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# Comparison of Bispectral Index™ values during the flotation restricted environmental stimulation technique and results for stage I sleep: a prospective pilot investigation

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## Abstract

**Objective:** To determine whether Bispectral Index™ values obtained during flotation-restricted environment stimulation technique have a similar profile in a single observation compared to literature-derived results found during sleep and other relaxation-induction interventions.

**Results:** Bispectral Index™ values were as follows: awake-state, 96.6; float session-1, 84.3; float session-2, 82.3; relaxation-induction, 82.8; stage I sleep, 86.0; stage II sleep, 66.2; and stages III–IV sleep, 45.1. Awake-state values differed from float session-1 (%difference 12.7%; Cohen's  $d = 3.6$ ) and float session-2 (%difference 14.8%; Cohen's  $d = 4.6$ ). Relaxation-induction values were similar to float session-1 (%difference 1.8%; Cohen's  $d = 0.3$ ) and float session-2 (%difference 0.5%; Cohen's  $d = 0.1$ ). Stage I sleep values were similar to float session-1 (%difference 1.9%; Cohen's  $d = 0.4$ ) and float session-2 (%difference 4.3%; Cohen's  $d = 1.0$ ). Stage II sleep values differed from float session-1 (%difference 21.5%; Cohen's  $d = 4.3$ ) and float session-2 (%difference 19.6%; Cohen's  $d = 4.0$ ). Stages III–IV sleep values differed from float session-1 (%difference 46.5%; Cohen's  $d = 5.6$ ) and float session-2 (%difference 45.2%; Cohen's  $d = 5.4$ ). Bispectral Index™ values during flotation were comparable to those found in stage I sleep and nadir values described with other relaxation-induction techniques.

**Keywords:** Flotation-REST, Flotation-tank, Sensory isolation, Relaxation, Bispectral Index, BIS monitor, Depth of sleep, Perception of sleep, Sleep EEG

## Introduction

The flotation-restricted environmental stimulation technique (REST), a process of floating horizontally and face up inside a quiet, dark tank filled with magnesium sulfate-saturated water held at normal skin temperature, has been associated with multiple benefits [1, 2]. However, investigations assessing intracranial neurophysiological events are limited. Sakata et al. showed that during float sessions stage I and stage II sleep were each present [3]. Using electroencephalography (EEG) monitoring, investigators have demonstrated increases in delta power [3]

and theta power [4], findings also documented during sleep [5]. The only other flotation EEG investigations have not provided spectral power analysis information [6–8].

Since the first author has had experience with Bispectral Index™ (BIS) monitoring in the intensive care environment [9, 10] and is conducting an investigation using the BIS monitor as a tool for neurofeedback (ClinicalTrials.gov: NCT03152331), we became interested in performing BIS monitoring during flotation-REST sessions. BIS values have been associated with distinct sleep stages [11–15], and found to decrease with relaxing guided imagery [16] and when viewing calming videos [17]. We hypothesized that BIS values obtained during flotation-REST would have a similar profile compared to

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literature-derived results found during sleep and other relaxation-induction interventions.

## Main text

### BIS monitoring during flotation

From April 7, 2017 to July 14, 2017, the first author underwent 22 1-hour flotation-REST sessions. During sessions 14 and 16, BIS monitoring was performed where BIS values were recorded on the BIS-X hard drive every minute during flotation. The monitor used was the BIS VISTA™ monitoring system, and the sensor established cutaneous contact at the FPz, FP2, AF8, and FT10 positions. As the monitor was located external to the tank and the first author was floating in darkness, there was no visual perception of the evolving BIS values. BIS values recorded on the hard drive were entered into a Microsoft Excel® 2010 spreadsheet and imported into SAS System for windows, release 9.2 for statistical analyses.

### Literature-derived BIS values

A PubMed literature search was performed to identify manuscripts that provided BIS values obtained during the awake state. An overall weighted mean BIS value in the awake state was computed after entering the mean value for each cohort into the Excel spreadsheet according to the number of individuals participating in the cohort investigation. Also, we identified manuscripts that provided BIS values obtained during sleep monitoring. An overall weighted mean BIS value was computed for each sleep stage. An overall weighted mean BIS value was also computed for the two relaxation-induction studies.

### Mood state assessment

Pre-flotation and post-flotation session mood scores were recorded for each session [18]. Using the mood qualities relaxation and freshness, two orientating prompts “right now I feel relaxed” and “right now I feel fresh” were evaluated. Each mood quality was scored as follows: definitely not, 1; not, 2; not really, 3; a little, 4; very much, 5; and extremely, 6. The two mood scores were summed (range 2–12).

### Statistical analysis

A two-sample t test was used to compare intergroup BIS values and determine significant differences ( $p < 0.05$ ). Cohen's d statistic was computed for intergroup BIS value differences. Pre-flotation and post-flotation mood scores were compared using the Wilcoxon test for paired samples and Cohen's d statistic.

## Results

BIS values for awake patients emanated from 20 cohorts within 18 studies [14, 16, 19–34] (Additional file 1).

Float session-1 monitoring lasted for 64 min and resulted in a BIS value of  $84.3 \pm 4.5$  (range 77–98). The BIS value at 2 min was 83. The duration of float session-2 was 63 min with a BIS value of  $82.3 \pm 4.1$  (range 77–97). The BIS value at 3 min was 83.

BIS values for stage I sleep emanated from 42 participants in 3 studies (Table 1). BIS values for stage II sleep came from 25 participants in 2 studies (Table 1). BIS values for stages III–IV sleep emanated from 39 participants in 4 studies (Table 1). The weighted-mean BIS progressively decreased from sleep stage I to sleep stages III–IV.

Nadir BIS values during relaxation-induction emanated from 54 participants in 2 studies [16, 17] (Additional file 2).

BIS value comparisons for the various conditions are presented in Table 2. The minimal mean percent differences and low Cohen's d values indicate that float session-1 and float session-2 were similar to relaxation induction and sleep stage I. The other comparisons demonstrated substantial mean differences between float session-1 and float session-2 and the awake state, stage II sleep, and stages III–IV sleep. The awake state and each sleep stage had a relatively large BIS mean difference ( $p < 0.0001$ ), and the Cohen's d values were as follows: awake state versus stage I sleep, 3.9; stage I versus stage II sleep, 5.3; and stage II versus stages III–IV sleep, 3.1.

Pre-flotation and post-flotation mood scores are depicted in Table 3. The mean pre-flotation mood score was  $6.5 \pm 1.3$  (median 6.0), and the mean post-flotation mood score was  $10.0 \pm 1.6$  (median 10.0) ( $p < 0.0001$ , Wilcoxon test for paired samples [two-tailed]; Cohen's

**Table 1 BIS values by sleep stage**

Sleep stage	Participants	BIS
Stage I		
Benini [11] {#2}	15	88.9
Dahaba [12] {#4}	10	80.0
Tung [13] {#35}	17	86.5
	42	$86.0 \pm 3.5$
Stage II		
Benini [11] {#2}	15	63.0
Dahaba [12] {#4}	10	71.0
	25	$66.2 \pm 4.0$
Stage III–IV		
Benini [11] {#2}	3	33.0
Benini [11] {#2}	1	16.0
Dahaba [12] {#4}	10	52.0
Dahaba [12] {#4}	10	41.0
Nieuwenhuijs [14] {#25}	10	42.0
Sleigh [15] {#33}	5	59.0
	39	$45.1 \pm 8.9$

BIS Bispectral Index™

**Table 2 Comparisons of BIS data by clinical conditions**

	BIS	p value	%difference	Cohen's d
Awake state	96.6 ± 1.7			
Float session-1	84.3 ± 4.5	< 0.0001	12.7	3.6
Awake state	96.6 ± 1.7			
Float session-2	82.3 ± 4.1	< 0.0001	14.8	4.6
Relaxation induction	82.8 ± 6.8			
Float session-1	84.3 ± 4.5	0.1548	1.8	0.3
Relaxation induction	82.8 ± 6.8			
Float session-2	82.3 ± 4.1	0.6256	0.5	0.1
Sleep stage I	86.0 ± 3.5			
Float session-1	84.3 ± 4.5	0.0292	1.9	0.4
Sleep stage I	86.0 ± 3.5			
Float session-2	82.3 ± 4.1	< 0.0001	4.3	1.0
Float session-1	84.3 ± 4.5			
Sleep stage II	66.2 ± 4.0	< 0.0001	21.5	4.3
Float session-2	82.3 ± 4.1			
Sleep stage II	66.2 ± 4.0	< 0.0001	19.6	4.0
Float session-1	84.3 ± 4.5			
Sleep stages III-IV	45.1 ± 8.9	< 0.0001	46.5	5.6
Float session-2	82.3 ± 4.1			
Sleep stages III-IV	45.1 ± 8.9	< 0.0001	45.2	5.4

BIS Bispectral Index™

**Table 3 Pre-flotation and post-flotation mood scores by flotation sessions**

Session	Pre-flotation	Post-flotation	Difference	BIS monitoring
1	5	8	3	
2	5	8	3	
3	5	8	3	
4	5	8	3	
5	5	8	3	
6	5	8	3	
7	5	8	3	
8	6	9	3	
9	6	10	4	
10	6	10	4	
11	6	10	4	
12	6	10	4	
13	7	10	3	
14	7	10	3	Session-1
15	7	10	3	
16	8	12	4	Session-2
17	8	12	4	
18	8	12	4	
19	8	12	4	
20	8	12	4	
21	8	12	4	
22	8	12	4	

BIS Bispectral Index™

d = 2.4). Pre-flotation mood scores progressively increased from 5 at sessions 1–7 to 8 at sessions 16–22. Similarly, post-flotation mood scores increased during later sessions. The mean pre-flotation and post-flotation difference for the 22 float sessions was 3.5 ± 0.5.

**Discussion**

**EEG spectral power and BIS for flotation-REST and sleep**

The principal finding of the current investigation suggests that BIS values for flotation-REST are comparable to literature-derived results transpiring during relaxation-induction and stage I sleep. As well, the flotation-REST BIS values were substantially different compared to the awake state and stages II and III–IV sleep values. Additionally, BIS values for the awake state and sleep stages I, II, and III–IV were substantially variant from each other. According to standard sleep EEG criteria, wakefulness is characterized by > 50% of the epoch consisting of alpha activity in a relaxed subject with eyes closed or by < 50% of the epoch with low-voltage, mixed frequency (2–7 Hz) activity [35, 36]. Further, wakefulness is associated with an obvious presence of beta activity, especially with open eyes and while concentrating [37, 38]. However, stage I sleep is characterized by 50% of the epoch consisting of relatively low-voltage, mixed frequency (2–7 Hz) activity and < 50% of epoch containing alpha activity [35, 36]. Stage I sleep is largely defined by exclusion: a low-voltage, mixed frequency back ground EEG activity devoid of sleep spindles and K-complexes, cessation of blinking, absence of saccadic eye movements, and alpha activity in < 50% of the epoch [36]. Since evidence indicates that stage I sleep can also be quantitatively described according to alpha or theta dominance [39] or depicted by several unique qualitative EEG findings [40], it is clear that stage I sleep consists of a diverse array of electrophysiological subpopulations.

Although the precise electrophysiological basis for computing BIS values is unclear, certain publications have been elucidative [41, 42]. Evidence indicates that for BIS values 60–100, there is a near-perfect correlation between the BIS value and beta ratio (spectral power of 30–47 Hz ÷ power of 11–20 Hz) [43]. It is relevant that spectral entropy, an EEG processing technique similar to BIS monitoring, has been recently shown to discriminate the transition from the awake state to stage I sleep [44].

In the current investigation, BIS values progressively decreased from the awake state to stage I sleep, stage II sleep, and stages III–IV sleep. The delta plus theta amplitude has been shown to account for 50% of the relative power in the awake state [38]. During stage I sleep, when compared to the awake state, investigators have demonstrated an increase in relative delta plus theta power and a decrease in relative beta power [5, 38]. Further, it

has been shown that relative to stage I sleep and when advancing from stage II to stage IV sleep, beta relative power progressively decreases, and theta plus delta relative power increases [5]; Uchida et al. demonstrated a power density reciprocal relationship between beta and delta activity across all stages of sleep [45]. Together, these observations provide an electrophysiological rationale as to reasons why BIS monitoring would discriminately correlate with the awake state and the various stages of sleep.

Several observations have been made during flotation-REST that are important; specifically, investigators have demonstrated that delta power [3] and theta power [4] increase during flotation-REST. Further, stage I and stage II sleep, using polysomnography, each have been found to account for 40% of the time during flotation-REST [3]. Additionally, Fine et al. concluded that the EEG during flotation-REST was consistent with stage I sleep [4].

#### **Cognitive experiences in stage I sleep and flotation-REST**

Multiple functional changes have been described during stage I sleep: slow-rolling eye movements, drowsiness, decreased eyelid blinking, slow eye movements, increasing number of wrong answers to questions, and a decrease in response to audible tones [35]. Drowsiness, a manifestation of stage I sleep, is characterized by increased eyelid closure (decreased eyelid opening) and a propensity for decreased alertness and inclination to fall asleep [44, 46, 47]. Cognitive experiences during stage I sleep have been described as a dream-like or half-awake, half-asleep state and may include random visual images, thoughts, or feelings; a decrease in awareness of the surrounding environment; and an alteration in time awareness [40, 48]. Qualitatively comparable hypnagogic mental phenomena have also been found during flotation-REST, suggesting that the two states have similar experiential features [49, 50]. Vivid and detailed written documentations [51] and results from comprehensive questionnaires [49] of persons immediately following emersion from the flotation-REST tank indicate that some degree of awareness is present during floating. As some degree of vigilance has also been described during stage I sleep [48], these findings further suggest that stage I sleep and flotation-REST are likely to be relatively similar states.

#### **Physiology in stage I sleep and flotation-REST**

Multiple physiologic alterations have been described during stage I sleep: decreased minute ventilation, muscle tone, heart rate, blood pressure, metabolic rate, and frontal lobe blood flow [35, 37]. Other investigations have demonstrated that flotation-REST is associated

with reductions in blood pressure [52, 53] and levels of plasma cortisol [52, 54, 55], plasma adrenocorticotropic hormone [54], thyroid stimulating hormone [55], plasma noradrenalin [56], and urinary catecholamine [55]. Each of these five researchers concluded in their manuscript that flotation-REST is conducive to relaxation. Although physiological changes in flotation-REST do not circumscribe a specific sleep stage, it is plausible that stage I sleep is included in this array of physiological alterations.

#### **Relaxation induction and flotation-REST**

In Hudetz et al.'s investigation of relaxing guided imagery, anxiety scores and BIS values decreased, indicating that a relaxation effect had indeed occurred [16]. The nadir BIS values with relaxation induction are virtually identical to the mean BIS values transpiring during the two flotation-REST sessions. This suggests that flotation-REST has an electrophysiological signature comparable to that of induced relaxation. BIS nadir onsets for the two relaxation-induction activities were at 15 and 55 min; however, during flotation-REST, the BIS value was substantially reduced within a couple of minutes, when compared to that in the awake state. This potentially speaks to the notion that flotation-REST may have a rapid onset and persistent calming effect. Since the relaxation-induction BIS values are similar to the stage I sleep results, this suggests that a peaceful demeanor is likely a feature of stage I sleep.

#### **Mood enhancement**

The first author's experience demonstrated that pre-flotation-REST mood scores increased in the later sessions compared to the early sessions. Further, the post-flotation-REST mood scores were significantly greater in contrast to the pre-flotation scores. These observations are corroborated by other flotation-REST studies that have demonstrated an objective improvement in relaxation [2, 18, 53, 55] and mood enhancement [18, 52].

#### **Conclusions**

The objective BIS electrophysiological signature implies that relaxation-induction, stage I sleep, and flotation-REST may be comparable conditions of consciousness. The qualitative similarities regarding cognitive experiences and partial awareness that occur during stage I sleep and flotation-REST also suggest that the two are likely to be analogous states.

#### **Limitations**

The principal limitation of this investigation is that only one person underwent flotation-REST while BIS monitoring was performed.

## Additional files

**Additional file 1.** Awake state BIS values. Data of awake state Bispectral Index™ values from previous studies.

**Additional file 2.** BIS values during relaxation-induction. Data of Bispectral Index™ values during relaxation-induction from previous studies.

### Abbreviations

BIS: Bispectral Index™; EEG: electroencephalography; REST: restricted environmental stimulation technique.

### Authors' contributions

CMD and JVM conceptualized and designed the study. CMD and JVM performed the Bispectral Index™ monitoring during flotation and the literature review. CMD performed the data analysis. CMD, JVM, and AB reviewed and interpreted the data, were involved in drafting the manuscript, and critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

### Authors' information

CMD has 35 years of experience as a trauma surgeon, is a retired board-certified surgical intensivist and general surgeon, has had extensive experience with Bispectral Index™ (BIS) monitoring in the intensive care unit, and has two peer-reviewed publications pertaining to use of the BIS monitor in the intensive care unit. JVM is a Clinical Nurse Specialist who is in a neurology practice with a respected Youngstown, OH neurologist. EB has a Ph.D. in psychology, is the Director of Behavioral Medicine for the St. Elizabeth Family Medicine Residency, has a clinical psychology practice, and participates in clinical research.

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### Competing interests

The authors declare that they have no competing interests.

### Availability of data and materials

The datasets generated during and/or analyzed during the current study are not publicly available due to statutory provisions regarding data and privacy protection, but are available from the corresponding author on reasonable request.

### Consent for publication

Not applicable.

### Ethics approval and consent to participate

Mercy Health Institutional Review Board for human investigations Chair reviewed this manuscript and determined that oversight of this investigation was not necessary (letter dated September 13, 2017). On September 20, the full committee reviewed the matter and agreed with the exemption indicating that there was no ethical concern.

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