaluated with another linear mixed model (LMM2) of the two intervention groups WF+ and WF–. The result indicates a significant increase of salivary IgA titers in the WF+ group on day 6 and day 66 (Fig. 3).

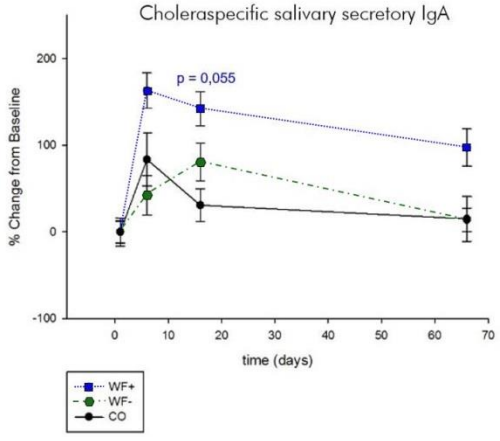

Figure 2: Antigen-specific salivary IgA levels of responders. Linear mixed model (LMM1) of both intervention groups compared to the control group. Data shown in percentage change (±SD) from baseline (pre-serum)

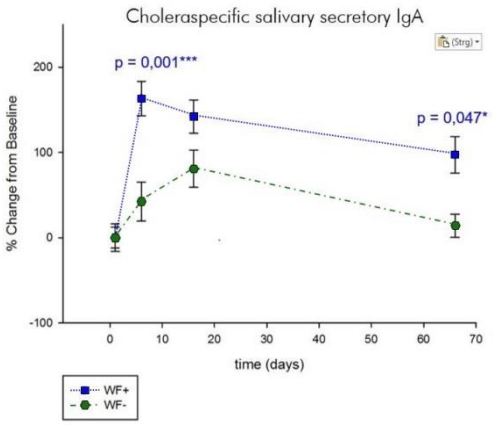

Figure 3: IgA levels of the two intervention groups (responder). Linear mixed model (LMM2) of the waterfall group (WF+) compared to the non-waterfall group (WF-). Data are shown in percentage change (±SD) from baseline (pre-serum)

VAS

The VAS assessing the subjective stress perception was applied on day 1 and day 6. A significantly lower stress level could be measured in the WF+ group after the intervention week on day 6, compared to the control group (p=0.000).

SCL 90

Linear mixed model analysis of the SCL-90 questionnaire revealed improvement in six of the ten symptom dimensions in both intervention groups after 6 days (compared to the control group). The data indicate a clear trend of a beneficial effect of the waterfall environment. Furthermore, on day 6, both the Global Severity Index assessing overall psychological distress, as well as the Positive Symptom Total which displays the number of self-reported symptoms, were significantly decreased in the waterfall group only, again indicating a waterfall-specific effect (p=0.009 and p=0.03).

EBF

The EBF questionnaire revealed less stress (p=0.068) and improved recovery (p=0.070) only in the waterfall group.

MBI-D

Measuring incidence and severity of burnout by means of the MBI-D elicited a significant improvement in the WF+ group in the category depersonalization, compared in the control group on day 66 (p=0.002). No differences could be measured concerning the other two components (emotional exhaustion, personal accomplishment).

Ksb-S BL

Reflecting constitutional changes during the trial, the WF+ group showed a significant positive long-term effect on day 66. Both intervention groups show a decrease of complaints on day 16 (p=0.011).

Bf– S

The mental state scale clearly indicates enhanced well-being short-term effects on day 6 (p=0.051).

Lung function & physiological stress test

Waterfall exposure had a significant positive effect on the PEF on day 6 (Fig. 4).
All signals of the physiological stress test decreased in the W+ and W– group after 1 week (Fig. 4). The results show the arithmetic mean [%] of the 4-min post-stress recovery phase, compared to a 100% reference line (mean of stressor phase). Results below 100% indicate the ability to reconstitute a parasympathetic physiological state within the 4-min post-stress recovery phase. The respiration- and heart rate was significantly decreased in both intervention groups. Skin conductance, indicating sympathetic activity was significantly reduced due to waterfall exposition.

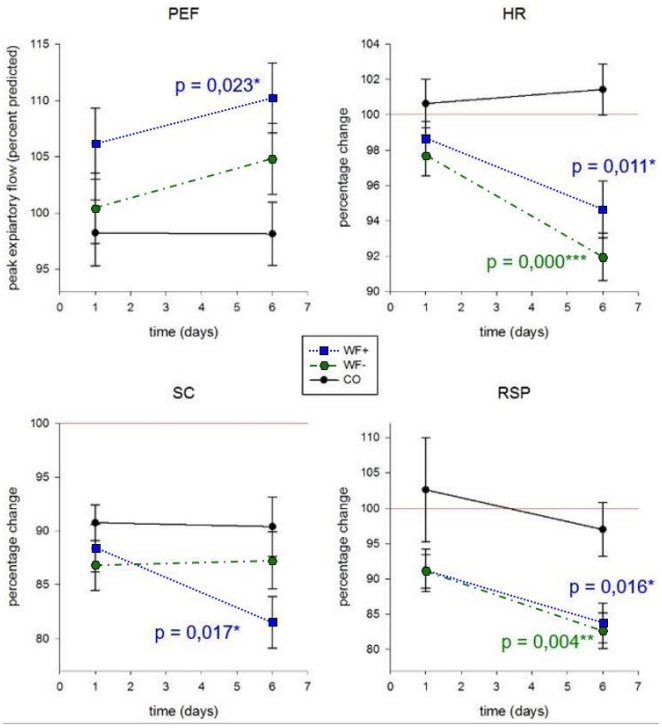

Figure 4: Lung function and physiological stress test. Linear regression analysis of lung function and peripheral signals of the physiological stress test. Means (±SD) of the PEF value is shown in percent of the predicted PEF, scaled on age, height, weight, gender, smoker (yes, no, former), and asthma (yes, no). Means (±SD) of the 4-min post-stress recovery phase shown in percentage compared to means of the 1-min stressor phase (100% reference,indicated as red line).

Discussion

Most investigated parameters were significantly changed with a 1-h/day exposure to the waterfall. The humoral immune response after oral vaccination was significantly improved by the additional waterfall exposure (GRAFETSTÄTTER et al. 2017). The specific microbiologic waterfall environment may directly affect the microbiota and thus be responsible for the observed effects on mucosal immunity.

Conclusion

The present RCCT provides evidence for an added value of a daily 1-h stay for 1 week in a waterfall environment in combination with green exercise and high-altitude climate therapy. Our data suggest to expand the applicability of this simple and cost-effective health provision for treatment of stress-related symptoms.

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