Explore 17 (2021) 122–126

Contents lists available at ScienceDirect

Explore

journal homepage: www.elsevier.com/locate/jsch

Original Research

Effects of winter sea bathing on psychoneuroendocrinoimmunological parameters

Ilaria Demori[a,b,*], Tommaso Piccinno[c], Daniele Saverino[d], Erika Luzzo[b], Stefano Ottoboni[e], Davide Serpico[b,f], Marco Chiera[b], Roberto Giuria[b]

[a] *Department of Earth, Environment and Life Sciences (DISTAV), University of Genoa, Corso Europa 26, 16132 Genoa, Italy*
[b] *Italian Society of Psychoneuroendocrinoimmunology (SIPNEI), Rome, Italy*
[c] *VIE – Valutazione Innovazione Empowerment s.r.l., Via della Libertà 9/3, 16129 Genoa, Italy*
[d] *Department of Experimental Medicine (DIMES), University of Genoa, Via Leon Battista Alberti 2, 16132 Genoa, Italy*
[e] *Department of Surgery Sciences and Integrated Diagnostics (DISC), University of Genoa, Viale Benedetto XV 6, 16132 Genoa, Italy*
[f] *Department of Classics, Philosophy and History, University of Genoa, Via Balbi 2, 16126 Genoa, Italy*

ARTICLE INFO

Keywords:
Winter sea bathing
Psychoneuroendocrinoimmunology
Stress response
Cortisol
Wellbeing
Personality

ABSTRACT

Context: Many people claim winter sea bathing gives them energy and health. According to the psychoneuroendocrinoimmunology (PNEI) paradigm, the stress response elicited by cold water immersion could indeed induce several beneficial psychophysical alterations.
Objective: To determine the effects of winter sea bathing on psychological wellbeing, stress and immune markers.
Design: A cross-sectional study.
Participants: 228 people, between 19 and 88 years, including 107 winter sea bathers and 121 controls.
Main Outcome Measures: A battery of questionnaires was administered to assess sociodemographic characteristics, self-perception of mental and physical heath, the number, duration and intensity of Upper Respiratory Tract Infections (URTIs) in the last year, and Big Five personality traits. 17 winter sea bathers and 15 controls (mean age 67 years) were further examined to evaluate physiological health, underwent one ear-nose-throat (ENT) examination, and provided saliva samples for measurements of biological markers (cortisol, sIgA, IL-1β, IL-6).
Results: Winter sea bathing was associated with lower levels of self-reported stress and higher wellbeing. The ENT examinations did not reveal signs of URTIs in winter sea bathers, who exhibited significantly higher levels of salivary sIgA compared to controls. Neither salivary IL-1β nor cortisol levels were significantly different between the two groups.
Conclusions: Winter sea bathers (even the elderly) had a perception of higher wellbeing and reported better health: thus, they appeared to take advantage of potential distress (cold water exposure) to improve their health.

Introduction

Winter sea bathing is not common but has fans all over the world, who claim that it is good for health.[1,2] Even if most people could consider it as an extreme activity, winter swimming is more a pastime that can be practiced by everyone.[1,2]

In the region of Liguria, as well as along other Italian sea-coasts, winter sea bathing is also a social activity. On all winter weekends, even hundreds of people meet on the same beach at the same time to share this experience also in adverse weather conditions, and they report feeling a sense of community and happiness.[3,4]

Immersion in cold water can result in short- and long-term metabolic, cardiovascular, and hormonal changes[2,5] which are exploited by water-based care systems such as hydrotherapy and balneotherapy.[2,5,6] For example, cold water immersion of the body of the patient has been used for centuries to obtain hypothermic, sedative and anti-inflammatory effects in case of fevers, bruises, infections and mental illnesses.[2,5,6]

The last decades have seen the rise and development of the psychoneuroendocrinoimmunology (PNEI) paradigm, which describes the complex relationships between the nervous, endocrine and immune systems, and the bidirectional connections between body and mind.[7] To face either physical or emotional environmental challenges, the body activates a stereotypical response known as the stress response, which consists in the coordinated and dynamic activation of the sympathetic nervous system, the hypothalamus-pituitary-adrenal (HPA) axis, and of immune circuits. According to the PNEI paradigm, the stress response is of utmost importance to regulate health and disease.[7,8]

* Corresponding author at: Department of Earth, Environment and Life Sciences (DISTAV), University of Genoa, Corso Europa 26, 16132 Genoa, Italy.
E-mail address: idemori@unige.it (I. Demori).

https://doi.org/10.1016/j.explore.2020.02.004
1550-8307/

Cold water immersion during winter sea bathing represents an obvious neuroendocrine/cardiovascular stress, but also a psychological self-challenge.[2]

In this study, winter sea bathers were examined for various psychological and biological parameters related to the PNEI network such as personality traits, general physiological conditions, stress markers, and immune system activity.

In agreement with the PNEI paradigm, we hypothesize that winter sea bathing can result in a positive circle between body and mind, thus improving the health of practitioners.

Material and methods

Participants

A cross-sectional study was conducted over one winter bathing season (November-April). The study enrolled 228 people (45% females), aged between 19 and 88 years, including 107 winter sea bathers and 121 controls. Control subjects were randomly chosen among the people who watched the winter sea bathing events: they were curious about this activity but never tried it. No exclusion criteria were considered.

All procedures were performed in compliance with the ethical standards of the local Ethical Research Committee, with the American Psychologist Association ethical guidelines, and with the 1964 Helsinki Declaration and its later amendments.[9] Full informed consent was obtained before participants started the study.

We want to emphasize that winter sea bathers were not athletes. They bathed in freely accessible seawater along many sea-coasts in Liguria (Italy). Water temperature ranged from 8 °C to 14 °C. Bathers used to enter the sea together, without wearing a wetsuit, and remained in the water for a variable time, typically around 20 min, either swimming or simply floating.

All participants completed questionnaires about their sociodemographic condition, self-reported health, and psychological traits.

In February, from 9 to 12 a.m., 17 winter sea bathers and 15 controls (mean age 67 years) that were randomly chosen among all participants underwent anamnesis of their medical history, current diseases or taking of medicines and medical measurements (arterial blood pressure, pulse rate, and peripheral oxygen saturation) as well as one ear-nose-throat (ENT) examination by an otolaryngologist. They also provided saliva samples for the evaluation of basal levels of neuroendocrine and immune parameters.

Questionnaires

A non-validated questionnaire encompassing several sections was specially developed for this study to collect information about sociodemographic characteristics and perceived psycho-physical and social health of participants.

The first section assessed age (years), sex (male, female), marital status (single, married, cohabitant, separated, divorced and widow) and sports activities (number of activities per month). For winter sea bathers, there were also some items exploring the number and frequency of winter sea baths in a season.

The second section assessed the self-perception of mental and physical health. Participants answered on a 7-point Likert scale (ranging from 1 = "not at all" to 7 = "very much") indicating how well they felt regarding their physical health, mental stress, physical stress symptoms (headache and/or migraines, sleep disorders), if they experienced mood swings and/or irritability and how much they felt satisfied with their lives, work, romantic relations, and friendships.

The third and final section of the questionnaire investigated the number (measured on ordinal scale on a 4-point Likert scale: "None", "From 1 to 2", "From 3 to 5" "More than 5"), duration (measured on ordinal scale on a 5-point Likert scale: "None", "Few days", "Less than two weeks" "Less than a month", "More than a month") and intensity of Upper Respiratory Tract Infections (URTIs) in the last year (measured on a 5-point Likert scale "None", "Mild cold", "Bad cold", "Mild flu", "Bad flu"). These measurements were not sufficient to see if potential differences in self-reported health and mental state were only due to winter sea bathing or if they were related to individual differences in personality. We decided to collect this data as control measures via administration of the validated Single-Item Measure of Personality (SIMP),[10] in the Italian version developed by C. Chiorri (Department of Education Sciences, University of Genova). SIMP is a self-reported measure based on the Big Five model of personality[10,11] that consists of 5 semantic differentials presenting two descriptions of the opposite poles for each Big Five factor. Participants were asked to mark their position between the two poles on a 9-point scale. Each item represented one of the five dimensions of the Big Five model, named *Extraversion, Agreeableness*, *Conscientiousness, Emotional Stability* and *Openness/Intellect*. The use of single items was chosen because they show a good correlation with the multiple-items scales and not to overload the questionnaire.[10]

Biological assays

Whole saliva was collected between 10 and 11 a.m. using oral swabs (Salimetrics Europe Ltd., UK) held underneath the tongue on the floor of the mouth for 2 min. Subjects were instructed not to consume water or food (including candies or chewing-gum) or brush their teeth within 30 min before sample collection. Oral swabs were maintained at 4 °C and centrifuged at 1000 g for 2 min as soon as possible. Supernatant volumes were measured, and saliva samples were collected and stored at −20 °C. The levels of cortisol, sIgA, IL-1β, IL-6 were measured by ELISA assays according to the manufacturer instructions (Salimetrics). Due to the influence that saliva flow rates have on SIgA levels,[12] the measured concentration of SIgA (μg/mL) was multiplied by the flow rate (mL/min) to express the results as μg/min.

Statistical analyses

Means, medians and standard deviations were calculated for number and frequency of winter sea baths, medical measurements, and biological assays. Statistical analysis was performed by the non-parametric Mann-Whitney test (GraphPad Software Inc., San Diego, CA, USA).

For questionnaire processing, age and sports activities were treated as metrical variables, whereas sex and marital status as categorical variables (0−1). Stress symptoms, satisfaction and personality items were treated as metrical assuming the equivalence of the levels of the scales used. Concerning the assessment of URTIs in the last year, the collected variables were treated as ordinal, since it was not possible to assume the distance between their levels to be equivalent.

Two multiple linear regressions were thus performed to assess the influence of socio-demographic variables (to be a winter sea bather or not, age, sex, marital status, sport activities) and SIMP items on (1) the perceived total stress (wellbeing) and (2) the perceived total satisfaction. The 2 independent variables (stress and satisfaction) were analyzed independently.

We used principal component analysis (PCA) and calculated 2 indexes to avoid collinearity problems and to facilitate the interpretation of results. The general stress index obtained through PCA on the items regarding headache, sleep disorders, mood disorders, and physical wellbeing, indicates the psycho-physical stress in its various manifestations. Therefore, the lower the score, the higher the perceived wellbeing.

The general satisfaction index, obtained through PCA on the items regarding life, work, romantic relations, and friendship satisfaction, indicates general life satisfaction. Therefore, the higher the score, the higher the satisfaction with one's own life.

Three ordered logistic regressions were performed to predict the number, duration and intensity of URTIs in the last year separately, based on socio-demographic variables (to be a winter sea bather or not, age sex, marital status, sports activities) and SIMP items.

The statistical significance of the regressions was assessed by post-hoc pairwise comparisons.

Results

Questionnaires

Participants reported practicing winter sea-bathing for 9.6 ± 8.0 years, ranging from newbies to veterans with even 46 years of winter swimming experience. The mean number of baths during one season (November-April) was 13.5 ± 10.5 (range 1–50), which means a frequency of 2–3 bathes per month on average.

Table 1 reports the results of the first multiple linear regression performed to predict wellbeing (measured by the general stress index) based on socio-demographic variables (to be a winter sea bather or not, age, sex, marital status, sports activities) and SIMP items. The regression showed a statistically significant result (F(14, 144) = 9.574, $p < 0.001$ with adjusted R-squared = 0.43), meaning that perceived wellbeing changed depending on some of the examined variables. In particular, winter sea bathers had stress index scores significantly lower than controls. This means that being a winter sea bather was a significant predictor of wellbeing (beta = 0.42, $p = 0.010$, partial $\eta^2 = 0.26$). Sociodemographic characteristics and personality traits do not affect this correlation since they are accounted for in the regression analyses. However, other significant results were found. Higher scores of Emotional Stability were associated with lower stress index (beta = −0.23, $p < 0.001$, partial $\eta^2 = 0.26$). Regarding marital status, separated participants had significantly lower scores of stress index than singles (beta = −0.65, $p = 0.026$).

Table 2 reports the results of the second linear regression used to predict satisfaction (measured by the general satisfaction index) based on socio-demographic variables (to be a winter sea bather or not, age, sex, marital status, sports activities) and SIMP items. The regression showed a statistically significant result (F(14, 144) = 4.04, $p < 0.001$ with adjusted R-squared = 0.21), meaning that perceived life satisfaction changed depending on some of the examined variables. Even though several significant effects were found (age, marital status, Agreeableness, and Emotional Stability), being a winter sea bather (beta = −0.134, $p = 0.476$) was not a predictor of general satisfaction with life.

Lastly, the three ordered logistic regressions evaluating the number, duration and intensity of URTIs in the last year, found that only the intensity of the diseases had significant predictors: being a winter sea bather (beta = 1.45, $p = 0.004$) and Agreeableness (beta = 0.19, $p = 0.020$).

Table 1
General stress index: linear regression results.

	Beta	Std. Error	t value	Sign.
(Intercept)	0.986	0.407	2.419	0.017*
Control vs. seabather	0.422	0.161	2.615	0.010**
Female vs. male	0.162	0.136	1.194	0.234
Age	−0.005	0.006	−0.857	0.393
Married vs. single	−0.076	0.180	−0.419	0.676
Cohabitant vs. single	−0.211	0.261	−0.809	0.420
Separated vs. single	−0.651	0.290	−2.245	0.026*
Divorced vs. single	0.330	0.348	0.95	0.344
Widowed vs. single	0.186	0.371	0.503	0.616
Sport	−0.257	0.141	−1.828	0.070
Agreableness	0.045	0.029	1.522	0.130
Extraversion	−0.019	0.027	−0.723	0.471
Conscientiousness	0.028	0.026	1.104	0.272
EmotionalStability	−0.233	0.033	−7.118	<0.001***
Openess	0.023	0.033	0.684	0.495

* $p \leq 0.05$.
** $p \leq 0.01$.
*** $p \leq 0.001$.

Table 2
General satisfaction index: linear regression results.

	Beta	Std. Error	*t* value	Sign.
(Intercept)	0.437	0.474	0.922	0.358
Control vs. seabather	−0.134	0.187	−0.715	0.476
Female vs. male	−0.238	0.158	−1.503	0.135
Age	−0.019	0.007	−2.684	0.008**
Married vs. single	0.602	0.212	2.843	0.005**
Cohabitant vs. single	0.256	0.327	0.782	0.436
Separated vs. single	0.494	0.340	1.454	0.148
Divorced vs. single	−0.451	0.408	−1.106	0.271
Widowed vs. single	1.171	0.573	2.046	0.043*
Sport	0.097	0.163	0.596	0.552
Agreeableness	−0.084	0.035	−2.428	0.016*
Extraversion	0.003	0.032	0.098	0.922
Conscientiousness	0.008	0.031	0.273	0.785
Emotional stability	0.159	0.038	4.130	<0.001***
Openess	−0.032	0.040	−0.800	0.425

* $p \leq 0.05$.
** $p \leq 0.01$.
*** $p \leq 0.001$.

Medical examination

At the time of the general medical examination performed in a smaller group of subjects (17 winter sea bathers and 15 controls), winter sea bathers' health was neither better nor worse than that of controls. The average age of participants was 67 years. As we did not consider any exclusion criteria, most of the subjects (except 4 winter bathers and 3 controls) were under treatment for different diseases (hypertension, diabetes, prostatic hypertrophy, arthrosis), as it can be expected in a typical elderly population. Nevertheless, median systolic/diastolic blood pressure, mean pulse rate and peripheral oxygen saturation were within the normal range for all participants. Particularly, for winter sea bathers these values were 145/83 mmHg, 64 ± 8.9 and 96%–98%, respectively.

The ENT specialist examination, which included rhinoscopy and otoscopy, was negative both for bathers and controls, and none of them showed signs of URTIs.

Biological assays

Fig. 1 shows the morning basal levels of salivary cortisol (panel A), IL-1β (panel B) and sIgA (panel C) in winter sea bathers (WSB) compared to the control group (C). Cortisol and IL-1β levels were not significantly different between the 2 groups. sIgA concentration in saliva was significantly higher in winter sea bathers as compared to controls (about 2-fold increase, $p \leq 0.05$). IL-6 was also measured in saliva, but its levels were undetectable in both groups (data not shown).

Discussion

In the present study, we analyzed people who go sea bathing in wintertime, also in adverse weather conditions. Based on the PNEI paradigm, which considers the human being as a whole mind-body unity, we tested the hypothesis that winter sea bathing could have beneficial effects on health, both physically and psychologically.

Our results demonstrate that winter sea bathing is associated with higher perceived psycho-physical wellbeing. Moreover, winter sea bathers self-reported to suffer from less intense URTIs than the control group. This was consistent with what was observed in the smaller group of subjects that underwent one ENT examination and provided saliva samples for measurements of biological markers. At the time of the examination, no signs of URTI were revealed neither in winter sea bathers nor in controls, but the bathers exhibited significantly higher levels of salivary sIgA when compared to controls. SIgA is the main secretory immunoglobulin present at the level of the mucous membranes as a first-line immune defense against viruses

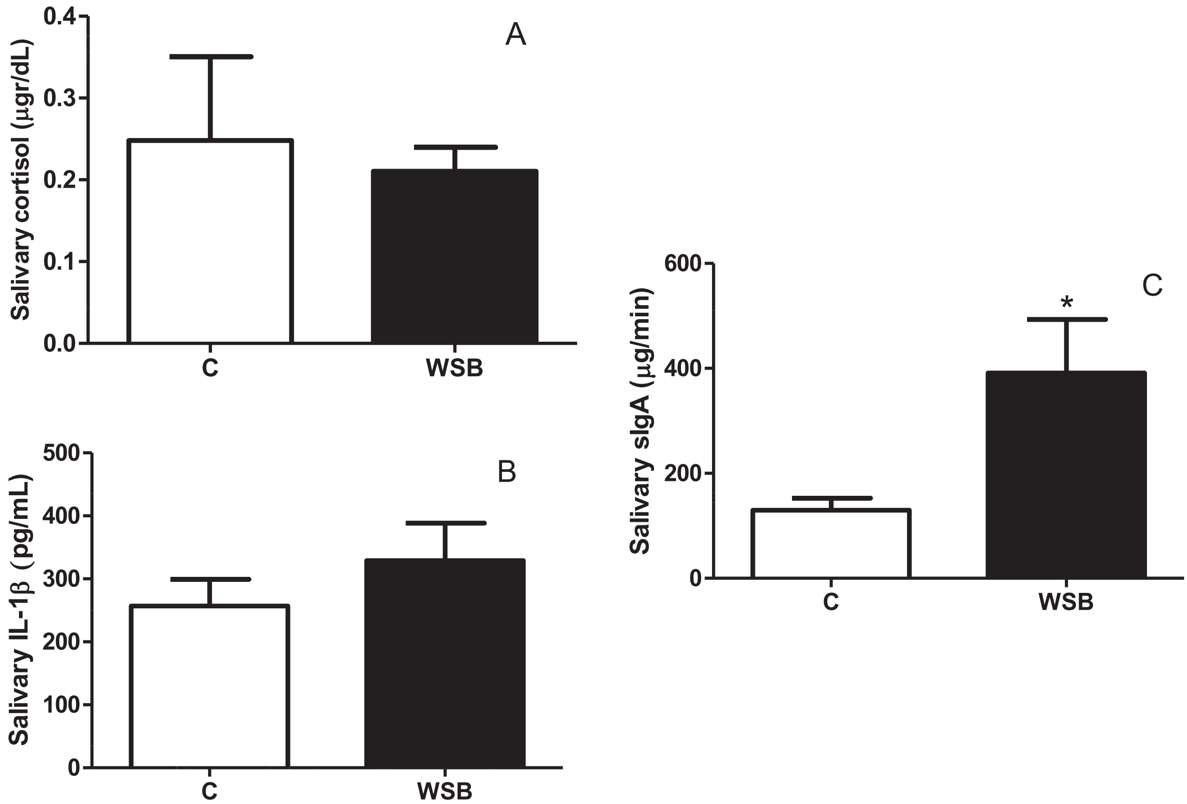

Fig. 1. Basal levels of salivary cortisol (A), IL-1β (B) and sIgA (C) in winter sea bathers (WSB, black bars) compared to controls (C, white bars). Data are expressed as means ± S.D. * $p \leq 0.05$.

and bacteria[12]: thus, higher sIgA could mean higher protection from URTI, which are very typical in wintertime.

Our results also demonstrated that winter sea bathing was associated with lower levels of self-reported stress. However, cold water immersion represents an obvious neuroendocrine/cardiovascular stress, as well as a psychological self-challenge.[2] The stress response stimulates the adrenal cortex to release cortisol, which is functional to help the organism overcoming the stressor, thanks to the catabolic (that is, pro-energetic) and anti-inflammatory action of the hormone.[8,13] Cortisol production by the adrenal cortex also displays a circadian rhythm, with levels peaking in the early morning and dropping to lowest values at night.[8] Morning cortisol levels are thought to be determined mainly by chronic stress related to social and work environment.[13–15] Our results showed that in winter sea bathers morning cortisol levels were not significantly different from those measured in the control group, suggesting that winter sea bathing did not elicit dangerous effects on the stress system. Furthermore, it is well known that repeated exposure to acute stressors results in adaptive physiological mechanisms.[16] Besides leading to cold adaptation,[2,3] winter sea bathing could make the organism able to cope with other stressors as well, via habituation of the HPA axis and cross-adaptive responses.[16,17] This seems in agreement with the existing literature about cold water immersion, which reports beneficial effects on health in regular winter swimmers, thanks to the same adaptive physiologic mechanisms that increase tolerance to cold.[2] For example, cold water immersion can induce a higher basal activity of antioxidant enzymes such as superoxide-dismutase and catalase,[18] while thermal stress (a hot sauna bath and then a cold water swimming) can improve the readiness and the efficacy of the stress and immune response (higher LPS-induced cytokine secretion) in habitual winter sea bathers.[19] Moreover, cold exposure can stimulate brown adipose tissue (BAT), a thermogenic tissue that could increase energy expenditure and thus be beneficial for dysmetabolic diseases such as obesity, type 2 diabetes and metabolic syndrome.[20–22] However, this is a much-debated topic: while open water bathing does induce BAT, this only accounts for a very small percentage of total dietary fatty acid metabolism (0.3% after 4-week cold acclimation), which is not of clinical significance.[21] On the other hand, metabolic dysfunctions and other age-associated non-communicable diseases are underpinned by chronic low-grade inflammation.[23] HPA axis dysfunction, particularly hyper-activation during chronic stress, can result in glucocorticoid-resistance, with subsequent systemic inflammation.[24] Our data shows that salivary levels of IL-1β in winter sea bathers did not differ significantly from those of the control group. IL-1β is a key pro-inflammatory cytokine that is released after infection, injury or antigenic challenge, and it is considered as a biomarker of systemic inflammation as well as of the stress response.[25,26] Thus, our data seem to exclude dangerous effects of winter sea bathing on chronic inflammation, and altogether they could suggest a possible role of this activity in the development of functional plasticity of the stress response.

We want to emphasize that the study participants were not athletes but rather "ordinary people", even elderly and with some ailments typical of their age. They entered the practice of sea bathing in winter as a good habit to stay active and healthy, claiming to get psychological and physical benefits, to live a more satisfying social life and to be more resistant to disease. This is a strength of our study. Indeed, most of the literature investigating the effect of cold water immersion in humans examined athletes who often underwent heavy sports training, not only in the sea, but in swimming pools as well.[2,27] Other papers investigated the practice of sauna and subsequent cold exposure, a quite common habit in Northern Europe.[28] In our study, winter sea bathers were just normal people trying to demystify cold water bathing, and demonstrate that it is an accessible and beneficial practice to everyone.[4]

A limitation of our research was the non-randomized sample, due to the nature of the study design. However, this issue was addressed by controlling the results for socio-demographic and personality variables assessed by the questionnaires. We are also aware that the limited number of subjects enrolled for biological analysis precludes drawing definitive conclusions regarding the association between winter sea bathing and biological markers of stress and/or inflammation. Moreover, the results of our research do not allow us drawing any causal inferences about the relationship between being a winter sea bather and general wellbeing, and it was not possible to perform a longitudinal study; however, we can state that the correlation between the two is independent of all the other variables investigated due to the regression analyses performed.

Conclusion

Our data suggest that winter sea bathing is associated with a higher perception of wellbeing and it is not damaging even for elderly people, at least regarding the investigated physiological parameters. Winter sea bathers feel to have a better perception of their state of health in comparison to people who do not bath in winter, thus appearing able to handle potentially negative distress (cold exposure) and to transform it into positive stress leading to wellbeing.

Authors' contributions

All authors contributed to this work significantly. ID participated in conceiving and designing the study, planned and performed biological assays, processed the data and wrote the manuscript; TP planned and processed questionnaires and contributed to manuscript writing; DSa supervised the biological assays and revised the manuscript; EL performed the anamnestic-clinical check and processed the data; SO performed the ENT examination and processed the data; DSe revised the data and contributed to manuscript writing; MC contributed to manuscript writing and revision; RG conceived and designed the study, supervised the experimental activities and data processing, revised the manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors have self-assessed to purchase kits for biological analyses.

Acknowledgments

The authors are grateful to Professor Antonio Guerci for continuous support, encouragement, and helpful discussions during this study.

References

1. The Guardian. The big chill: the health benefits of swimming in ice water. *2008. https://www.theguardian.com/global/2018/dec/23/the-big-chill-the-health-benefits-of-swimming-in-ice-water*. Accessed 19 November 2019.
2. Tipton MJ, Collier N, Massey H, et al. Cold water immersion: kill or cure? *Exp Physiol*. 2017;102(11):1335–1355. https://doi.org/10.1113/EP086283.
3. Cimento.it. https://cimento.it. Accessed 5 December 2019.
4. Nuotatori del tempo avverso. www.nuotatorideltempoavverso.org. Accessed 5 December 2019.
5. Mooventhan A, Nivethitha L. Scientific evidence-based effects of hydrotherapy on various systems of the body. *N Am J Med Sci*. 2014;6:199–209. https://doi.org/10.4103/1947-2714.132935.
6. Kneipp S. *My Water Cure*. kempten (Bavaria): J. Koesel Publisher; 1893.
7. Byrne D, Sivik T, Lipsitt D, et al. Psycho-Neuro-Endocrino-Immunology (PNEI), a common language for the whole human body. The Netherlands: Elsevier; 2002.
8. Russell G, Lightman S. The human stress response. *Nat Rev Endocrinol*. 2019;15(9):525–534. https://doi.org/10.1038/s41574-019-0228-0.
9. World Medical Association. WMA declaration of Helsinki – ethical principles for medical research involving human subjects, 1964. https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/. Accessed 11 December 2019.
10. Woods SA, Hampson SH. Measuring the Big five with single items using a bipolar response scale. *Eur J Pers*. 2005;19:373–390. https://doi.org/10.1002/per.542.
11. Goldberg LR. An alternative "description of personality": the big-five factor structure. *J Pers Soc Psychol*. 1990;59:1216–1229. https://doi.org/10.1037/0022-3514.59.6.1216.
12. Kugler J, Hess M, Haake D. Secretion of salivary immunoglobulin A in relation to age, saliva flow, mood states, secretion of albumin, cortisol, and catecholamines in saliva. *J Clin Immunol*. 1992;12:45–49. https://doi.org/10.1007/BF00918272.
13. Nicolaides NC, Kyratzi E, Lamprokostopoulou A, et al. Stress, the stress system and the role of glucocorticoids. *Neuroimmunomodulation*. 2015;22(1–2):6–19. https://doi.org/10.1159/000362736.
14. Steptoe A, Cropley M, Griffith J, Kirschbaum C. Job strain and anger expression predict early morning elevations in salivary cortisol. *Psychosom Med*. 2000;62(2):286–292. https://doi.org/10.1097/00006842-200003000-00022.
15. Wust S, Federenko I, Hellhammer DH, et al. Genetic factors, perceived chronic stress, and the free cortisol response to awakening. *Psychoneuroendocrinology*. 2000;25(7):707–720. https://doi.org/10.1016/s0306-4530(00)00021-4.
16. Herman JP, McKlveen JM, Ghosal S, et al. Regulation of the hypothalamic-pituitary-adrenocortical stress response. *Compr Physiol*. 2016;6(2):603–621. https://doi.org/10.1002/cphy.c150015.
17. Teramoto S, Ouchi Y. Swimming in cold water. *Lancet*. 1999;354(9191):1733. https://doi.org/10.1016/S0140-6736(05)76723-4.
18. Lubkowska A, Dołęgowska B, Szyguła Z, et al. Winter-swimming as a building-up body resistance factor inducing adaptive changes in the oxidant/antioxidant status. *Scand J Clin Lab Invest*. 2013;73(4):315–325. https://doi.org/10.3109/00365513.2013.773594.
19. Dugué B, Leppänen E. Adaptation related to cytokines in man: effects of regular swimming in ice-cold water. *Clin Physiol*. 2000;20(2):114–121. https://doi.org/10.1046/j.1365-2281.2000.00235.x.
20. Lichtenbelt W, Kingma B, van der Lans A, et al. Cold exposure – an approach to increasing energy expenditure in humans. *Trends Endocrinol Metab*. 2014;25(4):165–167. https://doi.org/10.1016/j.tem.2014.01.001.
21. Blondin DP, Tingelstad HC, Noll C, et al. Dietary fatty acid metabolism of brown adipose tissue in cold-acclimated men. *Nat Commun*. 2017;8:14146. https://doi.org/10.1038/ncomms14146.
22. Lizcano F. The beige adipocyte as a therapy for metabolic diseases. *Int J Mol Sci*. 2019;20(20). https://doi.org/10.3390/ijms20205058.
23. Franceschi C, Campisi J. Chronic inflammation (inflammaging) and its potential contribution to age-associated diseases. *J Gerontol A Biol Sci Med Sci*. 2014;69(1):S4–S9. https://doi.org/10.1093/gerona/glu057.
24. Cohen S, Janicki-Deverts D, Doyle WJ, et al. Chronic stress, glucocorticoid receptor resistance, inflammation, and disease risk. *Proc Natl Acad Sci U S A*. 2012;109(16):5995–5999. https://doi.org/10.1073/pnas.1118355109.
25. Dinarello CA. The IL-1 family and inflammatory diseases. *Clin Exp Rheumatol*. 2002;20(27):S1–S13.
26. Glaser R, Kiecolt-Glaser JK. Stress-induced immune dysfunction: implications for health. *Nat Rev Immunol*. 2005;5(3):243–251. https://doi.org/10.1038/nri1571.
27. Egaña M, Jordan L, Moriarty T. A 2.5 min cold water immersion improves prolonged intermittent sprint performance. *J Sci Med Sport*. 2019;22(12):1349–1354. https://doi.org/10.1016/j.jsams.2019.07.002.
28. Radtke T, Poerschke D, Wilhelm M, et al. Acute effects of Finnish sauna and cold-water immersion on haemodynamic variables and autonomic nervous system activity in patients with heart failure. *Eur J Prev Cardiol*. 2016;23(6):593–601. https://doi.org/10.1177/2047487315594506.