Navy SEAL Candidate Clinical Study

Neurophysiological Assessment of Cold-Water Immersion, Breath Hold, and Weighted High Physical Output Effects on Cognitive Function and Brain Activity in Elite Naval Special Warfare Operator Candidate: A Case Control EEG Study

This two-participant case-control study examined EEG activity, physiological responses, and cognitive performance during cold-water immersion, breath-hold cycles, and weighted physical activity. Ian Purcell, MD, PhD served as principal investigator.

Protocol Identification

Protocol ID: NSEEG-CWI-2025-001
Protocol Version: 1.0
Protocol Date: October 24, 2025
Study Phase: Exploratory Phase II
Short Title: Navy SEAL Cold Plunge, Hypoxemia, and High Physical Output EEG Study

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1 Study Synopsis

1.1 Study Objectives

Primary Objective:
To characterize the neurophysiological changes in brain activity patterns using electroencephalography (EEG) before and after cold water immersion (32°F/0°C), after a breath hold induced brief episode of hypoxemia, and after a weighted high physical output event in Navy SEAL candidates.

Secondary Objectives

- To assess cognitive performance during cold water exposure
- To evaluate autonomic nervous system responses during cold water exposure and during recovery
- To evaluate autonomic nervous system responses during breath-hold cycles
- To evaluate autonomic nervous system responses during a weighted high physical output activity

1.2 Study Design

Study Type: Prospective, single-arm, pre-post intervention case control study

Study Population: Active-duty U.S. Navy SEAL candidates in training (ages 26-28 years)

Sample Size: N=2 (1 test subject with history of loss of consciousness/altered mental status; 1 control subject without such history)

Study Duration

- Total Study Period: 3 days
- Individual Participation: Three sessions (approximately 1-3 hours each)

1.3 Study Schema

Screening & Enrollment

Session 1: Cold Water Immersion Protocol

Pre-immersion baseline EEG (20 min)
Cold water immersion at 34°F (6 min)
Cognitive testing during immersion
Post-immersion EEG (20 min)

Session 2: Breath Hold Protocol

Pre-breath hold baseline vitals
Breath hold cycles with hyperventilation
Post-breath hold EEG (20 min)

Session 3: Weighted Physical Output Protocol

Pre-exercise baseline vitals
1.5-mile weighted run (25 lb vest)
Post-exercise EEG (20 min)

Data Analysis & Study Completion

2 Background And Rationale

2.1 Scientific Background

Cold water immersion (CWI) and weighted high output physical activity have been shown to activate the sympathetic nervous system and trigger significant physiological responses including increased catecholamine release, altered cerebral blood flow, and modified neural activity patterns. Hypoxemia can predispose an individual to an epileptic event, particularly due to cardiac arrhythmia that leads to reduced blood flow to the brain, causing fainting and seizure or seizure-like activity.

Navy SEALs routinely undergo cold water exposure, high physical output, and hypoxic exposure as part of training and operations, making understanding of neurophysiological adaptations critical for optimizing performance and safety.

2.2 Study Rationale

The combination of pre- and post-intervention EEG recordings will allow for within-subject comparison of neural activity patterns, providing insights into:

- Acute neurophysiological adaptations to cold stress, hypoxemia, and high physical output
- Recovery patterns of brain activity
- Potential cognitive enhancement or impairment effects during brief cold-water exposure
- Individual variation in stress response among elite operators

In this case control study with N=2, the objective is to gather point data to detect any abnormal EEG findings or acute neurophysiological adaptations to cold, hypoxic, and high physical output stress that might place a participant at higher risk of autonomic dysfunction or an epileptic event.

3 Study Objectives And Endpoints

3.1 Primary Endpoints

- EEG evaluation pre and post cold water immersion to identify unusual electrical activity, such as spikes and sharp waves, indicating epilepsy or other brain injury
- EEG evaluation post breath-hold protocols to identify unusual electrical activity indicating epilepsy or other brain injury
- EEG evaluation post weighted high output physical activity to identify unusual electrical activity indicating epilepsy or other brain injury

3.2 Secondary Endpoints

- Cognitive task performance metrics (Mini-Mental State Examination)
- Identification of correlation between autonomic physiological responses and EEG changes
- Heart rate and heart rate variability patterns
- Oxygen saturation (SpO2) variations
- Near-core body temperature changes

4 Participant Selection

4.1 Inclusion Criteria

1. Active-duty U.S. Navy BUD/S candidate
2. Male, ages 26/28 years
3. Current medical clearance for active-duty operations
4. Able to provide informed consent
5. Willing to comply with all study procedures

4.2 Exclusion Criteria

1. Current use of medications affecting CNS function (anticonvulsants, antipsychotics, benzodiazepines)
2. Documented cardiovascular conditions (arrhythmias, uncontrolled hypertension, coronary artery disease)
3. Raynaud's phenomenon or cold urticaria
4. Open wounds or skin infections
5. Recent concussion within past 3 months
6. Implanted electronic devices (pacemaker, deep brain stimulator)
7. Claustrophobia or anxiety disorders affecting ability to complete immersion
8. Alcohol consumption within 24 hours prior to testing
9. Caffeine consumption within 4 hours prior to testing

5 Study Interventions

5.1 Cold Water Immersion Protocol

Specifications

- Temperature: 32°F ± 3°F (0°C ± 1.7°C)

- Immersion depth: Neck-level (C7 vertebra); head remains above water
- Duration: 6 minutes
- Position: Seated position in immersion tank
- Monitoring: Continuous near-core temperature (oral probe), heart rate, SpO2
- Cognitive testing: Performed while in immersion tank by trained personnel
- EEG testing: Performed by trained personnel immediately before and after immersion

Safety Termination Criteria

- Near-Core temperature drops below 95°F (35°C)
- Heart rate <40 bpm or >200 bpm
- SpO2 <90%
- Participant request to terminate
- Signs of cognitive impairment or altered consciousness
- Severe shivering preventing safe continuation

5.2 Breath Hold Protocol

Specifications

- 30 exaggerated inhales and exhales

Immediate breath hold following last inhale

  - Round 1: 2 minutes
  - Round 2: 2.5 minutes
  - Round 3: 3 minutes
- 15-second recovery breath between rounds (exhale, inhale, exhale)
- Continue until third round finalized

Safety Termination Criteria

- Heart rate <40 bpm or >200 bpm
- SpO2 <65%
- Participant request to terminate
- Signs of cognitive impairment or altered consciousness

5.3 Weighted High Output Physical Activity Protocol

Specifications

- Equipment: 25 lb weighted vest, SpO2 and heart rate monitor
- Duration: 1.5-mile course verified by real-time GPS monitoring
- Monitoring: Running partner accompanies subject throughout course
- EEG Testing: Performed immediately after completion, following vest removal and assumption of seated position

Safety Termination Criteria

- Heart rate <40 bpm or >200 bpm
- SpO2 <90%

- Participant request to terminate
- Signs of cognitive impairment or altered consciousness
- Reports of chest pain, severe shortness of breath, or presyncope

6 Study Procedures

6.1 Session 1: Cold Water Immersion (Total: ~115 minutes)

Pre-Immersion Phase (50 minutes)

1. Informed consent and screening (15 min)
2. Baseline vital signs and medical assessment (10 min)
3. EEG cap placement and impedance check (5 min)
4. Pre-immersion EEG recording (20 min)

Immersion Phase (20 minutes)

1. Pre-immersion body temp, SpO2, heart rate (2 min)
2. Cold water immersion at 34°F (6 min)
3. MMSE cognitive testing at 2-6 minutes during immersion (4 min)
4. Immersion body temp, SpO2, heart rate measurement
5. Exit and towel dry (3 min)
6. Immediate post-immersion body temp, SpO2, heart rate (5 min)

Post-Immersion Phase (45 minutes)

1. Immediate post-immersion blood pressure (0 min)
2. Immediate post-immersion EEG setup (T0: 3-5 min post-exit)
3. Immediate post-immersion body temp, SpO2, heart rate during EEG setup (1 min)
4. Post-immersion EEG recording during passive rewarming period (25 min)
5. Debriefing (15 min)

6.2 Session 2: Breath Hold Protocol (Total: ~60 minutes)

Pre-Breath Hold Phase (10 minutes)

1. Informed consent and screening (5 min)
2. Baseline vital signs, SpO2/pulse monitor placement, medical assessment (5 min)

Breath Hold Phase (10 minutes)

1. Monitor SpO2 and heart rate during breath hold protocols (10 min)

Post-Breath Hold Phase (40 minutes)

1. Immediate post-breath hold EEG setup (5 min)
2. EEG recording (20 min)
3. Debriefing (15 min)

6.3 Session 3: Weighted Physical Activity (Total: ~91 minutes)

Pre-Activity Phase (35 minutes)

1. Informed consent and screening (15 min)
2. Baseline vital signs and medical assessment (10 min)
3. Gear check of weighted vest, SpO2, heart rate, and GPS monitors (10 min)

Activity Phase (11 minutes)

1. Weighted run with GPS distance/time verification (11 min)

Post-Activity Phase (45 minutes)

1. Remove weighted vest and gear, assume sitting position (4 min)
2. Post-run medical assessment (1 min)
3. EEG cap placement and impedance check (5 min)
4. EEG recording (20 min)
5. Debriefing (15 min)

7 Study Assessments

7.1 Electroencephalography (EEG) Protocol

Equipment

- ZETO 19-channel EEG system with active electrodes
- International 10-20 electrode placement system
- Sampling rate: 250-500 Hz
- Impedance threshold: <500-1000 kΩ
- Wellue SpO2 monitor with Bluetooth

Recording Conditions (Each 20-minute session)

1. Resting State - Eyes Closed (3 minutes)
   - Participant seated comfortably
   - Minimal movement
   - Eyes gently closed
2. Resting State - Eyes Open (16 minutes)
   - Fixation on neutral target
   - Minimal blinking
3. Photic Stimulation - Eyes Open (1 minute)
   - Minimal blinking

EEG Analysis Parameters

Frequency Bands

- Delta (0.5-4 Hz)
- Theta (4-8 Hz)
- Alpha (8-12 Hz)
- Beta (12-30 Hz)
- Gamma (30-50 Hz)

Primary Metrics

- Abnormal Activity: Abnormal patterns in brain waves, such as spikes or sharp waves, or focal brainwave depression indicating neurological disorder
- Seizure Activity: Zeto system NeuroPulse AI™ for seizure detection and monitoring

7.2 Physiological Measurements

Continuous Monitoring

- Heart rate and heart rate variability (during all interventions)
- Oxygen saturation - SpO2 (during all interventions)

Time-Point Measurements

Near-core body temperature (oral probe)

  - Cold water immersion: 0 min, 6 min, and 1 min post-immersion

7.3 Cognitive Performance Assessment

Mini-Mental State Examination (MMSE)

- Administered during cold-water immersion (2-6 minutes)
- Scored out of 30 points
- Assesses orientation, attention, memory, language, and visual-spatial skills

8 Safety Considerations

8.1 Potential Risks

Cold Water Immersion Risks

- Hypothermia: Low risk given 6-minute duration and monitoring
- Cold shock response: Initial gasping, hyperventilation (expected, brief)
- Cardiac arrhythmias: Very low risk in screened healthy participants
- Autonomic dysfunction: Bradycardia, hypotension (monitored)

Breath Hold Risks

- Hypoxemia: Low risk given established Navy protocols, 2-3 minute duration, and monitoring
- Cardiac arrhythmias: Low risk in screened healthy participants
- Autonomic dysfunction: Bradycardia, hypotension (monitored)
- Loss of consciousness or altered mental status: Low risk with monitoring

Weighted High Output Physical Activity Risks

- Hyperthermia: Low risk given 11-minute duration, monitoring, and 68-70°F ambient temperature
- Cardiac arrhythmias: Low risk in screened healthy participants
- Autonomic dysfunction: Bradycardia, hypotension (monitored)

EEG-Related Risks

- Minor scalp irritation at Zeto EEG electrode contact points (very low risk)
- Induced seizure post cold-water immersion or with photic stimulation

8.2 Risk Mitigation Strategies

- Continuous physiological monitoring by physician during immersion, breath-hold, and weighted run
- Experienced cold immersion safety personnel on-site
- Immediate access to warming equipment and emergency medical care

- Physician present during all immersion sessions
- Strict adherence to termination criteria

8.3 Emergency Procedures

- Emergency warming protocols (warm blankets, warm fluids)
- Direct communication with emergency medical services
- Automated external defibrillator (AED) immediately accessible (except during run course)

9 Data Management And Quality Assurance

9.1 Data Collection Methods

- **EEG data:** Zeto digital recording system
- **Physiological data:** Electronic data capture system for SpO2 and heart rate with real-time validation
- **Temperature data:** Manual collection using oral probe
- **Questionnaires:** MMSE paper forms

9.2 Quality Control Measures

- Trained healthcare personnel administering cognitive testing and EEG
- Board-certified physician interpreting EEG data
- Annual calibration of Zeto EEG equipment
- Standard OTC temperature probe calibration by manufacturer
- Standard OTC cold water thermometer calibration by manufacturer

10 Statistical Analysis Plan

10.1 Sample Size Justification

While typical cold immersion studies suggest N=30 provides 80% power to detect significant changes in EEG parameters (Cohen's d = 0.6-0.8) at $\alpha = 0.05$, this case control study with N=2 aims to gather point data for individual risk assessment rather than powered statistical comparison.

10.2 Analysis Approach

- Descriptive statistics for all physiological measures
- Within-subject comparison of pre- and post-intervention EEG findings
- Qualitative assessment of EEG abnormalities by board-certified neurologist
- Case-control comparison of autonomic responses between test and control subjects

11 Ethical Considerations

11.1 Informed Consent

All participants will provide written informed consent after thorough explanation of

- Study purpose and procedures
- Potential risks and benefits
- Right to withdraw at any time without penalty

- Confidentiality protections

11.2 Confidentiality

All data will be de-identified and stored securely. Only the principal investigator and authorized study personnel will have access to identifiable information.

11.3 Participant Rights

Participants may withdraw from the study at any point without providing reason and without impact to their military status or training.

12 Study Results

12.1 EEG Findings

Pre cold-water immersion and post cold-water immersion EEG recordings on both control and test subjects were **within normal limits** and showed **no unusual electrical activity** such as spikes, sharp waves, or focal slowing suggestive of epilepsy or other brain injury.

Post-breath hold EEG recordings showed **no abnormalities**, including no epileptiform activity.

Post-weighted run EEG recordings showed **no abnormalities**, including no epileptiform activity.

Note: Increases and suppression of alpha activity were not assessed in this study.

12.2 Physiological Data

Cold Water Immersion (6 minutes at 32-34°F)

Parameter	Test Subject	Control Subject
Pulse rate distribution	100% between 50-120 BPM	100% between 50-120 BPM
Pulse rate range	44-89 BPM	52-89 BPM
SpO2 range	95-100%	86-100%
Body temp (Pre/During/Post)	98.6°F / 99.5°F / 95.7°F	97.5°F / 98.2°F / 97.7°F

Breath Hold Protocol

Parameter	Test Subject	Control Subject
Pulse rate range	59-169 BPM	51-91 BPM
Average pulse rate	89 BPM	67 BPM
SpO2 range	71-100%	85-100%
SpO2 nadir	71%	85%

Weighted Run (1.5 miles)

Parameter	Test Subject	Control Subject
Average pace	7:00 min/mile	6:57 min/mile
Pulse rate range	80-180 BPM	100-183 BPM

Parameter	Test Subject	Control Subject
Average pulse rate	163 BPM	169 BPM
SpO2 range	87-100%	85-100%
Average SpO2	92%	91%

12.3 Cognitive Performance

Mini-Mental State Examination (MMSE)

- Both test and control subjects scored **30/30 (perfect score)** during cold-water immersion (2-6 minutes)

13 Discussion

13.1 Study Purpose

The purpose of this study was to collect physical stressor data sets that might place an individual at risk for episodes of loss of consciousness (LOC) or altered mental status (AMS). Stimulus triggers included:

1. Cold-water immersion
2. Breath hold-induced hypoxemia
3. Weighted high physical output iteration simulating land portage and land evolution in Naval Special Warfare entrance physical standards test

13.2 Test Subject Analysis

Data presented focuses on the test subject with a history of LOC/AMS during BUD/S training.

Cold Water Immersion Phase: The test subject demonstrated

- Pulse rate: 44-89 BPM (100% within 50-120 BPM)
- SpO2: 95-100%
- Temperature: 98.6°F → 99.5°F → 95.7°F
- MMSE: 30/30 (perfect score)
- **No significant bradycardia, tachycardia, hypoxemia, hypothermia, or hyperthermia**
- **20-minute post-immersion EEG: Normal, no epileptiform activity or abnormalities**

Weighted High Physical Output Phase: The test subject demonstrated

- Pace: 7:00 min/mile for 1.5 miles
- Pulse rate: 80-180 BPM (average 163 BPM)
- SpO2: 87-100% (average 92%)
- Post-test temperature: 99.0°F
- **No significant bradycardia, tachycardia, hypoxemia, hypothermia, or hyperthermia**
- **20-minute post-exercise EEG: Normal, no epileptiform activity or abnormalities**

Breath Hold Phase: The test subject demonstrated

- Pulse rate: 59-169 BPM (average 89 BPM)
- SpO2: 71-100%
- SpO2 nadir of 71% achieved

- **No significant bradycardia or tachycardia**
- **20-minute post-breath hold EEG: Normal, no epileptiform activity or abnormalities**

13.3 Conclusions

Three physical stressor protocols were performed to provide objective data regarding etiologies of the test subject's history of LOC and AMS during BUD/S training.

Key Findings

- No worrisome autonomic recordings (pulse, SpO2, near-core body temperature) during cold-water immersion or weighted high physical output
- No abnormal EEG findings throughout any protocol, including post-breath holds at 71% SpO2 nadir
- No observed episodes of altered mental status or loss of consciousness during any testing
- Cognitive function remained intact (perfect MMSE score during cold stress)

13.4 Study Limitations

Important Considerations

- Data samples do not represent BUD/S candidates under actual training conditions (sleep deprivation, hypoglycemia, chronic stressed/fatigued state)
- All data collected in controlled environment with medical supervision
- Results must be taken at face value and **do not provide 100% guarantee of no future LOC episodes** in BUD/S training curriculum

14 Study Personnel

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