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Improved Mood Following Cold-Water Immersion: A Comparison of Differing Exposure Durations

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ABSTRACT

Background: Cold-water therapy is gaining popularity as a mood-enhancing intervention. However, immersion protocols vary, particularly in terms of temperature and duration. This study examined whether different durations of cold-water immersion produce differential effects on mood.

Materials and Methods: One hundred and forty participants with self-reported low mood were randomly assigned to one of four groups: a control group or immersion groups exposed to seawater at 13.6°C ± 0.3°C for 5, 10 or 20 min. Participants in the immersion groups completed the Profile of Mood States (POMS) 7 days before and immediately after immersion; control participants completed the same measures at matched intervals. Skin temperature and heart rate were recorded before and during immersion, and heart rate variability (HRV) was analysed in 10 participants from the 5-min group.

Results: Total mood disturbance (TMD) significantly improved across cold-water immersion groups. The greatest reduction was observed in the 20-min group (mean change −15.9 points; 49.7 ± 18.8 to 33.8 ± 10.8, $p < 0.0005$), followed by the 5-min group (−14.7 points; 47.6 ± 19.9 to 32.9 ± 13.7, $p < 0.0005$) and the 10-min group (−8.8 points; 41.8 ± 15.5 to 33.0 ± 12.3, $p = 0.001$). No significant change in TMD was observed in the control group (−1.9 points; 41.5 ± 9.5 to 39.6 ± 6.4, $p = 0.156$). Immersion significantly reduced skin temperature by 10.7°C, ($t_{(48)} = 21.8$, $p < 0.0005$) and increased heart rate by 33 bpm, ($t_{(48)} = -17.76$, $p < 0.0005$). HRV showed reduced root mean square of successive differences (RMSSD) (48.8 to 28 ms) and total power (4197 to 1812 ms^2), indicating a shift from parasympathetic to sympathetic dominance.

Conclusion: Cold-water immersion appears to effectively improve mood, with benefits observed across all durations. A 5-min immersion was as effective as longer exposures, offering a practical option for implementation. While safe in healthy, screened individuals under controlled conditions, caution is advised in less structured environments or with individuals with pre-existing health conditions.

1 | Introduction

Common mental health disorders (CMDs), such as depression and anxiety, are increasing, both in the United Kingdom and globally [1, 2]. CMDs are characterised by persistent emotional distress and reduced daily functioning [3]. Although often less severe than major psychiatric conditions, their widespread prevalence poses a substantial individual and societal burden. In England, the Adult Psychiatric Morbidity Survey [4] reported that one in six adults met the criteria for a CMD, with significantly higher rates in women (one in five) than in men (one in eight). Although prevalence remained stable between 2007 and 2014, longer term trends show a steady increase.

Internationally, the World Health Organization [2] reported a 13% rise in mental disorders between 2007 and 2017. The economic

implications are profound. In the United Kingdom, mental health disorders account for approximately 7% of ill-health, with estimated costs of at least £117 billion annually, mainly due to lost productivity [5]. Christensen et al. [6] further highlighted the global economic impact, reporting an average cost of $5703 per patient for mood disorders alone. Beyond the economic toll, these conditions often go unreported or untreated due to stigma [7], particularly in the workplace. At the same time, heightened public awareness has contributed to a paradoxical increase in self-diagnosis, especially among young people [8, 9], making it increasingly difficult to assess the true scale of the problem.

Although pharmacological and psychological interventions such as cognitive behavioural therapy remain the primary treatments for moderate to severe CMDs [10], many individuals with subclinical symptoms, or those who experience issues with medication adherence or side effects, seek alternative or adjunctive approaches. Lifestyle medicine, which promotes behaviour change to prevent and manage chronic conditions, may play an important role here. According to Phillips et al. [11], lifestyle medicine operates on three levels: promoting awareness of lifestyle determinants among all healthcare providers, integrating specific interventions like exercise prescription and social prescribing, and supporting wider, population-based programmes. The six core pillars of lifestyle medicine, mental well-being, minimising harmful substances, physical activity, healthy eating, sleep and healthy relationships, are all independently associated with improved mental health outcomes [12].

Physical activity is a well-established intervention for both the prevention and treatment of anxiety and depression [13, 14]. In recent years, a growing interest has emerged around a novel variation of this approach: cold-water swimming or immersion. Gaining popularity for its perceived physical and mental health benefits, this practice typically involves swimming or dipping in water below 15°C [15]. While rooted in long-standing cultural traditions, cold-water immersion is now receiving increasing attention both anecdotally and within academic research.

Anecdotal reports [16, 17] often describe cold-water swimming as life-changing, mood-enhancing, fostering resilience and increasing energy levels. Popular books and narratives [18–23] have further fuelled interest, blending personal experience with scientific insight. Moreover, beyond testimonials, a growing body of empirical research suggests that cold-water immersion may have measurable benefits for mood and well-being.

For instance, Kelly and Bird [24] observed significant reductions in total mood disturbance (TMD) following a 20-min sea immersion. Similarly, Massey et al. [25] reported immediate improvements in mood after immersion, and longer term benefits following a 10-week open-water swimming programme. Huttunen et al. [26] found that regular winter swimmers reported reduced tension and fatigue and enhanced vigour compared to non-swimmers. These findings are supported by Demori et al. [27], who found improved mood, vitality and immune function among winter sea bathers. Their study included self-reported outcomes and objective markers, such as changes in cortisol and immune parameters. The psychological benefits have also been linked to reduced stress [28], increased resilience [29] and the social support often embedded in group swimming activities [30, 31].

Physiologically, the body's response to cold-water immersion has been well documented, particularly in relation to risk and safety [32, 33]. The initial 'cold shock' response, first described by Golden and Hervey [34] and detailed further by Tipton [33], includes an involuntary gasp, hyperventilation, elevated heart rate and blood pressure and sympathetic nervous system activation [35–37]. These responses pose a cardiovascular risk, particularly to the unacclimated individual. However, experienced cold-water swimmers appear to manage this risk effectively, employing behavioural strategies to mitigate adverse effects [31, 38]. These acute physiological responses may trigger mood-related changes, though the exact mechanisms remain speculative.

Recent studies have begun investigating the physiological correlates of mood changes following cold-water immersion. For example, Reed et al. [39] explored cardiovascular dynamics, shear stress and stress biomarkers such as beta-endorphin and cortisol in a laboratory-based 15-min immersion at 10°C. Although mood improvements were modest and delayed, reductions in cortisol were observed at 180 min post-immersion. Similarly, Yankouskaya et al. [40] demonstrated enhanced brain network connectivity and increased positive affect following a brief 5-min immersion at 20°C, suggesting a possible neural basis for the observed psychological benefits.

Although the emerging picture is positive, immersion duration is one of the key inconsistencies across studies. Protocols vary widely, from as short as 20 s [41] to as long as 20 min [24], with many studies failing to report temperature, exposure time or participant characteristics in detail. Although all reported mood improvements, it remains unclear whether a minimum effective dose exists and whether longer exposures confer additional benefit or increased risk. Understanding the influence of immersion duration could help inform safe practice while maximising potential psychological gains.

1.1 | Study Aims

The primary aim of the study was to assess whether different durations of cold-water immersion produced differential effects on mood in individuals with self-reported low mood. Specifically, we examined whether 5-, 10- and 20-min immersions would yield varying improvements in mood, as measured by changes in TMD. A secondary aim was to collect field-based physiological data, including skin temperature, heart rate and heart rate variability (HRV), to characterise the acute physiological responses to immersion.

We hypothesised that cold-water immersion would significantly improve mood compared to the control condition, and that longer immersions would result in greater improvements than short durations.

2 | Materials and Methods

This study investigated whether cold-water immersion of varying durations produced different effects on mood states in individuals experiencing self-reported low mood. The intervention was carried out under field conditions using open-water sea immersion. The study received ethical approval from the University of Chichester ethics committee (UoC1904255), and all participants provided written informed consent prior to participation.

2.1 | Participants

A total of 140 undergraduate students from the University of Chichester were recruited using a combination of lecture announcements, university email communications and word-of-mouth. The participant pool was drawn from students enrolled on sport-related degree programmes, including sport and exercise science, physical education and sport psychology. All participants were physically active and confident in the water, although none had previous experience with cold-water swimming or immersion practices.

Participants were eligible if they self-reported recent or persistent low mood but were otherwise healthy. Recruitment materials invited individuals who were 'feeling low, stressed or anxious' to take part in a study examining the effects of cold-water on mood. This self-identification approach reflected a pragmatic and ecologically valid method consistent with the delivery of lifestyle-based interventions. Exclusion criteria included a clinical diagnosis of anxiety, depression or other mood-related disorders, use of mental health or cardiovascular medication, or any history of cardiovascular or circulatory disease (e.g., arrhythmia, Raynaud's). These exclusions reflected the elevated physiological risks associated with cold exposure in these populations [42, 43]. Screening was conducted using a structured health history questionnaire.

Of the 140 individuals recruited, 121 completed all aspects of the study; 19 withdrew or did not attend immersion. The final sample (82 males, 39 females; mean age 22 ± 4 years) had a mean height of 1.73 ± 0.09 m, mean body mass of 73 ± 10.7 kg and average BMI of 24.2 ± 3.4. Figure 1 presents the participant flow, including recruitment, group allocation and testing stages.

Participants were randomly allocated to one of four groups: control ($n = 26$), 5-min immersion (5MI, $n = 30$), 10-min immersion (10MI, $n = 30$) or 20-min immersion (20MI, $n = 35$). Allocation used a simple drawing system, balancing group sizes while accommodating daily testing constraints. Target group sizes were informed by prior studies demonstrating significant mood effects with similar samples in real-world conditions [24–26].

2.2 | Study Procedures

The study followed a repeated measures design, in which mood state was assessed 1 week before immersion and immediately after the intervention. Although the 7-day interval was fixed, the time of day varied due to scheduling availability. The baseline assessments were conducted indoors, in small groups, where participants completed a short demographic form and the short version of the Profile of Mood States (POMS) questionnaire [44]. The 7-day gap between the baseline and post-immersion assessment was chosen to minimise the influence of transient mood fluctuations, such as anxiety or excitement, associated with the novel experience of cold-water exposure. Garrido's [45] systematic review of mood measurement noted that the proximity of assessment to the stimulus can confound emotional and mood responses. Administering the POMS several days prior helped ensure that baseline measurements reflected mood rather than anticipatory emotional states.

All immersion and control sessions took place across four consecutive days at a local beach approximately 20 min from the university. Participants were transported to the site via minibus in groups ranging from 27 to 34, with 34 participants tested on Day 1, 28 on Day 2, 32 on Day 3 and 27 on Day 4. Testing was conducted at high tide each day to ensure relatively stable sea conditions, as high tide is typically associated with lower water movement [46]. A mix of immersion and control group participants was included each day to reduce the risk of day-specific environmental bias.

Environmental conditions were monitored throughout the study. Ambient air temperatures ranged from 12.5°C to 14.8°C (mean 13.7°C ± 0.8°C), with a consistent onshore breeze gusting up to 30 mph on all days. The sea state was classified as rough with a steady swell, and surface water temperatures were measured approximately 8 m from shore using a floating Oregon Scientific THWR800 thermometer. Daily water temperatures were 13.9°C, 13.7°C, 13.5°C and 13.3°C, resulting in an average temperature of 13.6°C ± 0.3°C across the study period.

Participants wore minimal clothing suitable for cold-water immersion, typically swimsuits or shorts, and entered the water individually but within visible range of the group and the support staff. They were instructed to walk into the water rapidly but cautiously, to immerse themselves to chest depth without submerging their faces and to remain stationary without swimming or excessive movement. All participants reached full immersion within the first minute. The allocated immersion duration was 5, 10 or 20 min, depending on the group assignment. Participants did not consciously alter their breathing pattern during immersion; rather, changes in respiratory frequency occurred naturally as part of the physiological cold shock response [36].

Participants in the 5MI and 10MI groups completed the full immersion durations without incident. In the 20MI Group, three participants exited the water early due to discomfort: one male after 15 min and two females together after 18 min and 30 s. The average immersion time for the 20MI Group was 19 min and 48 s. All early exits were voluntary, and none were associated with adverse effects.

Immediately after leaving the water, participants dried, dressed and were offered warm clothing, hats, gloves, hot drinks and carbohydrate-rich snacks. Blankets and additional warm items were available as needed. Participants were closely monitored for signs of cold stress or afterdrop, a common phenomenon in which cold peripheral blood returns to the core, leading to a further decline in core temperature and involuntary shivering [34, 47, 48]. Although no cases of hypothermia occurred, participants

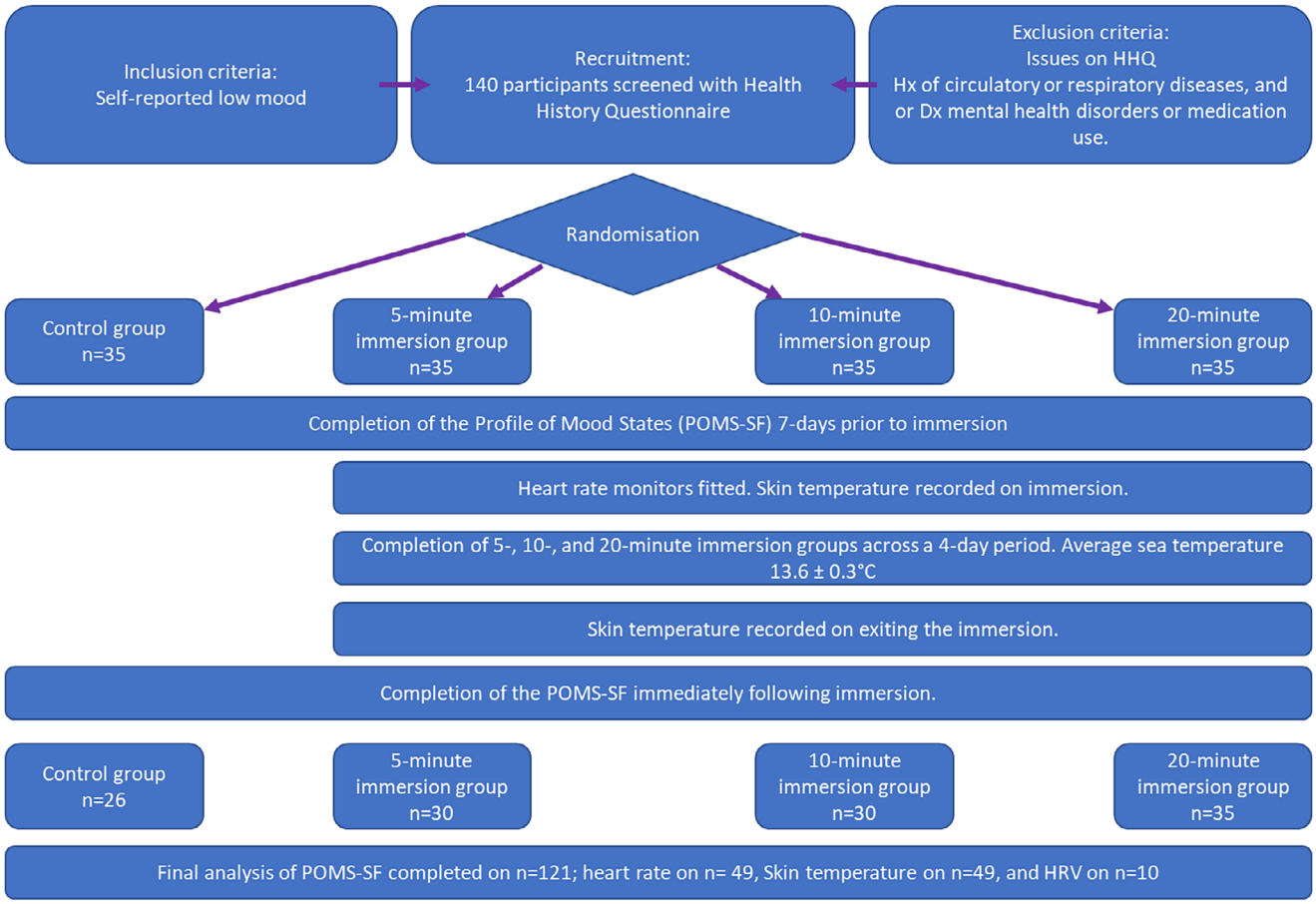

FIGURE 1 | *Participant selection and protocol CONSORT diagram*. Skin temperature data were obtained from 24 participants in the 5MI group and 25 in the 10MI group. Heart rate data were available from 20 participants in the 5MI group, 21 in the 10MI group and 8 in the 20MI group. HRV analysis was based on 10 useable traces from the 5MI group. HRV, heart rate variability.

were informed in advance about the possibility of afterdrop and reassured if symptoms occurred. Safety procedures adhered to Royal Life Saving Society UK (RLSS UK) guidance and were overseen by lifeguards trained to the National Beach Lifeguard Qualification (NBLQ) standard. A full risk assessment was completed in advance, and emergency equipment, including rescue kayaks and rewarming kits, was available on-site.

The control group participants also attended the beach on the same days as the immersion groups but did not enter the water. They remained outdoors under similar weather conditions and completed the same POMS assessments as the immersion groups, allowing for the isolation of immersion effects from environmental exposure alone.

2.3 | Measures

2.3.1 | Profile of Mood States

Mood state was assessed using the 37-item short form of the POMS [44], which captures six mood subscales: tension, anger, depression, fatigue, confusion and vigour, along with esteem-related affect. Responses are given on a 5-point Likert scale (0 = not at all, 4 = extremely). The TMD score is calculated by summing the negative mood subscales, subtracting vigour and esteem-related affect scores and adding a constant of 50 to avoid negative values. The short form has demonstrated strong psychometric properties and correlates highly ($r > 0.95$) with the original version [49] while reducing participant burden.

2.3.2 | Skin Temperature

Skin temperature was measured immediately before and after immersion using an Extech Instruments IR200 infrared thermometer set to body mode. For consistency, the sensor was aimed at the right pectoral region. This non-invasive method provided a rapid estimate of peripheral temperature changes in response to cold exposure. Post-immersion recordings were taken after participants towel-dried to remove surface water but prior to dressing to minimise evaporative cooling effects.

2.3.3 | Heart Rate and HRV

Heart rate was recorded using the Polar H10 monitor during the 5-min standing rest and throughout the subsequent 5-min immersion. From the immersion phase, the 1-min period showing the highest sustained heart rate was visually identified from the trace, and the average heart rate during this peak period was calculated.

In a sub-group of 10 participants from the 5MI group (selected on the basis of clean heart rate traces), heart rate data were analysed for HRV using the same two 5-min periods: standing rest immediately prior to immersion and during the full 5-min immersion. HRV refers to the variation in time intervals between heartbeats, capturing subtle fluctuations that reflect the dynamic balance of the autonomic nervous system (ANS), unlike heart rate, which simply measures beats per minute [50]. These fluctuations are influenced by the interplay between the sympathetic and parasympathetic branches of the ANS, modulating heart rhythm in response to internal and external demands [51, 52].

Data from the Polar H10 heart rate monitors were downloaded for assessment [53] and analysed using Kubios HRV Premium software (version 3.5; [54]). Heart rate traces were visually inspected for aberrant beats and artefacts, and a low artefact correction filter was applied.

Using Fast Fourier Transformation, two primary HRV measures were extracted. RMSSD (root mean square of successive differences) is a time-domain index that reflects short-term HRV and is particularly sensitive to high-frequency oscillations mediated by parasympathetic (vagal) activity [55]. Total power (TP), a frequency-domain measure, quantifies the overall variance in interbeat intervals across all spectral bands and reflects total autonomic input, including both sympathetic and parasympathetic influences [50]. Together, these measures provide complementary insights into autonomic function.

Non-linear HRV analysis was also conducted using Poincaré plots, which graphically display correlations between successive R–R intervals and illustrate changes in the complexity and variability of cardiac dynamics [50, 56]. Representative plots were used to visually demonstrate the shift in HRV from pre- to post-immersion. Due to the small sample size, all data are reported descriptively, and no inferential statistical analyses were conducted.

2.4 | Data Analysis

Data were analysed using SPSS version 23. The normality of the distribution was assessed using skewness and kurtosis ratios, with values between ±2 considered acceptable.

TMD scores were analysed using a two-way mixed-model ANOVA with one between-subjects factor (group: control, 5MI, 10MI, 20MI) and one within-subjects factor (time: pre- vs. post-immersion). Post hoc comparisons between groups were performed using Tukey's test. As there were only two time points (pre- and post), no additional post hoc tests were required for the main effect of time. Interaction effects between group and time were further explored using paired *t*-tests or non-parametric equivalents where assumptions of normality were violated.

Heart rate and skin temperature changes were analysed using two-way ANOVAs with appropriate follow-up comparisons. However, HRV parameters are presented as descriptive statistics due to the low sample size and large inter- and intra-variability.

Effect sizes for ANOVA tests were calculated using eta squared (η^2), interpreted according to standard conventions: 0.01 = small effect, 0.06 = medium effect and 0.14 = large effect [57, 58]. Data are presented as mean ± standard deviation, and statistical significance was accepted at $p < 0.05$.

3 | Results

The study immersed 95 individuals in cold water for 5–20 min. No incidents were reported during the immersion, immediately afterwards or in the days following.

3.1 | Mood

Table 1 presents the pre- and post-immersion scores ($M \pm$ SD) alongside the *t*-test results for TMD and all POMS subscales.

TMD showed a significant main effect for time, with scores lower after the immersion ($F_{(1,117)} = 59.026$, $p < 0.005$, eta = 0.335) and a significant interaction between time and group ($F_{(3,117)} = 5.403$, $p = 0.002$, eta = 0.122). There was no main effect for group ($F_{(3,117)} = 0.708$, $p = 0.549$, eta = 0.018). Post hoc *t*-tests confirmed that TMD was reduced in all three immersion groups but did not change in the control group. The greatest reduction was observed in the 20-min group (mean change −15.9 points; 49.7 ± 18.8 to 33.8 ± 10.8, $p < 0.0005$), followed by the 5-min group (−14.7 points; 47.6 ± 19.9 to 32.9 ± 13.7, $p < 0.0005$) and the 10-min group (−8.8 points; 41.8 ± 15.5 to 33.0 ± 12.3, $p = 0.001$). Although the 20-min group showed the greatest absolute improvement in TMD, between group comparisons revealed no significant differences across immersion groups. No significant change in TMD was observed in the control group (−1.9 points; 41.5 ± 9.5 to 39.6 ± 6.4, $p = 0.156$).

3.1.1 | Positive Sub-Scales

The ANOVA for vigour returned significant main effects for both time ($F_{(1,117)} = 12.38$, $p = 0.001$, eta = 0.96) and group ($F_{(1,117)} = 6.512$, $p < 0.0005$, eta = 0.143), and a significant interaction between time and group ($F_{(3,117)} = 4.533$, $p = 0.005$, eta = 0.104). The Tukey post hoc for the main effect group indicated that the control had significantly lower vigour than the immersion groups: 5.3 ± 3.3 versus 9.0 ± 3.2, 8.3 ± 3.3 and 8.1 ± 3.3 for the 5MI, 10MI and 20MI, respectively. This was largely an effect of the increase in vigour following the immersion. However, the groups differed at baseline, with the 10MI Group having statistically higher vigour than the other groups. There were significant increases in vigour for both the 5MI and 20MI groups. The 10MI Group did not change, and there was no change in the control group. The initial vigour value for the 10MI (8.3 ± 4.6 points) was the highest of the four groups, although both the 5MI and 20MI groups finished on higher values (5MI = 10.2 ± 2.9, 20MI = 9.2 ± 3.8, vs. 10MI = 8.2 ± 4.6). A comparison between the groups following immersion showed that all three immersion groups had significantly higher vigour than the control group.

Esteem-related affect (ERA) is presented in Table 1. The ANOVA returned significant main effects for both time ($F_{(1,117)} = 40.73$,

TABLE 1 | Comparison of pre- and post-immersion mood states across groups.

POMS scale	Group	Pre immersion (Means ± SD)	Post immersion (Means ± SD)	*t* value	*p* value
TMD	Control	41.5 ± 9.5	39.6 ± 6.4	$t_{(25)} = 1.463$	0.156
	5MI	47.6 ± 19.9	32.9 ± 13.7	$t_{(29)} = 5.416$	**<0.0005**
	10MI	41.8 ± 15.5	33 ± 12.3	$t_{(29)} = 3.904$	**0.001**
	20MI	49.7 ± 18.8	33.8 ± 10.8	$t_{(34)} = 4.749$	**<0.0005**
Vigour	Control	5.35 ± 3.6	5.31 ± 2.8	$t_{(25)} = 0.086$	0.932
	5MI	7.8 ± 3.6	10.2 ± 2.9	$t_{(29)} = -3.247$	**0.003**
	10MI	8.3 ± 4.6	8.2 ± 4.6	$t_{(29)} = 0.099$	0.922
	20MI	6.9 ± 3.3	9.2 ± 3.8	$t_{(34)} = -3.604$	**0.001**
ERA	Control	14.0 ± 3.3	14.2 ± 3.6	$t_{(25)} = -0.332$	0.743
	5MI	14.9 ± 2.9	17.4 ± 2.6	$t_{(29)} = -4.933$	**<0.0005**
	10MI	14.2 ± 4.0	16.0 ± 3.9	$t_{(29)} = -2.688$	**0.012**
	20MI	14.4 ± 3.4	17.4 ± 2.9	$t_{(34)} = -5.267$	**<0.0005**
Confusion	Control	3.2 ± 3.2	3.2 ± 3.0	$t_{(25)} = 0.000$	1.000
	5MI	4.2 ± 4.5	2.2 ± 3.2	$t_{(29)} = 2.681$	**0.012**
	10MI	4.1 ± 3.0	2.4 ± 3.2	$t_{(29)} = 3.474$	**0.002**
	20MI	5.6 ± 4.2	2.5 ± 2.6	$t_{(34)} = 4.957$	**<0.0005**
Depression	Control	0.7 ± 2.0	0.9 ± 1.1	$t_{(25)} = -0.390$	0.700
	5MI	2.8 ± 5.1	1.3 ± 2.5	$t_{(29)} = 2.343$	**0.026**
	10MI	1.3 ± 2.8	0.8 ± 1.9	$t_{(29)} = 0.906$	0.372
	20MI	2.5 ± 4.2	0.6 ± 1.3	$t_{(34)} = 2.622$	**0.013**
Tension	Control	2.3 ± 2.4	2.1 ± 2.0	$t_{(25)} = 0.531$	0.600
	5MI	4.4 ± 4.0	2.8 ± 3.1	$t_{(29)} = 2.138$	**0.041**
	10MI	3.0 ± 3.6	2.0 ± 2.0	$t_{(29)} = 1.714$	0.097
	20MI	4.3 ± 4.2	2.3 ± 2.4	$t_{(34)} = 2.629$	**0.013**
Anger	Control	1.1 ± 1.9	0.9 ± 1.6	$t_{(25)} = -0.700$	0.490
	5MI	2.4 ± 3.0	1.1 ± 2.0	$t_{(29)} = 2.959$	**0.006**
	10MI	0.7 ± 1.8	0.4 ± 1.1	$t_{(29)} = 1.179$	0.248
	20MI	1.8 ± 2.3	0.8 ± 1.8	$t_{(34)} = 1.927$	**0.062**
Fatigue	Control	3.4 ± 2.4	2.8 ± 2.5	$t_{(25)} = 1.486$	0.150
	5MI	6.3 ± 3.8	3.1 ± 2.8	$t_{(29)} = 4.513$	**<0.0005**
	10MI	4.2 ± 3.5	3.3 ± 3.3	$t_{(29)} = 1.405$	0.171
	20MI	6.5 ± 4.7	4.1 ± 3.3	$t_{(34)} = 2.572$	**0.015**

Note: The *t* values represent paired *t*-tests comparing pre- and post-immersion scores within each group. Boldface indicates statistically significant differences ($p < 0.05$). Total mood disturbance (TMD) was calculated by summing the negative sub-scales (tension, anger, depression, fatigue, confusion) and subtracting vigour and esteem-related affect and adding 50 to avoid negative values.

$p < 0.0005$, eta = 0.258) and group ($F_{(3,117)} = 2.707$, $p = 0.048$, eta = 0.065) and a significant interaction ($F_{(3,117)} = 4.258$, $p = 0.007$, eta = 0.098). A comparison between groups using the Tukey test indicated that the 5MI had significantly higher scores than the control group, but 10MI and 20MI were not different from the 5MI or control group. There were significant increases in ERA in all immersion groups but no change in the control group.

3.1.2 | Negative Sub-Scales

Results for the confusion sub-scale returned a significant main effect for time, lower confusion after the immersion ($F_{(1,117)} = 29.897$, $p < 0.0005$, eta = 0.204) but not group ($F_{(3,117)} = 0.672$, $p = 0.571$, eta = 0.017). There was a significant interaction ($F_{(3,117)} = 4.233$, $p = 0.007$, eta = 0.098). Confusion decreased in the 5MI and 20MI

immersion groups, but there was no change in the control group. There was an increase in confusion in the 10MI Group.

The results for the depression subscale showed a significant main effect for time ($F_{(1,117)}$ = 9.228, p = 0.003, eta = 0.073), demonstrating a reduction in depression. There was no group effect ($F_{(3,117)}$ = 1.785, p = 0.154, eta = 0.044) or interaction ($F_{(3,117)}$ = 2.174, p = 1.095, eta = 0.053). The 5MI and 20MI groups showed a significant reduction, but there was no change in the control group or the 10MI group. Both the control and the 10MI groups had low initial scores.

For the tension subscale, there was a significant main effect for time ($F_{(1,117)}$ = 12.815, p = 0.001, eta = 0.099). Tension was lower following the immersion. There was no group effect ($F_{(3,117)}$ = 1.896, p = 0.134, eta = 0.046) or interaction ($F_{(3,117)}$ = 1.257, p = 0.293, eta = 0.293). There were significant reductions in tension for the 5MI and 20MI groups and a trend towards significance in the 10MI group (p = 0.09). There was no change in the control group.

There was a significant main effect for anger for time ($F_{(1,117)}$ = 11.396, p = 0.001, eta = 0.089), showing a reduction in anger. There was a significant main effect for group ($F_{(3,117)}$ = 2.847, p = 0.039, eta 0.069). The 5MI group was significantly higher than the control, but there was no difference between the remaining groups. The interaction was not significant ($F_{(3,117)}$ = 1.579, p = 0.198, eta = 0.039). In this case, only the 5MI group significantly reduced anger (p = 0.006). The 20MI group was very close to significance (p = 0.062), but the 10MI and the control group showed no change. The 10MI and control groups had the lowest initial values.

For fatigue, there was a significant main effect for time ($F_{(1,117)}$ = 22.572, p < 0.0005, eta = 0.162), showing a reduction in fatigue. The main effect for the group was also significant ($F_{(3,117)}$ = 3.840, p = 0.012, eta = 0.090), with the 20MI group having higher fatigue than the control group, but no other differences between groups. The interaction was not significant but close ($F_{(3,117)}$ = 2.429, p = 0.069, eta = 0.059). Both the 5MI and 20MI showed significant reductions in fatigue, but the control group and the 10MI did not. Again, the control group and the 10MI had the lowest initial values.

3.2 | Skin Temperature

Skin temperature recordings were available for 49 participants (24 for the 5MI and 25 for the 10MI). There was a main effect for time ($F_{(1,46)}$ = 423, p = 0.01, eta = 0.753). Skin temperature was reduced from 28.2°C ± 2.2°C to 17.5°C ± 3.8°C. There was no main effect for group ($F_{(2,46)}$ = 0.645, p = 0.529, eta = 0.004) or an interaction ($F_{(2,46)}$ = 0.132, p = 0.877, eta < 0.000). This demonstrates a consistent decrease in skin temperature irrespective of the duration of the immersion, with skin temperature decreasing to the same extent in 5 min compared to the longer exposures.

3.3 | Heart Rate and HRV

Of the 95 participants immersed, 49 (5MI = 20, 10MI = 21 and 20MI = 8) returned usable heart rate recordings. The reminder was eliminated due to excessive artefacts and, or intermittent traces. Heart rate was significantly higher during the immersion (main effect Time), increasing from 87 ± 14 bpm in the 5 min prior to immersion to 1-min peak average values of 120 ± 20 bpm ($F_{(2,46)}$ = 224, p < 0.0005, eta = 0.841). There was no main effect for group ($F_{(2,46)}$ = 0.207, p = 0.814, eta = 0.009) or an interaction ($F_{(2,46)}$ = 0.234, p = 0.0793, eta = 0.010). Therefore, heart rate showed a very similar response pattern for each group: 5MI 86 ± 13 to 119 ± 21 bpm, 10MI 86 ± 14 to 120 ± 22 bpm and 20MI 91 ± 18 to 122 ± 13 bpm. Inspection of the trace showed that peak heart rate occurred within the first 2 min of immersion, irrespective of the group.

For the HRV subgroup of 10 participants, heart rate increased from 79 to 115 bpm during the 5-min immersion. HRV parameters showed a significant decrease in TP, dropping from 4197 to 1812 ms^2, indicating a clear withdrawal of vagal activity. This was further evidenced by the RMSSD decreasing from 47.8 to 28 ms. Figure 2 illustrates an individual participant's Poincaré plot, with panel A representing pre-immersion and panel B during immersion. These plots graph each R–R interval against the subsequent one (RR_n vs. RR_{n+1}), providing a visual and quantitative representation of heart rate dynamics [59]. The pre-immersion plots typically showed a broader, more dispersed elliptical shape, reflecting greater short-term beat-to-beat variability and higher parasympathetic modulation. In contrast, plots during cold-water immersion appeared noticeably smaller and more condensed, suggesting a reduction in variability and complexity, and a shift toward sympathetic dominance. These visual patterns supported the findings from RMSSD and TP, offering an intuitive representation of the autonomic response to cold exposure.

3.4 | Summary

Immersion in seawater provoked a reduction in skin temperature and an increase in heart rate. TMD was significantly reduced in the three immersion groups but not the control group, thus confirming that immersion in cold water does improve mood. The positive sub-scales also showed significant increases for the immersion groups but not the control group. The exception was the 10MI group's vigour score, which did not increase. However, the 10MI group had the highest initial value for vigour. The negative sub-scales showed a more complicated picture. Conversely, the control group showed no change in any negative subscales. The immersion groups generally showed an improvement. Where an immersion group showed no change, this was due to initial starting values.

4 | Discussion

This study supported the hypothesis that cold-water immersion improves mood, with all immersion durations producing signifi-

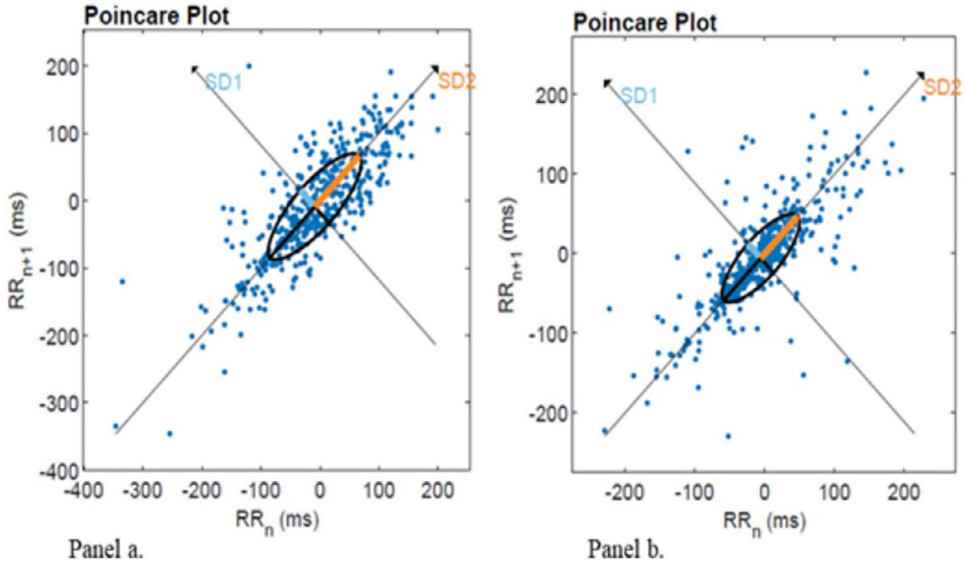

FIGURE 2 | Individual Poincaré plot of HRV 5 min before immersion (Panel a) compared to during immersion (Panel b).

cant reductions in TMD compared to the control group. However, the anticipated dose-response effect was not observed, as the 5-min immersion yielded improvements comparable to the 10- and 20-min exposures.

Furthermore, the study confirmed that immersion in cold seawater causes a rapid decrease in skin temperature and a sharp rise in heart rate, likely due to vagal withdrawal [36, 60]. Immediately after immersion, there was a notable improvement in mood, evidenced by a reduction in TMD, achieved by an increase in positive mood aspects and, to a lesser extent, a decrease in negative aspects. No mood changes were observed in the control group. Additionally, the mood improvement was independent of immersion duration, with 5 min in the sea being as effective as 20 min. The protocols were generally well tolerated, though three participants in the 20-min group exited the water early, unlike the other groups. No adverse events occurred during or after the immersions, and no issues were reported in the following 3 days, confirming that cold-water immersion is a safe practice for young, healthy individuals with self-reported low mood.

4.1 | Changes in Mood

The findings of this study align with prior research that consistently shows an enhancement in mood following cold water immersion [24–26, 39, 40, 61]. This effect is observed across various protocols, including sea swimming [25, 26], sea dipping [24], lake swimming [61] and controlled laboratory immersion [39, 40]. Additionally, the positive impact on mood persists despite different assessment methods (POMS, Positive and Negative Affect Schedule [PANAS] and self-reported well-being), notable variations in water temperature ranging from approximately 10°C to 20°C, and differences in immersion duration.

A key finding of our study was the minimal difference between groups in mood improvement. All three immersion groups exhibited a significant reduction in TMD, with changes of a similar magnitude, whereas the control group showed no change. This trend was generally consistent across the sub-scales, except for the 10MI group. Despite a significant improvement in TMD, the 10MI group showed no change in vigour, fatigue, depression or anger, and an increase in confusion. Despite these nuances, we conclude that a 5-min immersion in cold seawater is as effective in enhancing mood as longer immersions and may reduce the risks, such as afterdrop and impaired motor control, associated with longer durations.

However, despite the generally consistent responses observed in cold-water mood studies, there is notable variability in both the direction and magnitude of the effects reported in the literature. This inconsistency is further complicated by the use of different methods for assessing mood, such as the POMS and the PANAS. For instance, Reed et al. [39] found an improvement in mood, but this was limited to a modest reduction in negative affect, which only became apparent 3 h post-immersion. There was no observed change in positive affect. Reed et al.'s study is distinct from other research in that it did not show an immediate effect on mood. The study's findings are unlikely due to an insufficient thermal challenge, as the water temperature of 10°C and the 15-min duration were within the ranges commonly used in similar research. Moreover, the PANAS questionnaire is a well-established mood research tool known for its strong validity and reliability [62]. One important consideration is the initial baseline scores of the participants, which can influence outcomes, as evidenced in our study. Reed et al. reported that their participants had a positive affect score of 30 U, close to the normative mean of 31.3 U and a negative affect score of 11 U, significantly lower than the normative mean of 16.0 U [63]. This suggests that their participants already exhibited a relatively positive mood and low initial levels of negative mood. This issue was apparent in our study too, with the 10MI group displaying a much better mood profile than the other groups.

The impact of differing initial mood values poses a challenge for this study and others. Several critical issues should be considered when interpreting changes in mood and designing

future research protocols. These include regression to the mean [64], ceiling and floor effects [57, 65], baseline variability [66], differential responsiveness [67] and the interpretation of sub-scales, particularly those related to negative affect [68].

In our study, the initial high vigour score and low scores on negative sub-scales such as fatigue, depression, confusion and anger in the 10MI group may have influenced our findings. Specifically, the high initial vigour score suggests limited room for improvement in this sub-scale (ceiling effect). Conversely, the low initial scores for fatigue, depression and anger limited the potential for further reduction in these negative emotions (floor effect). In addition, some caution should be exercised as the 10MI group score for confusion increased. Changes in TMD may reflect a natural regression towards average scores rather than a genuine effect of the intervention (regression to the mean). Addressing the methodological challenges in cold-water and mood research is complex and will require careful consideration and application of appropriate strategies. For instance, we initially recruited participants reporting low mood and randomly assigned them to one of four groups, anticipating equalising differences across groups. Although this may hold true for the aggregate TMD score, significant differences were observed between groups at baseline in the sub-scales. An alternative approach would be to match the groups on TMD, but this would not necessarily have improved the sub-scale differences. Consideration needs to be given to the participant selection, and inclusion criteria should be used to select those individuals who would benefit from the intervention, that is, those with low mood scores. The inclusion of a matched control group is always necessary.

4.1.1 | Skin Temperatures

Although reductions in skin temperature during cold-water immersion have been widely reported, few studies have examined these changes under field conditions or in non-swimming participants. In this study, all three immersion groups showed a marked and comparable drop in skin temperature of nearly 11°C, with final values around 17.5°C. These changes are consistent with prior research [69] and reinforce the rapid cooling effect of cold water via stimulation of thermoreceptors and nociceptors [70, 71]. Notably, 5 min of immersion was sufficient to achieve the same degree of skin cooling as longer exposures, suggesting that even brief immersion provides a substantial physiological challenge.

4.1.2 | Heart Rate

Cold-water immersion significantly impacts heart rate due to the body's acute stress response to sudden cold exposure [33]. In the current study, all three immersion groups experienced heart rate increases consistent with the cold shock response, rising by an average of 33 bpm (from 87 to 120 bpm) and peaking in the first minute. This response occurred in seawater at 13.6°C ± 0.03°C, with participants standing and required to actively maintain their position in the water. In contrast, Reed et al. [39] reported a smaller average increase of 10 bpm (from 75 to 85 bpm) in participants immersed in 10°C water under passive conditions, seated and lifted into a bath via a hydraulic system. Similarly, Yankouskaya et al. [40] observed an increase from 85 to 110 bpm within 10 s of immersion in 20°C water, where participants stepped into the bath but remained stationary during the 5-min exposure. These variations in heart rate responses across studies likely reflect differences in water temperature, body positioning, physical activity during immersion and methodological control.

4.1.3 | Heart Rate Variability

Although HRV data were collected in only a small sub-sample of participants, some tentative observations can be made. These findings should be interpreted cautiously, as the low sample size and variability between individuals limit the strength of conclusions. Nonetheless, the data offer initial useful insights and highlight the need for further, well-controlled studies to better understand the autonomic responses to cold-water immersion in this context.

The findings from this study, namely an increase in heart rate and a decrease in HRV, indicate reduced vagal activity during immersion and a shift towards sympathetic predominance [72], albeit in a small sample of 10 participants. Both TP and RMSSD decreased, and the Poincaré plot showed notable compression. Although a reduction in HRV, particularly vagal tone, can sometimes be interpreted as a diminished capacity for physiological flexibility, this must be viewed in context. In this case, the observed changes reflect an acute, adaptive response to a strong environmental stressor, rather than a pathological state. Short-term reductions in HRV, such as those occurring during physical exertion, anxiety or cold-exposure, are well-established features of autonomic reactivity and can be compatible with good health [73]. In contrast, chronically suppressed HRV is more closely associated with increased cardiovascular risk. Individual variation in response to immersion is also important: What might be a manageable sympathetic activation for one person could present a greater challenge to another, particularly those with pre-existing cardiovascular conditions. We, therefore, do recommend caution when attempting cold-water immersion for the first time, and we suggest a discussion with a general practitioner before engaging in the practice. It would also be prudent to start in the warmer summer months and go with a friend. The outdoor swimming society provides excellent guidance for beginners [74].

Speculating on the connection between physiological measures and mood changes from this study leads to several intriguing hypotheses. The sharp rise in heart rate upon cold-water immersion suggests an acute stress response, with changes in HRV indicating a shift towards sympathetic activation and parasympathetic withdrawal in the subgroup studied. This initial stress response may prompt the release of endorphins and other neurochemicals [39], potentially contributing to an improved mood thereafter. Yankouskaya et al. [40] also support this idea, noting changes in brain networks in their research.

Moreover, the transition from vagal (parasympathetic) to sympathetic dominance during immersion, followed by a return to a parasympathetic state post-immersion (although not recorded in

this study), could lead to a rebound effect or vagal overdrive. This shift back to vagal dominance is associated with relaxation and a positive mood, as documented in the literature on vagal activation and relaxation states [75]. Sullivan et al. propose that activities directly stimulating the vagus nerve enhance parasympathetic activity, promoting calmness and social engagement, aligning with the polyvagal theory [76].

Alternatively, a more direct mechanism could involve the release of neurotransmitters triggered by the stimulation of thermoreceptors [71] and nociceptors [70]. Previous studies have shown increases in norepinephrine [77] and cortisol [39] following cold water immersion. However, cold exposure induces complex hormonal responses, including heightened stress-related hormones and potential decreases in thyroid hormones [37], thus presenting a complex and interactive picture.

5 | Conclusion

This study demonstrated that immersion in cold seawater induces rapid skin temperature decreases and significant heart rate increases, primarily due to vagal withdrawal. Immediately following immersion, participants experienced a notable improvement in mood, characterised by enhanced positive mood aspects and a modest reduction in negative aspects. Importantly, this mood enhancement was independent of immersion duration, with even 5 min in the sea yielding similar benefits as longer durations. Importantly, these effects were observed in participants who had been appropriately screened, and who followed procedures that had been fully risk assessed and implemented under controlled, supervised conditions, ensuring the safety of the protocol. From a practical standpoint, the lack of difference in mood improvement between the differing durations suggests that longer immersions may be unnecessary for psychological benefit and could increase the physiological strain or risk (afterdrop, impaired motor function, etc.) without additional mood-related gain. However, longer immersions may still be beneficial for other populations or outcomes, such as inflammatory conditions or musculo-skeletal pain, and this warrants further investigation.

The study's protocols were generally well tolerated, though a few participants in the 20-min group exited the water early. No adverse events occurred during or after the immersions, reaffirming the safety of cold-water immersion for young healthy individuals. Physiologically, the acute stress response triggered by cold exposure was evident through increased heart rates and reduced HRV, indicating a shift towards sympathetic activation.

Speculative hypotheses on the physiological mechanisms underlying mood improvement suggest that the initial stress response during immersion may release endorphins and other neurochemicals, contributing to enhanced mood. Additionally, shifts between sympathetic and parasympathetic dominance during and after immersion could promote relaxation and a positive mood state, supported by theories on vagal activation and neurotransmitter release.

Although further research is needed to fully elucidate these mechanisms and address methodological considerations such as baseline mood variability and assessment tools, this study contributes valuable insights into cold-water immersion's psychological and physiological effects in a field-based setting.

It is important to note that the cold-water immersions in this study were conducted under carefully controlled conditions, with trained lifeguards on hand and full safety protocols in place. All participants were physically active, fit and screened for pre-existing issues, and the sessions were closely supervised in a structured group format. These conditions differ significantly from unsupervised, individual immersions in natural environments. As such, although the results suggest cold-water immersion can offer psychological benefits, individuals should approach the practice with caution, particularly those with pre-existing health conditions. We recommend that anyone considering cold-water immersion for mood or well-being first consult their general practitioner. Starting in the warmer summer months, gradually acclimatising and swimming with others are all sensible strategies to reduce risk. Reputable organisations such as the Outdoor Swimming Society [74] offer useful safety guidance for beginners.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The dataset supporting the findings of this study is available upon request from the corresponding author. J.S.Kelly@chi.ac.uk

References

1. R. Vadivel, S. Shoib, and S. El Halabi, "Mental Health in the Post-COVID-19 Era: Challenges and the Way Forward," *General Psychiatry* 34, no. 1 (2021): e100424, https://doi.org/10.1136/psych-2020-100424.

2. World Health Organisation, *Mental Health* (World Health Organisation, 2024), https://www.who.int/health-topics/mental-health#tab=tab_2.

3. National Institute for Health and Care Excellence, *Common Mental Health Problems: Identification and Pathways to Care* (National Institute for Health and Care Excellence, 2011), https://www.nice.org.uk/guidance/cg123.

4. S. McManus, P. Bebbington, R. Jenkins, and T. Brugha, eds., *Mental Health and Well-being in England: Adult Psychiatric Morbidity Survey 2014* (NHS Digital, 2016), https://www.gov.uk/government/statistics/adult-psychiatric-morbidity-survey-mental-health-and-wellbeing-england-2014.

5. D. McDaid, A.-L. Park, and G. Davidson, *The Economic Case for Investing in the Prevention of Mental Health Conditions in the UK* (Mental Health Foundation, 2022), https://pure.qub.ac.uk/en/publications/the-economic-case-for-investing-in-the-prevention-of-mental-healt.

6. M. K. Christensen, C. C. W. Lim, and S. Saha, "The Cost of Mental Disorders: A Systematic Review," *Epidemiology and Psychiatric Sciences* 29 (2020): e161, https://doi.org/10.1017/S204579602000075X.

7. M. O. McGrath, K. Krysinska, N. J. Reavley, K. Andriessen, and J. Pirkis, "Disclosure of Mental Health Problems or Suicidality at Work: A Systematic Review," *International Journal of Environmental Research and Public Health* 20, no. 8 (2023): 5548, https://doi.org/10.3390/ijerph20085548.

8. L. Foulkes and J. L. Andrews, "Are Mental Health Awareness Efforts Contributing to the Rise in Reported Mental Health Problems? A Call to Test the Prevalence Inflation Hypothesis," *New Ideas in Psychology* 69 (2023): 101010, https://doi.org/10.1016/j.newideapsych.2023.101010.

9. L. Foulkes and A. Stringaris, "Do no Harm: Can School Mental Health Interventions Cause Iatrogenic Harm?," *BJPsych Bulletin* 47, no. 5 (2023): 267–269, https://doi.org/10.1192/bjb.2023.22.

10. D. J. Miklowitz, O. Efthimiou, and T. A. Furukawa, "Adjunctive Psychotherapy for Bipolar Disorder: A Systematic Review and Component Network Meta-Analysis," *JAMA Psychiatry* 78, no. 2 (2021): 141–150, https://doi.org/10.1001/jamapsychiatry.2020.2993.

11. E. M. Phillips, E. P. Frates, and D. J. Park, "Lifestyle Medicine," *Physical Medicine and Rehabilitation Clinics* 31, no. 4 (2020): 515–526, https://doi.org/10.1016/j.pmr.2020.07.006.

12. British Society of Lifestyle Medicine, *What is Lifestyle Medicine?* (British Society of Lifestyle Medicine, 2023), https://bslm.org.uk/lifestyle-medicine/what-is-lifestyle-medicine/.

13. E. Anderson and J. L. Durstine, "Physical Activity, Exercise, and Chronic Diseases: A Brief Review," *Sports Medicine and Health Science* 1, no. 1 (2019): 3–10, https://doi.org/10.1016/j.smhs.2019.08.006.

14. D. L. Gill, C. C. Hammond, and E. J. Reifsteck, "Physical Activity and Quality of Life," *Journal of Preventive Medicine and Public Health* 46, no. S1 (2013): S28–S34, https://doi.org/10.3961/jpmph.2013.46.S.S28.

15. B. Knechtle, Z. Waśkiewicz, C. V. Sousa, L. Hill, and P. T. Nikolaidis, "Cold Water Swimming—Benefits and Risks: A Narrative Review," *International Journal of Environmental Research and Public Health* 17, no. 23 (2020): 8984, https://doi.org/10.3390/ijerph17238984.

16. K. Kamleitner. *How Cold Water Swimming Helps me to Cope With Depression and Grief* (2023), https://adventurequeens.co.uk/2023/10/31/how-cold-water-swimming-helps-me-to-cope-with-depression-and-grief/.

17. R. Starr, *From Starr to Starrfish: A Non-Swimmer's Quest to Swim the English Channel* (Book Guild Publishing, 2013).

18. L. Cox, *Open Water Swimming Manual* (Vintage Books, 2013).

19. R. Deakin, *Waterlog: The Book That Inspired the Wild Swimming Movement* (Vintage, 2000).

20. M. Harper, *Chill: The Cold Water Swim Cure—A Transformative Guide to Renew Your Body and Mind*, 1st ed. (Chronicle Books, 2022).

21. R. Jones, *Toes in the Water: Stories of Lives Changed by Wild Swimming* (Vertebrate Publishing, 2023).

22. K. Rew, ed., *The Outdoor Swimmers' Handbook: Collected Wisdom on the Art, Sport and Science of Outdoor Swimming* (Rider, 2022).

23. B. Tsui, *Why We Swim* (Rider, 2021).

24. J. S. Kelly and E. Bird, "Improved Mood Following a Single Immersion in Cold Water," *Lifestyle Medicine* 3, no. 1 (2022): e53, https://doi.org/10.1002/lim2.53.

25. H. Massey, N. Kandala, C. Davis, M. Harper, P. Gorczynski, and H. Denton, "Mood and Well-Being of Novice Open Water Swimmers and Controls During an Introductory Outdoor Swimming Programme: A Feasibility Study," *Lifestyle Medicine* 1, no. 2 (2020): e12, https://doi.org/10.1002/lim2.12.

26. P. Huttunen, L. Kokko, and V. Ylijukuri, "Winter Swimming Improves General Well-Being," *International Journal of Circumpolar Health* 63, no. 2 (2004): 140–144, https://doi.org/10.3402/ijch.v63i2.17700.

27. I. Demori, T. Piccinno, and D. Saverino, "Effects of Winter Sea Bathing on Psychoneuroendocrinoimmunological Parameters," *Explore* 17, no. 2 (2021): 122–126, https://doi.org/10.1016/j.explore.2020.02.004.

28. M. A. Christie and D. Elliott, "From a Dark Place to a Blue Space: Open Water Swimming Transformed Our Lives," *Sport in Society* 28 (2025): 1082–1112, https://doi.org/10.1080/17430437.2024.2357231.

29. R. Foley, "Swimming in Ireland: Immersions in Therapeutic Blue Space," *Health & Place* 35 (2015): 218–225, https://doi.org/10.1016/j.healthplace.2014.09.015.

30. S. Gould, F. McLachlan, and B. McDonald, "Swimming With the Bicheno "Coffee Club": The Textured World of Wild Swimming," *Journal of Sport and Social Issues* 45, no. 1 (2021): 39–59, https://doi.org/10.1177/0193723520928594.

31. J. S. Kelly and D. Dahl, "Cold Water Swimming: The Risk is the Reward," in Proceedings of the 10th International Mountain and Outdoor Sports Conference (2022), https://www.researchgate.net/publication/365743512_CWS_risk_benefits_Prague_2022.

32. J. J. Bierens, P. Lunetta, M. Tipton, and D. S. Warner, "Physiology of Drowning: A Review," *Physiology* 31, no. 2 (2016): 147–166, https://doi.org/10.1152/physiol.00002.2015.

33. M. J. Tipton, "The Initial Responses to Cold-Water Immersion in Man," *Clinical Science* 77, no. 6 (1989): 581–588, https://doi.org/10.1042/cs0770581.

34. F. S. C. Golden and G. R. Hervey, "The Mechanism of the After-Drop Following Immersion Hypothermia in Pigs," *Journal of Physiology* 272, no. 1 (1977): 26–27.

35. J. W. Castellani and A. J. Young, "Human Physiological Responses to Cold Exposure: Acute Responses and Acclimatisation to Prolonged Exposure," *Autonomic Neuroscience* 196 (2016): 63–74, https://doi.org/10.1016/j.autneu.2016.02.009.

36. A. Datta and M. Tipton, "Respiratory Responses to Cold Water Immersion: Neural Pathways, Interactions, and Clinical Consequences Awake and Asleep," *Journal of Applied Physiology* 100, no. 6 (2006): 2057–2064, https://doi.org/10.1152/japplphysiol.01201.2005.

37. T. Pääkkönen and J. Leppäluoto, "Cold Exposure and Hormonal Secretion: A Review," *International Journal of Circumpolar Health* 61, no. 3 (2002): 265–276, https://doi.org/10.3402/ijch.v61i3.17474.

38. M. Christie and D. Elliott, "You Have to Respect the Water': Participant Experiences of Appreciating and Managing the Risks Associated With Open Water Swimming—A Rapid Ethnographic Study," *International Journal of Aquatic Research and Education* 14, no. 3 (2024): 3, https://insight.cumbria.ac.uk/id/eprint/7628.

39. E. L. Reed, C. L. Chapman, and E. K. Whittman, "Cardiovascular and Mood Responses to an Acute Bout of Cold Water Immersion," *Journal of Thermal Biology* 118 (2023): 103727, https://doi.org/10.1016/j.jtherbio.2023.103727.

40. A. Yankouskaya, R. Williamson, C. Stacey, J. J. Totman, and H. Massey, "Short-Term Head-Out Whole-Body Cold-Water Immersion Facilitates Positive Affect and Increases Interaction Between Large-Scale Brain Networks," *Biology* 12, no. 2 (2023): 211, https://doi.org/10.3390/biology12020211.

41. J. Leppäluoto, T. Westerlund, and P. Huttunen, "Effects of Long-Term Whole-Body Cold Exposures on Plasma Concentrations of ACTH, Beta-Endorphin, Cortisol, Catecholamines and Cytokines in Healthy Females," *Scandinavian Journal of Clinical and Laboratory Investigation* 68, no. 2 (2008): 145–153, https://doi.org/10.1080/00365510701516350.

42. C. M. Eglin, F. S. Golden, and M. J. Tipton, "Cold Sensitivity Test for Individuals With Non-Freezing Cold Injury: The Effect of Prior Exercise," *Extreme Physiology & Medicine* 2 (2013): 1–8, https://doi.org/10.1186/2046-7648-2-16.

43. M. J. Tipton, N. Collier, H. Massey, J. Corbett, and M. Harper, "Cold Water Immersion: Kill or Cure?," *Experimental Physiology* 102, no. 11 (2017): 1335–1355, https://doi.org/10.1113/EP086283.

44. S. Shacham, "A Shortened Version of the Profile of Mood States," *Journal of Personality Assessment* 47, no. 3 (1983): 305–306, https://doi.org/10.1207/s15327752jpa4703_14.

45. S. Garrido, "A Systematic Review of the Studies Measuring Mood and Emotion in Response to Music," *Psychomusicology: Music, Mind, and Brain* 24, no. 4 (2014): 316–327, https://doi.org/10.1037/pmu0000072.

46. T. Butt, P. Russell, and R. Grigg, *Surf Science: An Introduction to Waves for Surfing* (University of Hawaii Press, 2004).

47. G. K. Savard, K. E. Cooper, W. L. Veale, and T. J. Malkinson, "Peripheral Blood Flow During Rewarming From Mild Hypothermia in Humans," *Journal of Applied Physiology* 58, no. 1 (1985): 4–13, https://doi.org/10.1152/jappl.1985.58.1.4.

48. P. Webb, "After Drop of Body Temperature During Rewarming: An Alternative Explanation," *Journal of Applied Physiology* 60, no. 2 (1986): 385–390, https://doi.org/10.1152/jappl.1986.60.2.385.

49. S. L. Curran, M. A. Andrykowski, and J. L. Studts, "Short Form of the Profile of Mood States (POMS-SF): Psychometric Information," *Psychological Assessment* 7, no. 1 (1995): 80–83.

50. F. Shaffer and J. P. Ginsberg, "An Overview of Heart Rate Variability Metrics and Norms," *Frontiers in Public Health* 5 (2017): 258, https://doi.org/10.3389/fpubh.2017.00258.

51. H. T. H. Duong, G. A. Tadesse, and P. T. H. Nhat, "Heart Rate Variability as an Indicator of Autonomic Nervous System Disturbance in Tetanus," *American Journal of Tropical Medicine and Hygiene* 102, no. 2 (2020): 403–407, https://doi.org/10.4269/ajtmh.19-0720.

52. D. S. Quintana and J. A. Heathers, "Considerations in the Assessment of Heart Rate Variability in Biobehavioral Research," *Frontiers in Psychology* 5 (2014): 805, https://doi.org/10.3389/fpsyg.2014.00805.

53. D. Giles, N. Draper, and W. Neil, "Validity of the Polar V800 Heart Rate Monitor to Measure RR Intervals at Rest," *European Journal of Applied Physiology* 116 (2016): 563–571, https://doi.org/10.1007/s00421-015-3303-9.

54. M. P. Tarvainen, J. P. Niskanen, J. A. Lipponen, P. O. Ranta-Aho, and P. A. Karjalainen, "Kubios HRV—Heart Rate Variability Analysis Software," *Computer Methods and Programs in Biomedicine* 113, no. 1 (2014): 210–220, https://doi.org/10.1016/j.cmpb.2013.07.024.

55. S. Laborde, E. Mosley, and J. F. Thayer, "Heart Rate Variability and Cardiac Vagal Tone in Psychophysiological Research–Recommendations for Experiment Planning, Data Analysis, and Data Reporting," *Frontiers in Psychology* 8 (2017): 213, https://doi.org/10.3389/fpsyg.2017.00213.

56. R. Tiwari, R. Kumar, S. Malik, T. Raj, and P. Kumar, "Analysis of Heart Rate Variability and Implication of Different Factors on Heart Rate Variability," *Current Cardiology Reviews* 17, no. 5 (2021): e160721189770, https://doi.org/10.2174/1573403X16999201231203854.

57. J. Cohen, *Statistical Power Analysis for the Behavioral Sciences* (Routledge, 2013), https://doi.org/10.4324/9780203771587.

58. D. Lakens, "Calculating and Reporting Effect Sizes to Facilitate Cumulative Science: A Practical Primer for T-Tests and ANOVAs," *Frontiers in Psychology* 4 (2013): 863, https://doi.org/10.3389/fpsyg.2013.00863.

59. M. Brennan, M. Palaniswami, and P. Kamen, "Do Existing Measures of Poincare Plot Geometry Reflect Nonlinear Features of Heart Rate Variability," *IEEE Transactions on Biomedical Engineering* 48, no. 11 (2002): 1342–1347, https://doi.org/10.1109/10.959330.

60. T. Fontolliet, V. Pichot, and A. Bringard, "Testing the Vagal Withdrawal Hypothesis During Light Exercise Under Autonomic Blockade: A Heart Rate Variability Study," *Journal of Applied Physiology* 125, no. 6 (2018): 1804–1811, https://doi.org/10.1152/japplphysiol.00619.2018.

61. C. van Tulleken, M. Tipton, H. Massey, and C. M. Harper, "Open Water Swimming as a Treatment for Major Depressive Disorder," *BMJ Case Reports* 21 (2018): bcr, https://doi.org/10.1136/bcr-2018-225007.

62. J. R. Crawford and J. D. Henry, "The Positive and Negative Affect Schedule (PANAS): Construct Validity, Measurement Properties and Normative Data in a Large Non-Clinical Sample," *British Journal of Clinical Psychology* 43, no. 3 (2004): 245–265, https://doi.org/10.1348/0144665031752934.

63. D. Watson, L. A. Clark, and A. Tellegen, "Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales," *Journal of Personality and Social Psychology* 54, no. 6 (1988): 1063, https://doi.org/10.1037/0022-3514.54.6.1063.

64. A. G. Barnett, J. C. van der Pols, and A. J. Dobson, "Regression to the Mean: What It Is and How to Deal With It," *International Journal of Epidemiology* 34, no. 1 (2005): 215–220, https://doi.org/10.1093/ije/dyh299.

65. J. C. Nunnally, *Psychometric Theory*, 3rd ed. (McGraw Hill, 1993).

66. P. Kuppens, Z. Oravecz, and F. Tuerlinckx, "The Relation Between Valence and Arousal in Subjective Experience Varies With Personality and Culture: Towards a Dynamic Model of Core Affect," *Emotion (Washington, DC)* 10, no. 6 (2010): 797–806, https://doi.org/10.1111/jopy.12258.

67. H. C. Kraemer, G. T. Wilson, C. G. Fairburn, and W. S. Agras, "Mediators and Moderators of Treatment Effects in Randomised Clinical Trials," *Archives of General Psychiatry* 59, no. 10 (2002): 877–883, https://doi.org/10.1001/archpsyc.59.10.877.

68. M. L. Pe, K. Kircanski, and R. J. Thompson, "Emotion-Network Density in Major Depressive Disorder," *Clinical Psychological Science* 3, no. 2 (2015): 292–300, https://doi.org/10.1177/2167702614540645.

69. M. Ntoumani, B. Dugué, E. Rivas, and K. Gongaki, "Thermoregulation and Thermal Sensation During Whole-Body Water Immersion at Different Water Temperatures in Healthy Individuals: A Scoping Review," *Journal of Thermal Biology* 112 (2023): 103430, https://doi.org/10.1016/j.jtherbio.2022.103430.

70. M. Campero, J. Serra, and J. L. Ochoa, "C-Polymodal Nociceptors Activated by Noxious Low Temperature in Human Skin," *Journal of Physiology* 497, no. 2 (1996): 565–572, https://doi.org/10.1113/jphysiol.1996.sp021789.

71. D. D. McKemy, "How Cold Is It? TRPM8 and TRPA1 in the Molecular Logic of Cold Sensation," *Molecular Pain* 1 (2005): 1744–8069, https://doi.org/10.1186/1744-8069-1-1.

72. A. J. Camm, M. Malik, and J. T. Bigger, "Heart Rate Variability: Standards of Measurement, Physiological Interpretation and Clinical Use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology," *Circulation* 93, no. 5 (1996): 1043–1065, https://doi.org/10.1111/j.1542-474X.1996.tb00275.x.

73. A. E. Aubert, B. Seps, and F. Beckers, "Heart Rate Variability in Athletes," *Sports Medicine* 33 (2003): 889–919, https://doi.org/10.2165/00007256-200333120-00003.

74. K. Rew and H. Massey, *How to Acclimatise. The Science and Practice of Adapting to Cold Water* (Outdoor Swimming Society, 2024), https://www.outdoorswimmingsociety.com/how-to-acclimatise-to-cold-water/.

75. S. W. Porges, "The Polyvagal Theory: New Insights Into Adaptive Reactions of the Autonomic Nervous System," *Cleveland Clinic Journal of Medicine* 76, no. S2 (2009): S86–S90, https://doi.org/10.3949/ccjm.76.s2.17.

76. M. B. Sullivan, M. Erb, L. Schmalzl, S. Moonaz, J. Noggle Taylor, and S. W. Porges, "Yoga Therapy and Polyvagal Theory: The Convergence of Traditional Wisdom and Contemporary Neuroscience for Self-Regulation and Resilience," *Frontiers in Human Neuroscience* 12 (2018): 67, https://doi.org/10.3389/fnhum.2018.00067.

77. P. Huttunen, H. Rintamäki, and J. Hirvonen, "Effect of Regular Winter Swimming on the Activity of the Sympathoadrenal System Before and After a Single Cold Water Immersion," *International Journal of Circumpolar Health* 60, no. 3 (2001): 400–406, https://doi.org/10.1080/22423982.2001.12113043.