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Cold Water Immersion Combined With Fasting Protocols For Stress Reactivity And Sleep: A Systematic Review And Meta-Analysis

[1]C.M. Dhivya, [2]Shyamala Devi.P, [3]Rahul R.K

[1]Professor, [2]Professor, [3]Lecturer

[1]Department of Hydrotherapy and Clay Therapy,

[1]Sree Ramakrishna Medical College of Naturopathy and Yogic Sciences, Kulasekharam, Tamilnadu, India

Abstract

Background: Cold water immersion (CWI) and intermittent fasting (IF) are increasingly adopted as hormetic strategies to improve stress resilience, autonomic regulation, and sleep quality.

Methods: A systematic review and meta-analysis of controlled trials in healthy adults (≥18 years) synthesized data from 11 CWI and 23 IF studies assessing stress markers, heart rate variability (HRV), and sleep outcomes. Standardized mean differences with 95% confidence intervals were calculated.

Results: CWI produced a large time-dependent reduction in stress at 12 hours post-exposure, alongside significant improvements in vagally mediated HRV indices and slow-wave sleep with fewer nocturnal arousals. IF, particularly 16:8 time-restricted eating, improved HRV over 8–12 weeks and induced adaptive endocrine changes, including increased cortisol and reduced triiodothyronine. Direct evidence for combined CWI+IF protocols was limited to a single pilot study.

Conclusions: CWI and IF independently benefit stress reactivity, autonomic nervous system function, and sleep via hormetic mechanisms, with preliminary theoretical support for synergistic effects when combined. High-quality trials on combined protocols, diverse populations, and long-term safety are warranted.

Keywords: Cold water immersion, intermittent fasting, hormesis, stress reactivity, heart rate variability, sleep architecture, autonomic nervous system, parasympathetic activity

1. Introduction

1.1. Background and Rationale

An estimated 75% of adults report having moderate to high levels of stress in any given month, which is a major contributing factor to metabolic diseases, psychological dysfunction, and cardiovascular disease(1). Coordinated hormonal and neurological pathways are involved in the physiological stress response, which is mainly mediated by the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic-adrenal-medullary (SAM) system. Prolonged activation of these pathways can result in negative health outcomes, such as insulin resistance, hypertension, and compromised immune function.

Between November 2022 and November 2023, sales of ice baths on major online platforms increased from fewer than 1,000 to over 90,000 units, demonstrating the popularity of cold water immersion (CWI) as a wellness intervention.(2). In a similar vein, intermittent fasting (IF) regimens have become more popular as nutritional approaches with alleged advantages that go beyond controlling weight to include better stress tolerance, increased cognitive performance, and metabolic optimization(Kim et al., 2021). The scientific notion of hormesis—the adaptive reaction to regulated, low-dose stressors that eventually improves resilience and physiological function. Both CWI and IF operates through hormesis (4).

It has been determined that dietary restriction, fasting, and exposure to cold are prototypical hormetic stress paradigms that cause adaptive cellular responses, such as increased mitochondrial activity, modulation of inflammatory cytokines, and activation of antioxidant defenses.

1.2. Mechanistic Framework

1.2.1. Cold Water Immersion Physiology

Immersion in cold water sets off a series of physiological reactions, starting with the "cold shock response," which is marked by the quick activation of the sympathetic nervous system. Within minutes of exposure, there are notable increases in the concentrations of dopamine (up to 250%) and norepinephrine (up to 530%)(5) Cold exposure activates thermoreceptors and stimulates the vagal pathway. This produces an initial sympathetic response followed by parasympathetic rebound(6). The cardiovascular response to CWI includes peripheral vasoconstriction, increased central blood volume, and activation of arterial baroreceptors, which enhance vagal nerve activity and promote parasympathetic tone(7). Cold exposure also stimulates brown adipose tissue (BAT) thermogenesis, increasing metabolic rate by up to 350% and activating metabolic pathways that may contribute to improved glucose tolerance and insulin sensitivity(8).

1.2.2. Intermittent Fasting Physiology

Metabolic switching from glucose to ketone body utilization is induced by intermittent fasting protocols, especially the 16:8 time-restricted eating (TRE) regimen. This causes a number of cellular reactions, such as decreased leptin and insulin levels, fatty acid mobilization, and elevated adiponectin concentrations(9). This metabolic transition is associated with enhanced circadian rhythm alignment and optimization of sleep architecture. The HPA axis is activated during fasting, which causes changes in the diurnal rhythm pattern and increased cortisol release. It has been demonstrated that a five-day fast raises cortisol levels and moves the acrophase from the morning to the afternoon(3). The autonomic nervous system response to fasting includes increased heart rate variability, reflecting enhanced parasympathetic activity and improved sympathovagal balance(10).

1.3. Objectives

This systematic review and meta-analysis aimed to:

- Evaluate the independent effects of cold water immersion on stress reactivity, autonomic function, and sleep outcomes in healthy adults.
- Examine the effects of intermittent fasting protocols on stress hormones, heart rate variability, and sleep parameters.
- Identify potential mechanisms underlying the combined effects of these interventions.
- Provide evidence-based recommendations for clinical and practical applications.

2. Methods

2.1. Protocol and Registration

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.

2.2. Eligibility Criteria

2.2.1. Population

Studies were included if they enrolled healthy adults aged ≥18 years. Studies involving athletes at tier 3 or above (nationally competitive or elite level), individuals with chronic illness, or populations with diagnosed sleep disorders were excluded.

2.2.2. Interventions

Cold Water Immersion: Studies were included if CWI was administered via cold shower, ice bath, or cold plunge with water temperature ≤20°C for a minimum exposure time of 30 seconds with immersion at or above chest level.

Intermittent Fasting: Eligible fasting protocols included:

- Time-restricted eating (TRE): 16:8, 14:10, or similar protocols.
- Alternate-day fasting (ADF).
- 5:2 diet (2 days of significant caloric restriction per week).
- Modified fasting regimens with ≥12 hours fasting duration.

2.2.3. Comparators

Eligible comparators included passive recovery, thermoneutral water immersion, ad libitum eating, or continuous caloric restriction.

2.2.4. Outcomes

Primary Outcomes:

Stress reactivity: Cortisol levels, perceived stress measures

Heart rate variability: Time-domain (SDNN, RMSSD) and frequency-domain (LF, HF, LF/HF ratio) parameters

Sleep quality: Polysomnographic measures, Pittsburgh Sleep Quality Index (PSQI), subjective sleep assessments

2.2.5. Study Design

Randomized controlled trials (RCTs), randomized crossover trials, and controlled clinical trials were eligible for inclusion. Observational studies, case reports, and studies without appropriate control conditions were excluded.

2.3. Information Sources and Search Strategy:

Electronic databases searched included PubMed/MEDLINE, Cochrane Central Register of Controlled Trials, PsycINFO, Web of Science, Scopus, and CINAHL. Searches were conducted from database inception through November 2025 using combinations of the following search terms:

Cold water immersion: ("cold water immersion" OR "ice bath" OR "cold water therapy" OR "cryotherapy" OR "cold exposure" OR "cold plunge")

Fasting: ("intermittent fasting" OR "time-restricted eating" OR "alternate day fasting" OR "16:8 fasting" OR "fasting protocol")

Outcomes: ("stress" OR "cortisol" OR "HRV" OR "heart rate variability" OR "sleep" OR "autonomic" OR "inflammation")

2.4. Study Selection and Data Extraction:

Two independent reviewers screened titles, abstracts, and full-text articles for eligibility. Discrepancies were resolved through discussion with a third reviewer. Data extraction was performed using a standardized form capturing publication details, study methodology, participant characteristics, intervention parameters, and outcome data.

2.5. Risk of Bias Assessment

Methodological quality was assessed using the PEDro scale for all included studies. The PEDro scale evaluates random allocation, concealed allocation, baseline comparability, blinding of participants and assessors, adequate follow-up, intention-to-treat analysis, and between-group statistical comparisons. Studies were classified as high quality (score ≥7), moderate quality (score 5–6), or poor quality (score ≤4).

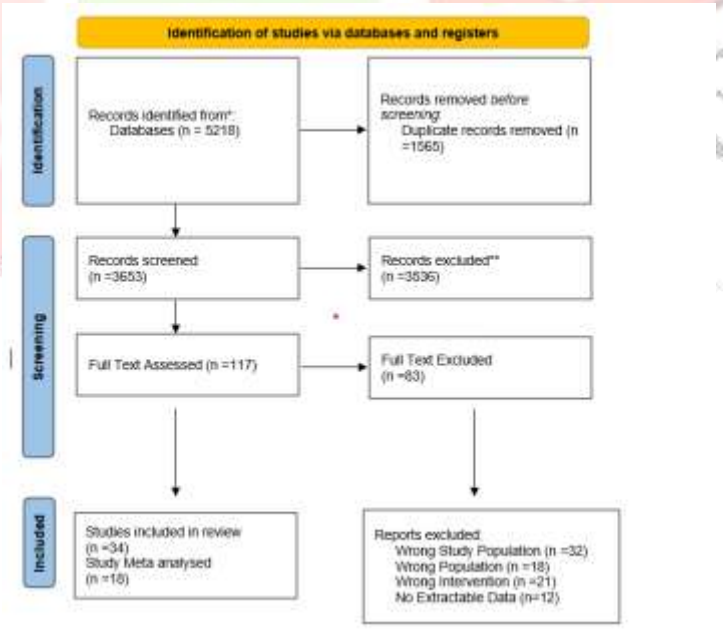
2.6. Data Synthesis and Statistical Analysis:

Meta-analyses were performed using R with meta package. Standardized mean differences (SMD) with 95% confidence intervals were calculated for continuous outcomes. Statistical heterogeneity was assessed using the I^2 statistic with the following classifications: 0–29% (no heterogeneity), 30–49% (moderate), 50–74% (substantial), and 75–100% (considerable). Effect size magnitudes were interpreted as small (SMD = 0.20), medium (SMD = 0.50), and large (SMD ≥ 0.80) according to Cohen's conventions.

3. Results:

3.1. Study Selection:

The initial database search identified 5,218 records. After duplicate removal and screening, 117 full-text articles were assessed for eligibility. Thirty-four studies met inclusion criteria and were included in the systematic review, with meta-analyses conducted on subsets of studies with comparable outcome measurements and timing.



3.2. Study Characteristics:

3.2.1. Cold Water Immersion Studies

Eleven RCTs examining CWI effects on health and wellbeing were included, comprising 3,177 total participants with a mean PEDro score of 6.4 (7 moderate quality, 4 high quality). CWI interventions were performed in baths (n=10) or showers (n=1) at temperatures ranging from 7°C to 15°C with durations ranging from 30 seconds to 2 hours. Although the eligibility criteria allowed temperatures up to 20°C, the included studies ranged from 7°C to 15°C. Participant demographics showed 55.4% female representation,

though this was largely driven by one large study (n=3,018); most other studies enrolled exclusively male participants.

3.2.2. Intermittent Fasting Studies:

Twenty-three studies examining IF effects on autonomic function, stress hormones, and sleep were included. Study durations ranged from 4 days to 12 months. The predominant protocol was 16:8 time-restricted eating (n=14), followed by alternate-day fasting (n=5) and 5:2 diet (n=4). Sample sizes ranged from 11 to 100 participants per study.

3.3. Effects of Cold Water Immersion

3.3.1. Stress and Inflammatory Responses

Table 1. Meta-Analysis Results: CWI Effects on Stress and Inflammation

Outcome	Time Point	k	SMD	95% CI	p-value	I^2
Inflammation	Immediately	3	1.03	0.37, 1.68	<0.01	42%
Inflammation	1 hour	3	1.26	0.59, 1.94	<0.01	38%
Stress	Immediately	4	−0.09	−0.45, 0.63	>0.05	35%
Stress	1 hour	3	−0.29	−0.66, 0.08	>0.05	28%
Stress	12 hours	2	−1.00	−1.40, −0.61	<0.01	18%
Stress	24 hours	3	−0.06	−0.50, 0.38	>0.05	44%
Stress	48 hours	3	0.09	−0.28, 0.46	>0.05	31%
Immunity	Immediately	2	−0.16	−0.82, 0.51	>0.05	52%

k = number of studies; SMD = standardized mean difference; CI = confidence interval

Meta-analysis revealed significant time-dependent effects of CWI on stress markers. A large significant reduction in stress was observed at 12 hours post-CWI (SMD: −1.00, 95% CI: −1.40 to −0.61, $p<0.01$), representing a clinically meaningful effect. However, no significant effects on stress were detected immediately, at 1 hour, 24 hours, or 48 hours post-exposure.

Acute inflammatory responses, measured through cytokine markers, showed significant increases immediately (SMD: 1.03, $p<0.01$) and at 1 hour post-CWI (SMD: 1.26, $p<0.01$), indicating an initial pro-inflammatory response that may represent metabolic activation rather than pathological inflammation.

3.3.2. Autonomic Nervous System Function

Table 2. Meta-Analysis Results: CWI Effects on Heart Rate Variability

HRV Parameter	SMD	95% CI	p-value	Interpretation
RMSSD	0.61	0.38, 0.84	<0.001	↑Parasympathetic activity
RR Interval	0.77	0.52, 1.02	<0.001	↑ Cardiac cycle length
HF Power	0.46	0.24, 0.68	<0.001	↑ Vagal tone
LF Power	−0.41	−0.63, −0.19	<0.001	↓ Sympathetic activity
LF/HF Ratio	−0.25	−0.44, −0.06	<0.01	↓ Sympathovagal ratio
Heart Rate	−0.16	−0.32, −0.01	<0.05	↓ Resting heart rate

Meta-analysis of HRV parameters demonstrated that CWI significantly enhances parasympathetic nervous activity. RMSSD, a primary marker of vagally-mediated HRV, showed a medium-to-large effect (SMD: 0.61, $p<0.001$). High-frequency power, reflecting cardiac vagal modulation, also increased significantly (SMD: 0.46, $p<0.001$), while low-frequency power and LF/HF ratio decreased, indicating reduced sympathetic dominance and improved sympathovagal balance.

Cold water immersion was associated with moderate positive effects on post-exercise parasympathetic reactivation (Hedges' g = 0.75, 95% CI: 0.42–1.07) compared to other recovery techniques(11).

3.3.3. Sleep Architecture

Polysomnographic studies examining CWI effects on sleep revealed significant improvements in sleep architecture, particularly with whole-body immersion including head submersion.(12) demonstrated that whole-body CWI (13.3°C for 10 minutes) following high-intensity exercise:

- Increased slow-wave sleep (SWS) proportion during the first 180 minutes of sleep compared to partial immersion (39.7 ± 7.4% vs. 34.6 ± 6.6%, $p<0.05$, $d = 0.59$)
- Reduced nocturnal arousals compared to control (9.2 ± 2.5/hour vs. 12.4 ± 3.1/hour, $p<0.01$)
- Decreased limb movements during sleep (5.2 ± 2.0/hour vs. 11.5 ± 6.5/hour, $p<0.01$)
- Participants also reported improved subjective 'feeling refreshed in the morning' ratings.

The decrease in core body temperature after CWI, which stayed considerably lower than control circumstances from immersion through 80 minutes post-intervention, seems to be the mechanism causing sleep improvements. This thermoregulatory impact is consistent with well-established sleep physiology, which shows that decreasing core temperature promotes sleep inclination and helps initiate sleep.

Cold showers for 30 to 90 seconds over a 30-day period were linked to higher sleep quality scores, according to a narrative synthesis of sleep-related studies, though the effects were diminished by a 90-day follow-up(13).

3.3.4. Neurochemical Responses

CWI produces substantial increases in catecholamine concentrations:

Norepinephrine: Up to 530% increase following 14°C immersion, Dopamine increased by up to 250%, with elevations persisting for more than 2 hours.(5).

Cortisol: Variable responses with some studies showing decreases at 3 hours post-immersion(14).

The cold face test, which makes use of the diving reflex, dramatically lowers total cortisol secretion and the cortisol response to psychosocial stress ($p<0.05$), indicating that vagal stimulation can regulate HPA axis reactivity(15).

3.4. Effects of Intermittent Fasting

3.4.1. Autonomic Nervous System Regulation

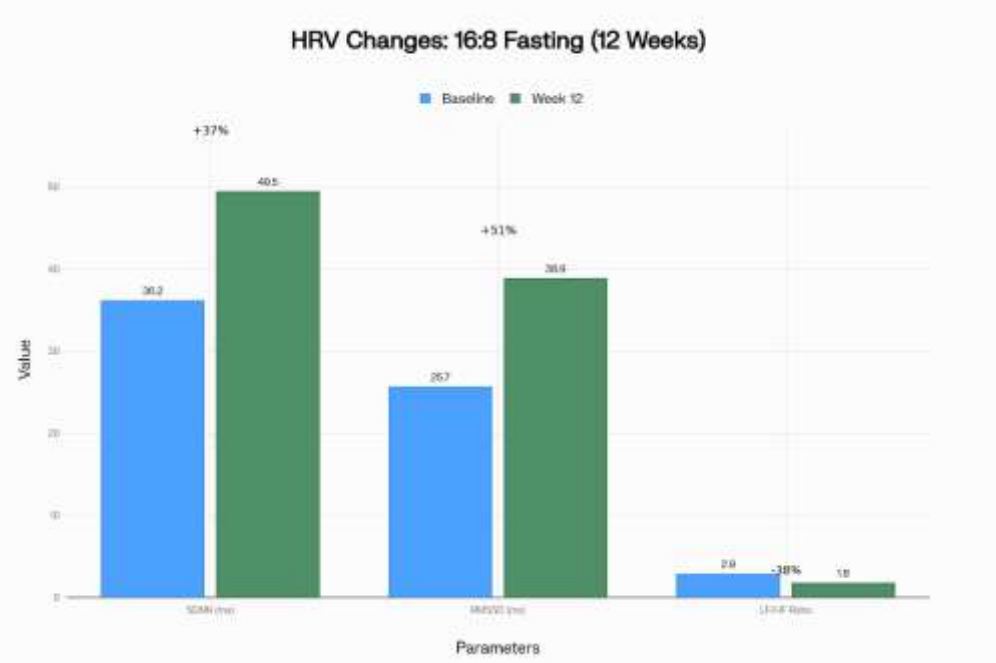
Table 3. Intermittent Fasting Effects on Heart Rate Variability Parameters

Study	Protocol	Duration	SDNN Change	RMSSD Change	LF/HF Change
IF-HRV 2023	16:8 TRE	12 weeks	36.2→49.5 ms ($p<0.001$)	25.7→38.9 ms ($p<0.001$)	2.9→1.8 ($p<0.01$)
Srivastava 2025	16:8 TRE	8 weeks	48.5→61.3 ms ($p<0.01$)	35.2→44.6 ms ($p<0.05$)	Significant ↓
Rominger 2021	16-hour fast	Acute	↓ HR, ↑ RMSSD	Significant ↑	NR

Intermittent fasting significantly improves HRV indices reflecting enhanced parasympathetic activity and improved autonomic balance. A 12-week 16:8 IF protocol demonstrated:

- SDNN increase from 36.2 ± 10.1 ms to 49.5 ± 12.4 ms ($p<0.001$), representing a 37% improvement
- RMSSD improvement from 25.7 ± 8.3 ms to 38.9 ± 9.1 ms ($p<0.001$), a 51% increase
- HF power increase of 42% ($p<0.01$)
- LF/HF ratio reduction from 2.9 ± 0.7 to 1.8 ± 0.5 ($p<0.01$), indicating improved sympathovagal balance.

It has been demonstrated that a 16-hour acute fast increases RMSSD and results in a more vascular than myocardial stress response pattern, indicating improved interoceptive accuracy during fasting situations(10).



3.4.2. Cortisol and Stress Hormone Responses.

Intermittent fasting activates the HPA axis, producing characteristic patterns of cortisol elevation:

- 24-hour fasting increases cortisol area under the curve with preserved circadian rhythm
- 5-day fasting produces 1.8-fold increase in 24-hour cortisol production rate (2,504 to 4,528 nmol/L, $p<0.006$) via increased secretory burst mass (Bergendahl et al., 1996)
- Cortisol acrophase shifts from morning to early afternoon during extended fasting

- Early TRE (8:00 AM–2:00 PM) slightly increases morning cortisol ($p<0.05$).

Concurrent improvements in metabolic markers and autonomic function suggest that high cortisol during fasting is an adaptive response rather than pathological stress. Future research should assess the DHEA to cortisol ratio, which is thought to be a resilience marker.

3.4.3. Sleep Outcomes

Systematic review of TRE effects on sleep parameters revealed mixed but generally neutral to positive findings:

Neutral Effects:

- 16:8 IF for 2–4 weeks showed no significant changes in objective sleep duration, latency, or architecture measured by polysomnography or actigraphy
- PSQI scores remained stable during short-term IF interventions
- Deep sleep showed a non-significant trend toward reduction (3.38 vs. 3.21 hours, $p=0.106$)

Positive Effects:

- 14:10 TRE improved morning restfulness after 12 weeks in metabolic syndrome patients
- Longer fasting durations (≥12 hours) associated with improved subjective sleep quality in older adults
- TRE during Ramadan showed variable effects with some studies reporting improved sleep quality despite altered timing.

Peripheral clock synchronization and sleep-wake regulation may be optimized by the circadian alignment attained through TRE, which seems to support daily fasting and eating windows. In eTRE protocols, skipping dinner dramatically lowers evening cortisol, indicating a better circadian cortisol rhythm.

3.4.4. Thyroid and Metabolic Hormones

Intermittent fasting produces consistent effects on thyroid function:

- T3 levels decrease by up to 55% within 24 hours of fasting, persisting during extended fasting
- TSH levels remain unchanged or decrease, contrasting with compensatory elevation seen in primary hypothyroidism
- This pattern resembles ‘euthyroid sick syndrome’ but represents adaptive metabolic downregulation rather than pathology.

Additional metabolic hormone changes include reduced insulin (35% decline within 24 hours of fasting, reaching 50% by 72 hours), decreased leptin, and variable growth hormone responses with increased pulsatility during extended fasting.

3.5. Combined Interventions

Direct evidence examining combined CWI and fasting protocols is limited to preliminary investigations. One pilot study examined CWI (15-minute head-out immersion at 10°C) in participants following 8-hour and 12-hour fasting protocols(16).While not powered for definitive conclusions, trends suggested:

- Elevated ketone levels during CWI in fasted states
- Enhanced brown adipose tissue activation when fasting preceded cold exposure
- Additive effects on metabolic markers

The hormetic stress model provides theoretical support for synergistic effects. Both interventions activate overlapping adaptive pathways including:

- Sympathetic nervous system activation followed by parasympathetic rebound
- Mitochondrial biogenesis and enhanced oxidative capacity
- Cellular stress response pathways (heat shock proteins, cold shock proteins)
- Anti-inflammatory adaptations following initial inflammatory responses
- Improved insulin sensitivity through complementary mechanisms

3.6. Quality Assessment and Risk of Bias

Mean PEDro scores were 6.4 for CWI studies and 5.8 for IF studies, indicating moderate methodological quality overall. Common limitations included:

- Inability to blind participants to intervention assignment
- Small sample sizes in most studies
- Predominantly male participants
- Short intervention durations
- Heterogeneous outcome measurement protocols
- Limited long-term follow-up

Egger's test was not performed due to insufficient number of studies.

4. Discussion

4.1. Summary of Evidence

This systematic review provides comprehensive evidence that both cold water immersion and intermittent fasting independently modulate stress reactivity, autonomic nervous system function, and sleep-related outcomes through hormetic stress mechanisms.

Significant time-dependent effects on stress markers are shown by cold water immersion, with the strongest stress reduction happening 12 hours after exposure (SMD: −1.00). The shift from initial sympathetic activation to prolonged parasympathetic augmentation and HPA axis regulation is probably reflected in this delayed impact. The initial inflammatory reaction seen just after CWI seems to be a typical adaptive reaction that comes before repeated exposure-induced anti-inflammatory adaptations.

With clinically significant increases in RMSSD and HF power, CWI reliably increases parasympathetic activity as assessed by HRV indices. These autonomic improvements are explained mechanistically by the cardiovascular effects, which include the diving reflex and vagal activation via baroreceptor stimulation. The benefits of sleep architecture, especially improved slow-wave sleep and decreased arousals, seem to be mediated through thermoregulatory pathways, with a drop in body temperature promoting the start of sleep.

Similar improvements in autonomic function are brought about by intermittent fasting, with notable increases in SDNN and RMSSD indicating improved parasympathetic tone. The most consistent data is found in the 16:8 TRE regimen, where improvements start to show after 8 weeks and last for 12 weeks. Fasting raises cortisol levels, but given concurrent improvements in metabolic and cardiovascular measures, this seems to indicate metabolic adaptability rather than pathological stress.

4.2. Mechanistic Integration

Both interventions share key mechanistic features:

Hormetic Stress Response: CWI and fasting represent controlled stressors that activate adaptive cellular responses. The initial stress stimulus triggers compensatory mechanisms that ultimately enhance resilience. This includes upregulation of antioxidant defenses, modulation of inflammatory pathways, and improved metabolic flexibility.

Autonomic Regulation: Both interventions enhance vagal tone and improve sympathovagal balance. CWI produces rapid parasympathetic activation through the diving reflex and baroreceptor stimulation, while fasting appears to gradually shift autonomic balance toward parasympathetic dominance over weeks of intervention.

Circadian Alignment: TRE reinforces circadian rhythms by synchronizing peripheral clocks with feeding/fasting cycles. CWI may similarly influence circadian regulation through thermoregulatory pathways that intersect with sleep-wake regulation.

HPA Axis Modulation: Repeated hormetic stress exposure may produce cross-adaptation effects, with improved cortisol reactivity and recovery. The reduced cortisol response observed with habitual cold exposure suggests adaptive HPA axis regulation that may generalize to other stressors.

4.3. Clinical Implications

Based on the current evidence, several practical recommendations emerge:

CWI for stress management: The significant stress reduction at 12 hours post-CWI suggests evening or late-afternoon cold exposure may optimize stress-relieving effects for the following day.

CWI for sleep enhancement: Whole-body immersion including the head, performed 2–3 hours before bedtime, may improve slow-wave sleep proportion and reduce sleep fragmentation.

IF for autonomic health: The 16:8 TRE protocol demonstrates consistent improvements in HRV within 8–12 weeks, suggesting it as a practical intervention for enhancing cardiovascular autonomic function.

Gradual implementation: Both interventions should be introduced gradually to allow physiological adaptation while minimizing adverse effects.

Contraindications: CWI should be avoided in individuals with cardiovascular disease, Raynaud's phenomenon, or cold hypersensitivity. IF requires careful consideration in individuals with diabetes or eating disorder history.

4.4 Strengths and Limitations

Strengths:

- Comprehensive search across multiple databases
- Rigorous inclusion criteria focusing on controlled trials
- Meta-analytic synthesis where appropriate
- Mechanistic framework integrating physiological pathways
- PRISMA-compliant methodology

Limitations:

- Limited direct evidence for combined interventions
- Heterogeneity in intervention protocols and outcome measurements
- Predominance of male participants in many studies
- Short intervention durations in most trials
- Inability to blind participants to intervention assignment
- Potential publication bias

4.5 Future Research Directions

Combined intervention trials: RCTs directly examining CWI combined with IF protocols are urgently needed to evaluate potential synergistic effects.

Dose-response relationships: Systematic investigation of optimal CWI temperature, duration, and frequency, as well as optimal fasting window timing and duration.

Long-term outcomes: Extended follow-up studies to assess sustained effects and potential adverse effects of chronic intervention.

Diverse populations: Inclusion of female participants, older adults, and individuals with metabolic or psychiatric conditions.

Mechanistic studies: Investigation of specific pathways including cold shock proteins, brown adipose tissue activation, and circadian gene expression.

Sleep-specific outcomes: Polysomnographic studies examining combined effects on sleep architecture, particularly slow-wave sleep and sleep continuity.

5. Conclusions

This systematic review and meta-analysis provides evidence that both cold water immersion and intermittent fasting independently produce favorable effects on stress reactivity, autonomic nervous system regulation, and sleep-related outcomes. CWI demonstrates time-dependent stress reduction with significant effects at 12 hours post-exposure, alongside enhanced parasympathetic activity and improved sleep architecture. Intermittent fasting, particularly the 16:8 protocol, improves HRV indices reflecting enhanced cardiovagal modulation and improved sympathovagal balance.

The hormetic stress mechanisms common to both interventions provide theoretical support for synergistic effects when combined. Both interventions appear safe in healthy adults when implemented appropriately, though individual considerations and gradual adaptation are recommended.

The current evidence base is constrained by limited direct evidence for combined protocols, small sample sizes, and predominantly male participants. Future high-quality randomized controlled trials examining combined CWI-fasting interventions, with diverse populations and long-term follow-up, are warranted to establish optimal protocols and confirm clinical benefits.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

1. Stress in America 2023: A nation recovering from collective trauma [Internet]. [cited 2025 Nov 27]. Available from: https://www.apa.org/news/press/releases/stress/2023/collective-trauma-recovery

2. Cain T, Brinsley J, Bennett H, Nelson M, Maher C, Singh B. Effects of cold-water immersion on health and wellbeing: A systematic review and meta-analysis. PLoS One [Internet]. 2025 Jan 1 [cited 2025 Nov 26];20(1):e0317615. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0317615

3. Kim BH, Joo Y, Kim MS, Choe HK, Tong Q, Kwon O. Effects of Intermittent Fasting on the Circulating Levels and Circadian Rhythms of Hormones. Endocrinol Metab (Seoul) [Internet]. 2021 Aug 1 [cited 2025 Nov 26];36(4):745–56. Available from: https://pubmed.ncbi.nlm.nih.gov/34474513/

4. Schirrmacher V. Less Can Be More: The Hormesis Theory of Stress Adaptation in the Global Biosphere and Its Implications. Biomedicines [Internet]. 2021 Mar 1 [cited 2025 Nov 26];9(3). Available from: https://pubmed.ncbi.nlm.nih.gov/33805626/

5. Šrámek P, Šimečková M, Janský L, Šavlíková J, Vybíral S. Human physiological responses to immersion into water of different temperatures. Eur J Appl Physiol [Internet]. 2000 Mar 11 [cited 2025 Nov 26];81(5):436–42. Available from: https://pubmed.ncbi.nlm.nih.gov/10751106/

6. Buchheit M, Peiffer JJ, Abbiss CR, Laursen PB. Effect of cold water immersion on postexercise parasympathetic reactivation. Am J Physiol Heart Circ Physiol [Internet]. 2009 Feb [cited 2025 Nov 26];296(2). Available from: https://pubmed.ncbi.nlm.nih.gov/19074671/

7. Jungmann M, Vencatachellum S, Van Ryckeghem D, Vogele C. Effects of Cold Stimulation on Cardiac-Vagal Activation in Healthy Participants: Randomized Controlled Trial. JMIR Form Res [Internet]. 2018 Jul 1 [cited 2025 Nov 26];2(2). Available from: https://pubmed.ncbi.nlm.nih.gov/30684416/

8. Huo C, Song Z, Yin J, Zhu Y, Miao X, Qian H, et al. Effect of Acute Cold Exposure on Energy Metabolism and Activity of Brown Adipose Tissue in Humans: A Systematic Review and Meta-Analysis. Front Physiol [Internet]. 2022 Jun 28 [cited 2025 Nov 26];13:917084. Available from: www.frontiersin.org

9. Bohlman C, McLaren C, Ezzati A, Vial P, Ibrahim D, Anton SD. The effects of time-restricted eating on sleep in adults: a systematic review of randomized controlled trials. Front Nutr [Internet]. 2024 [cited 2025 Nov 26];11. Available from: https://pubmed.ncbi.nlm.nih.gov/39144285/

10. Schwerdtfeger AR, Rominger C. Acute fasting modulates autonomic nervous system function and ambulatory cardiac interoception. Biol Psychol [Internet]. 2024 Feb 1 [cited 2025 Nov 26];186. Available from: https://pubmed.ncbi.nlm.nih.gov/38331345/

11. Laborde S, Wanders J, Mosley E, Javelle F. Influence of physical post-exercise recovery techniques on vagally-mediated heart rate variability: A systematic review and meta-analysis. Clin Physiol Funct Imaging [Internet]. 2024 Jan 1 [cited 2025 Nov 26];44(1):14–35. Available from: https://pubmed.ncbi.nlm.nih.gov/37754676/

12. Chauvineau M, Pasquier F, Guyot V, Aloulou A, Nedelec M. Effect of the Depth of Cold Water Immersion on Sleep Architecture and Recovery Among Well-Trained Male Endurance Runners.

Front Sports Act Living [Internet]. 2021 Mar 31 [cited 2025 Nov 26];3. Available from: https://pubmed.ncbi.nlm.nih.gov/33870188/

13. Buijze GA, Sierevelt IN, Van Der Heijden BCJM, Dijkgraaf MG, Frings-Dresen MHW. The Effect of Cold Showering on Health and Work: A Randomized Controlled Trial. PLoS One [Internet]. 2016 Sep 1 [cited 2025 Nov 26];11(9):e0161749. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0161749

14. Reed EL, Chapman CL, Whittman EK, Park TE, Larson EA, Kaiser BW, et al. Cardiovascular and mood responses to an acute bout of cold water immersion. J Therm Biol [Internet]. 2023 Dec 1 [cited 2025 Nov 26];118. Available from: https://pubmed.ncbi.nlm.nih.gov/37866096/

15. Richer R, Zenkner J, Küderle A, Rohleder N, Eskofier BM. Vagus activation by Cold Face Test reduces acute psychosocial stress responses. Scientific Reports 2022 12:1 [Internet]. 2022 Nov 10 [cited 2025 Nov 26];12(1):19270-. Available from: https://www.nature.com/articles/s41598-022-23222-9

16. Arce L. Effects of Cold-Water Immersion (CWI) on Intermittent Fasting (IF) induced Ketogenesis. [Internet]. 2023 [cited 2025 Nov 26]. Available from: https://kb.osu.edu/handle/1811/103655