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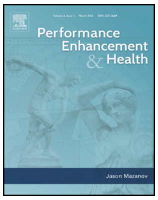

Flotation-restricted environmental stimulation therapy improves sleep and performance recovery in athletes

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ABSTRACT

Objective: The purpose of the current study was to examine the effects of flotation-restricted environmental stimulation therapy (FLOAT) on recovery from exercise.
Methods: Nineteen trained, male team-sport athletes (age: 21 ± 2 years) completed two trials separated by seven days; FLOAT, which included one-hour of FLOAT recovery following exercise, and CON, which included one-hour of passive recovery following exercise. Performance and pressure-to-pain algometer measures were taken pre and post exercise and the following morning. Performance measures included an isometric mid-thigh pull, countermovement jump (CMJ), a 15 m sprint, and a repeated sprint test. Perceived measures of muscle soreness (MS) and physical fatigue (PF) were recorded up to 24 h post testing. Salivary cortisol samples were collected pre and post exercise and post recovery. Sleep was monitored via wrist-actigraphy.
Results: FLOAT was found to significantly enhance CMJ ($p = 0.05$), 10 m sprint ($p = 0.01$) and 15 m sprint performance ($p = 0.05$) with *small* to *moderate* effects ($d = 0.21$–0.68) for all performance measures, except CMJ (*unclear*), compared to CON. The results also show significantly higher pressure-to-pain thresholds across all muscle sites (p's < 0.01) and lower MS and PF 12 h following FLOAT ($p < 0.05$). All sleep measures resulted in *small* to *large* effects ($d = 0.20$–0.87) with a significantly greater perceived sleep quality ($p = 0.001$) for the FLOAT trial compared to CON. There were no significant differences and a *trivial* effect size between trials for changes in cortisol concentration.
Conclusion: FLOAT may prove to be an effective method of exercise recovery, improving aspects of performance, pressure-to-pain threshold, perceived MS and PF, and sleep quality.

1. Introduction

Flotation-restricted environmental stimulation therapy (FLOAT) is a practice that involves an individual lying supine in a light and sound proof chamber that contains a saline solution (Epson salt - Mg_2SO_4) heated to skin temperature ($\sim$34–35 °C) (Driller & Argus, 2016). This unique environment compromises the body's ability to register external stimuli produced by light, sound, and touch (Morgan, Salacinski, & Stults-Kolehmainen, 2013), resulting in the elicitation of the relaxation response (Bood et al., 2006). Research has indicated its benefits to treat numerous health-related issues such as essential hypertension (Suedfeld, Roy, & Landon, 1982), chronic headaches (Wallbaum, Rzewnicki, Steele, & Suedfeld, 1991), and as a stress management tool (Bood et al., 2006; van Dierendonck & Te Nijenhuis, 2005). Recent research has also shown that this technique may be used as a recovery strategy by athletes following exercise (Driller & Argus, 2016). However, despite the current literature in support of FLOAT as a method to treat various health related issues, reports on its efficacy on post-exercise recovery is limited, warranting further research.

The use of FLOAT as a stress-management and relaxation method via the elicitation of the relaxation response has been well documented within the literature (van Dierendonck & Te Nijenhuis, 2005). The relaxation response is defined as the increased activity within the parasympathetic nervous system, resulting in lowered heart rate and blood pressure, reduced blood flow to the extremities, and a decrease in the release of hormones such as epinephrine and cortisol (Ghoncheh & Smith, 2003; Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991; Rosenzweig et al., 2010). Turner and Fine (1983) investigated the effects on plasma cortisol in 12 male participants pre and post FLOAT when compared to sitting on a reclined chair in a dim lit, soundless room (control). Blood samples were collected before and after various repeated trials. The results showed a significantly lower level of plasma cortisol pre to

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post FLOAT for the fifth trial, whereas no significant difference was found pre to post treatment for the control group.

The description and influence of sleep quantity and quality on recovery in elite athletes has seen an increase in the research literature over the last decade, drawing considerable attention to the practical application of promoting sleep practices and interventions in the athlete setting (Kroshus et al., 2019; Rattray, Argus, Martin, Northey, & Driller, 2015). This is important to note as sleep is also thought to be one of the most effective recovery strategies for elite athletes following exercise (O'Donnell, Beaven, & Driller, 2018), and previous research has shown that athletes may face unique issues that can impair their sleep, including training or competing late at night (Driller, Mah, & Halson, 2018; O'Donnell, Bird, Jacobson, & Driller, 2018). FLOAT has been shown to influence sleep, not only during the treatment but also following FLOAT. A study on 10 patients suffering from stress-related issues causing sleep disturbance, investigated the effects of FLOAT on perceived sleep quality (Kjellgren, Buhrkall, & Norlander, 2010). Participants' experience with FLOAT was recorded during week four and following the final trial during week 10. The authors indicated that the majority of statements from participants reported feelings of deeper sleep, fewer awakenings during the night, and a sense of renewed energy upon awakening in the morning. They concluded that sleep may be enhanced following FLOAT, specifically the night following treatment.

To our knowledge, only two studies have investigated the effects of FLOAT on athlete recovery following exercise. Morgan et al. (2013) assessed isometric muscle strength in 24 male participants pre and post a single FLOAT trial and a control (Morgan et al., 2013). Participants performed a fatiguing exercise bout including 50 repetitions of eccentric isokinetic muscle contractions on their non-dominant knee extensors and flexors at $60^{\circ}\cdot s^{-1}$. Following the fatiguing task, participants completed the one-hour recovery period (FLOAT or passive recovery). Maximal knee extension and flexion, blood glucose, blood lactate, heart rate, rate of perceived exertion (RPE), and perceived pain were assessed following the recovery period, for up to 48 -hs. Their results indicated no significant difference between conditions for muscle strength. However, post-FLOAT blood lactate levels were significantly lower than post-control blood lactate levels. Perceived muscle soreness one hour following the FLOAT trial was also found to be significantly lower. A more recent study by Driller and Argus (2016) investigated the effects of FLOAT on mood-state and muscle soreness in 60 elite athletes. Following a routine training trial for their sport, participants used FLOAT for an average duration of 45-min. A modified version of a multidimensional mood-state questionnaire consisting of sixteen different mood dimensions was completed pre and post FLOAT. Their findings showed that 15 of the 16 mood-state measures were significantly enhanced and perceived muscle soreness was significantly reduced. Additionally, *small* to *moderate* effect sizes showing enhanced mood-states for 9 of the 16 variables were found for athletes who had a nap during the FLOAT compared to athletes who did not. The authors concluded that the use of FLOAT following exercise significantly influenced mood-state and muscle soreness, with greater effects on mood-state when napping during FLOAT.

Despite the anecdotal use of FLOAT in the professional sport setting, there is a lack of scientific literature describing the use of FLOAT for recovery in athletes. In addition, there are yet to be any studies that have assessed the influence of FLOAT in the evening on sleep and next-day performance in athletes. Many studies have identified the positive effects of FLOAT on health-related issues in other settings, however, a clear gap still exists for its efficacy during post-exercise recovery. Therefore, the aim of the current study was to compare the effects of FLOAT with passive recovery on post-exercise recovery. Recovery was determined using a combination of measures including hormonal assessment, perceptual measures of physical fatigue and muscle soreness, sleep and various physical performance measures. Based on the findings from previous research (Driller & Argus, 2016; Morgan et al., 2013), we hypothesize that FLOAT will improve perceptions of muscle soreness, sleep and subsequent performance recovery in trained athletes.

2. Materials and methods

2.1. Participants

A total of 19 male, trained, team-sport athletes (mean ± SD; 21 ± 2y; height = 178.8 ± 7.2 cm; weight = 78.1 ± 8.9 kg) volunteered to participate in the study. The team-sports from which the participants partook in were basketball (n = 4), football (n = 11), and rugby (n = 4). All participants played at regional level, where they performed an average of three training sessions and one match per week for their sport. None of the participants had previous experience with FLOAT prior to participation in the study. Approval of the study was granted by the institution's Human Research Ethics Committee.

2.2. Design

A counterbalanced, randomized, controlled, crossover design was implemented in the current study. Participants attended four separate testing sessions (2 evening testing sessions, 2 morning testing sessions) over a period of two weeks. Each set of evening and morning testing sessions were associated with either the experimental (FLOAT) or control trial (CON), with all testing sessions taking place at the same time of day (refer to Fig. 1) separated by 7 days. As participants were new to FLOAT and the general protocols associated with it, a familiarization trial of the float was performed two days prior to the first testing session. Participants were to refrain from any high intensity exercise 24 h preceding the testing sessions in order to mitigate any influence on performance during the testing and exercise task. Dietary variables were controlled by instructing participants to ingest meals one hour prior to testing (17:30) and keep a diet diary for replication during the subsequent trial. Participants were also advised to arrive in a hydrated state, excluding the use of caffeinated drinks (<12 h prior to testing).

2.3. Procedure

As demonstrated in Fig. 1, both experimental and control trials followed the same procedure, differing only by the recovery intervention (FLOAT or CON). All physical tests and the exercise circuit were performed in a temperature-controlled gymnasium (~21 °C).

Following the pre-exercise testing and warm-up (19:00), participants performed the exercise circuit – the Basketball Exercise Simulation Test (BEST - refer to Scanlan, Dascombe, and Reaburn (2012))). This task is a running-based exercise simulation designed to stress an athlete's aerobic and anaerobic energy-system. The BEST involves walking, jogging, running, sprinting, shuffling and jumping. It was originally developed using time-motion analysis to establish an exercise protocol that would replicate the fitness demands commonly found during basketball competitions (Scanlan et al., 2012). The circuit was situated on a basketball court, running for a duration of 2 × 12-min bouts with a rest period of 2-min between the bouts. The 2 × 12-min bouts simulate the average on-court time a basketball player contributes to a game, whereas the 2-min period between the bouts simulates the intervals between the first and second, and the third and fourth quarters (Scanlan et al., 2012). Although BEST was strictly developed to replicate the energy demands found during a basketball match, its purpose within this study was to utilise the fatiguing aspect associated with it and to simulate the demands similar to that experienced during a team-sport match. Participants were instructed to

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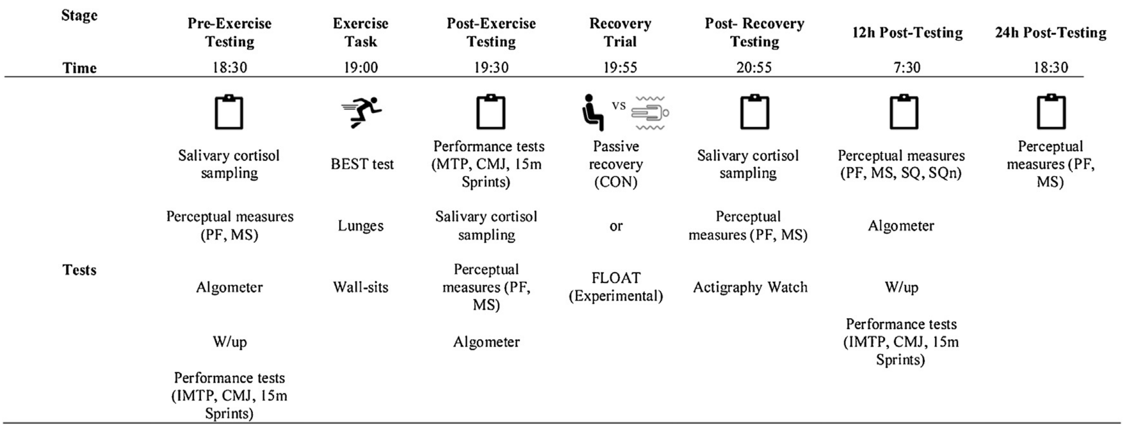

Stage	Pre-Exercise Testing	Exercise Task	Post-Exercise Testing	Recovery Trial	Post- Recovery Testing	12h Post-Testing	24h Post-Testing
Time	18:30	19:00	19:30	19:55	20:55	7:30	18:30
Tests	Salivary cortisol sampling Perceptual measures (PF, MS) Algometer W/up Performance tests (IMTP, CMJ, 15m Sprints)	BEST test Lunges Wall-sits	Performance tests (MTP, CMJ, 15m Sprints) Salivary cortisol sampling Perceptual measures (PF, MS) Algometer	Passive recovery (CON) vs or FLOAT (Experimental)	Salivary cortisol sampling Perceptual measures (PF, MS) Actigraphy Watch	Perceptual measures (PF, MS, SQ, SQn) Algometer W/up Performance tests (IMTP, CMJ, 15m Sprints)	Perceptual measures (PF, MS)

Fig. 1. Study testing protocol. Abbreviations: W/up, warm up; IMTP, isometric mid-thigh pull; CMJ, countermovement jump; BEST, basketball exercise simulation test; PF, physical fatigue; MS, muscle soreness; SQ, sleep quality; SQn, sleep quantity.

complete walking lunges (28 m) and a 2-min wall-sit upon completion of the BEST. The addition of these exercises ensured a greater level of fatigue by incorporating specific exercises (isometric contraction based) that are not present during the BEST. In addition, these movements are commonly found in the sports associated with the participants in the study. The 2-min wall-sit required participants to maintain a seated position with their back to the wall and a 90° flexion at both the hip and knee joints. During the 2-min, participants had their arms fully extended and adducted and were therefore unable to support themselves with their hands in any manner. If participants were to fail before the conclusion of the wall-sit, their time was recorded. This time was replicated during the subsequent trial.

Upon completion of the exercise task (19:30), post-exercise measures (performance test, saliva collection, perceptual measures, and algometer) were assessed to determine the level of fatigue induced in the participants. Once all post-exercise tests were complete (19:55), participants performed one of the two recovery interventions (FLOAT or CON). Participants then went home to sleep, before returning the next morning (7:30) to perform the 12-h post-testing session. Perceptual measures were taken again at 24-h post.

Prior to any of the physical tests taking place, the same standardized warm-up was completed. The procedure included: jogging three laps of the gym, one lap of high knees, one lap of butt kicks, two laps of grape vines, ten leg swings each side; 60%, 70%, 80% and 100% maximum sprint (15 m) and five maximal countermovement jumps (three second intervals between jumps).

2.4. Recovery interventions

One energy bar was ingested by all participants prior to the recovery period (post-exercise) on both occasions to assist in refuelling the participants. The recovery period began at 19:55, taking a total of one hour, whereby either FLOAT or CON was performed:

FLOAT: This involved the participant laying in a FLOAT tank for 45 min. The structure of the tanks comprised of a light-proof and sound-proof material enclosing a space large enough for an individual to lie supine in. This material also helps regulate the tank's temperature by acting as insulation, helping maintain an air temperature of 35 °C (approximate skin temperature) produced by an inbuilt heat pump. Like that of the air temperature, a saline solution (Epson salts–Mg2SO4) situated within the tank was also regulated to 35 °C by a hydro pump. The duration of 45-min was used as this has been indicated by previous researchers as the average period of time spent using this technique by athletes (Driller & Argus, 2016). The additional 15-min comprised of preparing for the float; showering (∼35 °C), and dressing following the float.

CON: Following the post-exercise testing, participants sat in a temperature-controlled (21 ± 1 °C), dim-lit room for one-hour where they were to refrain from the use of any electronic devices. Participants sat in a slightly reclined position and were able to talk to the researcher(s) during this time. The intention of the CON condition was for it to be as relaxing as possible, however, participants were not permitted to sleep during this time.

2.5. Cortisol assessment

Saliva samples were obtained at three separate time points for each participant (pre-exercise: 18:30, post-exercise: 19:30, and immediately post-recovery intervention: 20:55) during both evening testing sessionss. Collection of saliva was established by instructing the participants to passively drool into a serial tube (Cellstar 50-ml tube) for 5 min or until 5-mls was obtained. The saliva samples were then stored at a temperature of −20 °C until testing. The assessment of the saliva samples involved thawing the samples to room temperature. Centrifugal force was then applied (3000 rpm at 1500 g (g for gravity)) for a duration of 15 min, separating the glycoprotein content (mucin) within the sample. Once separation of the sample was complete, a highly sensitive Enzyme Linked Immunosorbent Assay (ELISA [sensitivity = > 0.007 μg/dL]) was utilised to determine the cortisol content (Salimetrics, NSW, Australia), following the manufacturer's instructions. Duplicate samples of saliva were assessed at a volume of 25 μL.

2.6. Perceived muscle soreness and fatigue

A visual analogue scale (VAS; Stubbs, 1979 (Stubbs, 1979)) was presented to the participants to assess their perceived physical fatigue and perceived muscle soreness. The VAS followed a standardized 0–10 weighting, with: 0 = no fatigue/no muscle soreness; 5 = moderate fatigue/moderate muscle soreness; 10 = maximal fatigue/maximal muscle soreness. These perceptual measures were assessed at five specific time points during both trials; 18:30 (pre-exercise), 19:30 (post-exercise), 20:55 (post-recovery), 7:30 (12 h post-testing), and 18:30 (24 h post-testing).

2.7. Pressure-to-pain algometer

A handheld algometer (FDN 100, Wagner Algometer, London, England) was used to measure participants pressure-to-pain threshold at three specific time points during both trials; 18:30 (pre-exercise), 19:30 (post-exercise), and 7:30 (12 h post testing).

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Fig. 2. Pressure-to-pain algometer application at the three different landmarks on the right leg a) vastus medialis; b) vastus lateralis; c) gastrocnemius.

This procedure involved participants sitting on a chair, with a 90° angle at their hip and knee joints. Measurements were then made to locate the three specific landmarks on the right leg; the vastus medialis (Fig. 2a), the vastus lateralis (Fig. 2b), and the gastrocnemius (Fig. 2c). To ensure application of the device was at the exact same point for each repeat-test, a permanent marker was used to mark the pressure point locations. Application of the device was performed following the manufacturer's instructions, perpendicular to the body at a rate of 10 N/s-^{1} while using one hand to stabilize the leg. Participants were instructed to precisely indicate the exact point at which the force being applied transitioned from pressure to pain (Fischer, 1988).

2.8. *Isometric mid-thigh pull*

Strength was measured using an isometric mid-thigh pull dynamometer (Baseline, New York, USA) which was calibrated prior to testing, using a method described by Dobbin et al. (2018). The initial position involved: participants standing with their knees and hips flexed; their feet shoulder-width apart; shoulders retracted and depressed; a neutral spine position; and the bar gripped with both hands pronated. The bar was set to a fixed height. Participants were then to pull the bar in a controlled manner, pushing the ground with the heels of their feet, maintaining posterior musculature flexion (DeWeese, Serrano, Scruggs, & Sams, 2012). The maximum force was recorded in kg for analysis.

2.9. *Countermovement jump*

A linear position transducer (GymAware, Canberra, Australia) was used to calculate countermovement jump height, similar to the protocol described by Argus, Gill, Keogh, Blazevich, and Hopkins (2011). The linear position transducer was magnetically positioned on the ground, with the tethered cable attached to the end of a lightweight (500 g) wooden dowel. Participants started in a static position whilst sitting the wooden dowel horizontally across their trapezius. Instructions were given to jump using maximal force to achieve a maximal jump height. Three jumps, with an interval of five seconds between jumps were performed by each participant during each performance test of the study (O'Donnell, Tavares, McMaster, Chambers, & Driller, 2017). The highest jump of the three (in cm) was used for analysis.

2.10. *Sprint and repeated-sprint testing*

To assess participants' speed over a distance of 15 m, dual-beam timing gates (Swift Performance Speedlight Timing systems, Queensland, Australia) were utilised. Timing gates were set at 5 m, 10 m and 15 m to determine split times at each distance. Participants were to start each sprint from a stationary position with their front foot directly on the zero-meter mark. Three sprints were performed by each participant. During each sprint, three splits were measured (5 m, 10 m, and 15 m). For analysis, their fastest split times (to the nearest 0.01 s) and total sprint time (total of all three sprints) were recorded. Participants were given 20 s-intervals between each of the three sprints.

2.11. *Sleep monitoring*

Following the conclusion of the recovery period (20:55), participants were required to wear a wrist actigraph (Readiband, Fatigue Science, Vancouver, Canada) until their arrival at the morning testing session (7:30). The data collected by the actigraphs was translated to sleep-wake scores by algorithms developed by the manufacturer's computer software (Fatigue Science, Vancouver, Canada). The inter-device reliability of the Readiband has been demonstrated previously (Driller, McQuillan, & O'Donnell, 2016). The sleep data obtained from the actigraph included sleep quality, sleep latency (mins), total sleep time (mins), sleep efficiency (%), wake after sleep onset (WASO (mins)), awakenings per hour, and mean wake durations (mins)

In addition to the monitoring of sleep via actigraphy, participants were required to self-report on their sleep quality upon waking and arriving to the 12-h post-testing session (7:30). Sleep quality was measured using a scale from 0 to 10; 0 being 'worst possible sleep', and 10 being 'best possible sleep' (Cappelleri et al., 2009).

2.12. *Statistical analysis*

Statistical analyses were performed using the Statistical Package for Social Science (SPSS 25.0 IBM Corp, Armonk, NY, USA). To examine the efficacy of the fatigue protocol, 2 (Condition: CON, FLOAT) x 2 (Time: pre-exercise, post-exercises) repeated measures ANOVAs were performed for each of the performance, perceived muscle soreness and physical fatigue, algometer, and cortisol measures. Change scores were then computed for each available time point compared to post-exercise (pre-recovery) for all physical performance measures, perceived muscle soreness and physical fatigue, algometer, and cortisol. Comparisons between CON and FLOAT were conducted using separate paired samples t-tests for each of the measures, except for muscle soreness and physical fatigue for which 2 (Condition: CON, FLOAT) x 3 (Time: Δ post-recovery, Δ 12 h post-recovery, Δ 24 h post-recovery) repeated measures ANOVAs were employed. A Bonferroni adjustment was made if significant main effects were present. Analysis of the studentised residuals was verified visually with histograms and also by the Shapiro-Wilk test of normality. Separate paired samples t-tests were used for each of the sleep measures. Statistical significance was set at $p \leq 0.05$.

Additionally, effect size statistics are reported to determine differences between FLOAT and CON groups across time points. For these measures, the standardized change in mean between time points was calculated and expressed as standardised (Cohen's *d*) effects. The magnitude of each effect size was interpreted using

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Table 1
Comparison of all physical measures across all time-points for experimental (FLOAT) and control (CON) trials. Data presented as means ± SD. IMTP = Isometric Mid-Thigh Pull, CMJ = countermovement jump, VMO = vastus medialis, VL = vastus lateralis, GN = gastrocnemius).

	Pre-Exercise		Post-Exercise		12 h Post-Recovery	
	FLOAT	CON	FLOAT	CON	FLOAT	CON
IMTP (kg)	167 ± 30	170 ± 36	153 ± 33	152 ± 35	173 ± 25	164 ± 23
CMJ (cm)	46.0 ± 5.8	45.7 ± 6.2	43.3 ± 5.9	43.5 ± 9	45.1 ± 5	42.0 ± 8.2
secs)	1.13 ± 0.06	1.14 ± 0.06	1.15 ± 0.06	1.16 ± 0.05	1.13 ± 0.05	1.16 ± 0.06
10-m SPRINT (secs)	1.88 ± 0.09	1.89 ± 0.10	1.94 ± 0.08	1.93 ± 0.09	1.90 ± 0.07	1.95 ± 0.12
15-m SPRINT (secs)	2.58 ± 0.10	2.58 ± 0.10	2.65 ± 0.12	2.64 ± 0.12	2.61 ± 0.10	2.65 ± 0.11
Repeated Sprint (sec)	7.82 ± 0.32	7.84 ± 0.31	8.05 ± 0.38	8.05 ± 0.36	7.96 ± 0.30	8.09 ± 0.34
VMO Algometer (N)	40 ± 11	41 ± 12	35 ± 11	39 ± 14	38 ± 11	32 ± 12
VL Algometer (N)	38 ± 12	39 ± 14	33 ± 10	36 ± 13	37 ± 12	32 ± 11
GN Algometer (N)	25 ± 5	27 ± 8	21 ± 6	25 ± 11	22 ± 5	21 ± 8

Table 2
Comparison of all performance and perceptual measures (post-recovery, 12 h post recovery and 24 h post recovery) compared to post-exercise (pre-recovery) values. Data presented as raw difference in values (mean ±90% confidence intervals) with effect sizes (and 90% confidence intervals) for comparison between experimental (FLOAT) and control (CON) trials. * represents significant difference between trials ($p \leq 0.05$). IMTP = Isometric mid-thigh pull, CMJ = countermovement jump. VMO = Vastus Medialis, VL = Vastus Lateralis, GN = Gastrocnemius, AU = arbitrary units.

	Post-Recovery ΔFLOAT - ΔCON Effect size	12 h Post- Recovery ΔFLOAT - ΔCON Effect size	24 h Post-Recovery ΔFLOAT - ΔCON Effect size
IMTP (kg)		7±13 0.21±0.39, *Small*	
CMJ (cm)		3.1±2.5* 0.40±0.72, *Unclear*	
secs)		−0.02±0.03 −0.40±0.46, *Small*	
10-m SPRINT (secs)		−0.06±0.04* −0.68±0.43, *Moderate*	
15-m SPRINT (secs)		−0.05±0.05* −0.47±0.39, *Small*	
Repeated Sprint (sec)		−0.12±0.10 −0.32±0.28, *Small*	
Muscle Soreness (AU)	−1.55±0.88* −1.07±0.61, *Large*	−1.84±0.80* −1.27±0.55, *Large*	−2.11±1.21* −1.46±0.83, *Large*
Physical Fatigue (AU)	−0.71±0.88 −0.67±0.83, *Moderate*	−1.05±0.83* −0.98±0.78, *Large*	0.10±0.86 0.10±0.80, *Unclear*
VMO Algometer (N)	–	9.68±4.40* 0.74±0.34, *Moderate*	–
VL Algometer (N)	–	8.00±4.34* 0.66±0.36, *Moderate*	–
GN Algometer (N)	–	5.82±3.03* 0.62±0.32, *Moderate*	–

thresholds of 0.2, 0.5, and 0.8 for *small*, *moderate*, and *large*. An effect size of <0.2 was considered *trivial*. Where the 90% confidence limits overlapped the thresholds for small positive and small negative values the effect was considered *unclear*.

3. Results

The mean ± SD pre-exercise, post-exercise, and 12h-post recovery values for performance measures are presented in Table 1 and perceived sleep quality, sleep latency (mins), total sleep time (mins), sleep efficiency (%), wake after sleep onset (WASO) (mins), awakenings per hour, wake episodes, mean wake duration (mins) measures in Table 3, separately for FLOAT and CON.

3.1. *Pre to post-exercise differences*

Significant main effects of Time from pre to post-exercise were found for all measures (all p's ≤ 0.012), demonstrating reduced physical performance and increased fatigue and muscle soreness following the exercise protocol (see Table 1). No significant Condition or interaction effects between Time and Condition were found, suggesting that there were no differences in the response to the exercise protocol between FLOAT and CON.

Table 3
Comparison of all sleep measures following experimental (FLOAT) and control (CON) trials. Data presented as means ± SD. WASO = wake after sleep onset.

	FLOAT	CON	p-value
Perceived Sleep Quality	7.7 ± 1.2	5.9 ± 2.0	0.001
Sleep Latency (mins)	15 ± 12	20 ± 20	0.288
mins)	403 ± 48	391 ± 62	0.329
Sleep Efficiency (%)	90 ± 5	86 ± 8	0.148
WASO (mins)	20 ± 16	29 ± 27	0.254
Awakenings per hour	0.45 ± 0.28	0.55 ± 0.42	0.310
Wake episodes	3.0 ± 1.7	3.7 ± 2.6	0.247
Mean wake duration (mins)	5.4 ± 2.4	7.4 ± 2.8	0.060

3.2. *Post-exercise recovery*

Performance. The results revealed significant differences between FLOAT and CON for CMJ ($t_{18} = 2.14$, $p = 0.046$), 10m sprint ($t_{18} = -2.71$, $p = 0.014$), 15m sprint ($t_{18} = -2.06$, $p = 0.05$), and approaching significance for repeated sprint ($t_{18} = -2.00$, $p = 0.06$), indicating better performance following FLOAT. No significant differences were found for 5m sprint ($t_{18} = -1.52$, $p = .146$) and IMTP ($t_{18} = 0.94$, $p = 0.359$). *Small* to *moderate* effects were associated with all performance measures in favour of FLOAT, except for CMJ, which was associated with an *unclear* effect (Table 2).

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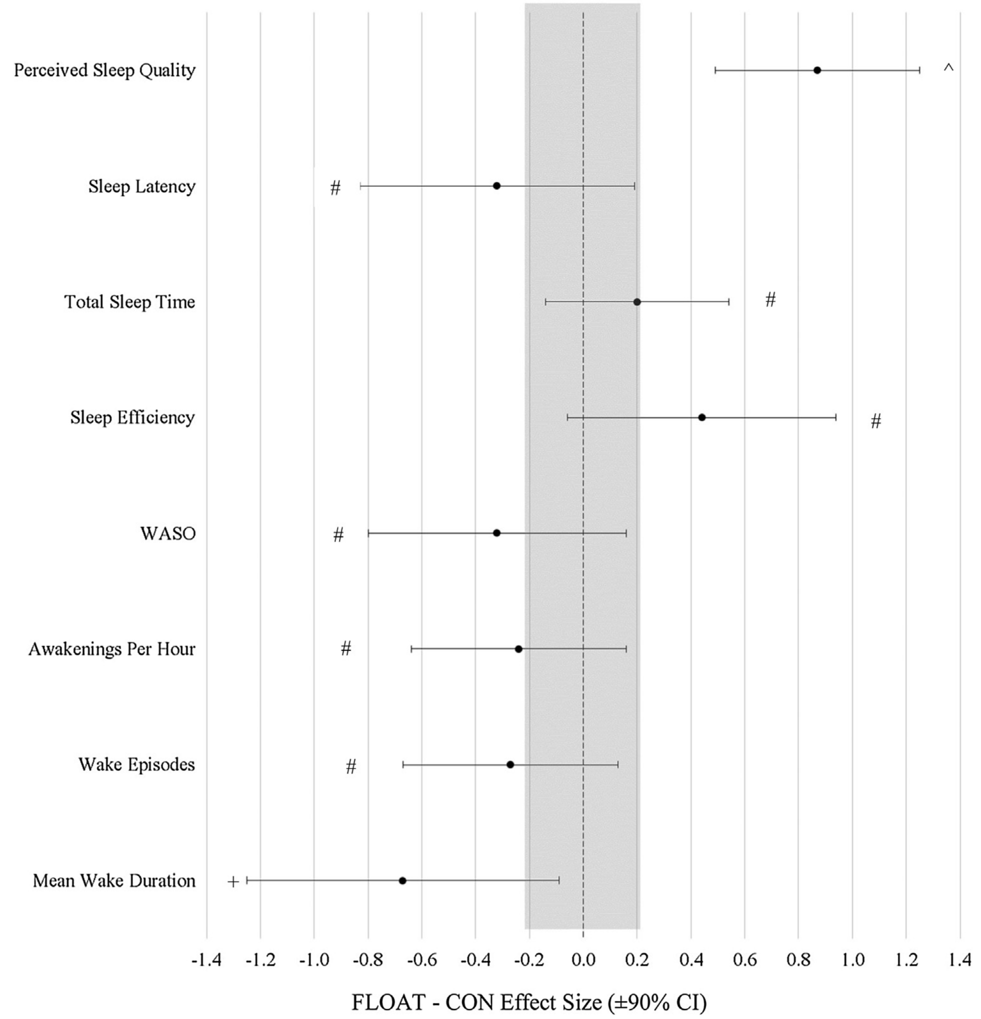

Fig. 3. Effect sizes for measured sleep variables between experimental (FLOAT) and control (CON) trials. Error bars represent 90% confidence intervals (90%CI), with the shaded area representing a *trivial* effect (±0.2) between trials. # *small* effect between trials, + *moderate* effect between trials, ^*large* effect between trials.

Algometer. The results revealed significant differences between FLOAT and CON for all algometer readings: VMO ($t_{18}=3.81$, $p=$ 0.001), VL ($t_{18}=3.20$, $p=$ 0.005), and GN ($t_{18}=3.33$, $p=$ 0.004), suggesting greater pressure-to-pain threshold following FLOAT. These measures were associated with *moderate* effects (Table 2) in favour of FLOAT.

Perceived muscle soreness and physical fatigue. For perceived muscle soreness, the results revealed a significant main effect of Condition, F(1, 17) = 13.69, $p=$ 0.002, indicating that participants reported having less sore muscles after FLOAT than CON. No significant main effect of Time, F(2, 34) = 1.01, $p=$ 0.375, or interaction effect between Time and Condition, F(2, 34) = 1.16, $p=$ 0.325, were found. For perceived physical fatigue, the results revealed a non-significant main effect of Condition, F(1, 16) = 1.50, $p=$ 0.239, and a significant main effect of Time, F(2, 32) = 4.02, $p=$ 0.028; however, it was superseded by a significant interaction between Time and Condition, F(2, 32) = 3.60, $p=$ 0.039. The follow-up tests revealed that the participants reported being significantly less physically fatigued at 12h post-recovery following FLOAT than CON. No significant differences between conditions were found for post-recovery and 24h post-recovery. Muscle soreness and physical fatigue were associated with *moderate* to *large* effects in favour of FLOAT at all time points except for 24 h post-recovery for physical fatigue, which was associated with an *unclear* effect (Table 2).

Cortisol. There was a significant pre to post-exercise increase in cortisol for both FLOAT (0.135 to 0.253 μg/dL) and CON (0.144 to 0.273 μg/dL). These levels decreased significantly for both trials following the recovery period to 0.087 μg/dL and 0.128 μg/dL for FLOAT and CON, respectively, however, there was no significant differences and a *trivial* effect size in the pre to post change between trials ($t_{17}=0.95$, $p=$ .354. $d=-0.12$).

Sleep. The results revealed a significant difference between FLOAT and CON for perceived sleep quality ($t_{18}=-4.03$, $p=$ 0.001), and the difference was approaching significance for mean wake duration ($t_{16}=2.03$, $p=$ 0.06). No other significant differences were evident (all p's ≥ .148). *Small* to *large* effects in favour of FLOAT were found for all sleep measures (Fig. 3).

4. Discussion

The purpose of the current study was to assess the effects of flotation-restricted environmental stimulation therapy (FLOAT) on post-exercise recovery in trained, male team-sport athletes. The main findings from the study indicated beneficial results for performance recovery, with significantly greater countermovement jump (CMJ), 10 m sprint, and 15 m sprint performance following FLOAT, when compared to a passive control trial. *Small* to *moderate* effect sizes were found for all performance measures in favour of FLOAT, excluding CMJ, which was considered *unclear*.

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The findings also showed significant benefits in pressure-to-pain threshold across all muscle landmarks following FLOAT compared to CON. Furthermore, *small* to *large* effect sizes were found for all sleep measures, and a significantly greater perceived sleep quality, suggesting FLOAT may be an effective method to influence sleep following exercise. These findings provide the first evidence that the utilisation of FLOAT following exercise may enhance sleep and performance recovery in athletes.

The physical performance findings of the current study are in contrast with previous research by Morgan et al. (2013). Morgan and colleagues assessed maximal isometric strength via an isokinetic dynamometer pre and post FLOAT and a passive control. Their results showed no statistical significance in muscle strength between conditions. The authors suggested that due to the decrease in central nervous system activity following FLOAT, proprioception stemming from the somatosensory system may be compromised, inhibiting the ability to exert maximal force during subsequent exercise. Immediate post-treatment performance was not evaluated in the current study, instead we opted for 12 h post-treatment performance measures, resulting in significant findings in support of FLOAT. When compared to the control group, FLOAT resulted in *small* benefits to IMTP, 5 m sprint, 15 m sprint, and repeated sprint, and a *moderate* benefit to 10 m sprint. It is therefore possible that the timing of performance measures may have separated the results from both studies.

While performance may be impaired immediately post-FLOAT as shown in the Morgan et al. study, improvement in sleep quality and subsequent performance recovery 12 h post FLOAT may prove to be beneficial, as seen in the current study. While the mechanisms remain purely speculative, a plausible reason for this could be due to a cascading effect originating from what is known as the relaxation response (Bood et al., 2006), thereby increasing parasympathetic nervous system activity (Ghoncheh & Smith, 2003; Petruzzello et al., 1991; Rosenzweig et al., 2010). During this increased activity, blood flow is redirected from the extremities to the internal organs, subsequently increasing digestive processes (McCorry, 2007). This in turn promotes the restoration of resources (e.g. muscle glycogen and protein) expended during exercise (Saunders, Kane, & Todd, 2004), ultimately reducing muscle damage found post-exercise (Newham, McPhail, Mills, & Edwards, 1983) as well as diminishing the negative effects post-exercise muscle damage has on performance (Saunders et al., 2004).

The results of the current study are consistent with previous research that assessed perceived muscle soreness following FLOAT (Driller & Argus, 2016; Morgan et al., 2013). Driller and Argus (2016) investigated pre to post perceived muscle soreness following FLOAT in 60 elite athletes. Their results indicated a significant reduction ($p < 0.01$, $d = -0.87$) in perceived muscle soreness pre to post FLOAT. Morgan et al. (2013) also reported significantly lower perceived muscle soreness one hour following FLOAT compared to the measures obtained during the passive control trial. A possible contributing factor to these findings could be due to the hydrostatic pressure, caused by the water within the chamber (Wilcock, Cronin, & Hing, 2006). Wilcock et al. (2006) argued that as a body immerses into water, it causes what is known as driving potential, where the pressure acting upon the body increases, forcing fluid and gases from high pressure areas to low pressure areas. Wilcock et al. (2006) further explained that this mechanism has a direct influence on lactic acid and oedema, two waste products understood to accumulate in areas where tissue damage has occurred (Cheung, Hume, & Maxwell, 2003). This displacement of waste product decreases pressure on pain receptor in muscle tissue, ultimately reducing muscle soreness (Eston & Peters, 1999).

Improvement in sleep the night following the FLOAT trial has been documented previously. Research by Kjellgren et al. (2010) on patients suffering from stress-related issues causing sleep problems found numerous statements by patients to suggest an increase in perceived sleep quality. The authors further stated the cause of this derives from the level of relaxation produced by the environment within the FLOAT tank (Kjellgren et al., 2010). As described previously, the relaxation response, whereby a reduction in heart rate and blood pressure, blood flow to the extremities, and a decrease in the release of hormones such as epinephrine and cortisol occurs (Ghoncheh & Smith, 2003; Petruzzello et al., 1991; Rosenzweig et al., 2010), may lead to enhanced sleep (Smith, 1998).

A study by Jacobs, Heilbronner, and Stanley (1984) on 25 university students assessed blood pressure and mood state pre and post two trials (FLOAT and control) held on separate days. The control trial included participants lying in a supine position within a room designed to replicate normal auditory, visual and temperature stimulation. The results indicated a significant pre to post difference for blood pressure and results from three out of five relaxation questionnaires were significantly improved following FLOAT compared to the control trial, suggesting participants who used FLOAT experienced lowered blood-pressure and greater overall relaxation (Jacobs et al., 1984). Another study on 65 participants suffering from stress-related issues investigated the effects of FLOAT as a preventative health-care intervention (Kjellgren & Westman, 2014). Participants were randomly assigned to either the FLOAT group ($n = 37$) or the control group ($n = 28$). Participants in the FLOAT group completed 12 FLOAT trials over a period of seven weeks. Findings indicated a significant increase in sleep quality following FLOAT ($p < 0.05$), whereas no difference was detected for the control group. Although these studies were performed in non-athlete populations, their results support the current study's findings showing that sleep quality following FLOAT may be significantly enhanced. Enhanced sleep in the current study via significant improvements in perceived sleep quality and *small* to *moderate* benefits to all other sleep measures following FLOAT when compared to CON, may lead to improved psychological and physiological recovery, leading to next-day physical performance improvements (O'Donnell, Beaven et al., 2018).

The results of the current study regarding cortisol are somewhat inconsistent with previous research (Turner & Fine, 1983). Turner and Fine (1983) showed a significant decrease between FLOAT sessions one to five in plasma cortisol levels in 21 healthy participants. The authors argued that the occurrence of this significant decrease was possibly a result of internal strategies gradually being constructed by the participants throughout the duration of the study. Kjellgren et al. (2010) further suggest the impact of increased familiarity and experience in FLOAT as they found a growing trend towards 'psychological development' and 'quality of life' during the ten weeks of treatment. Due to this reason, increasing the number of trials (e.g. $\sim$ 5) may increase familiarity with the environment associated with FLOAT and possibly further decrease cortisol levels within participants. Only two FLOAT sessions were performed in the current study (including the familiarization trial), and despite a significant decrease in cortisol concentration pre to post FLOAT, there was no significant differences between the FLOAT and CON trials, perhaps due to the similarly relaxing nature of the CON trial. Future research may give insight into whether habitual or regular floaters have different cortisol responses than those relatively new to the technique .

This study provided unique insight to the effects of FLOAT as a post-exercise recovery method; however, our results are not without limitations. Integrating a placebo trial into the study would be beneficial as it would help determine whether FLOAT as a recovery method is effective. The novelty of such a foreign technique may cause a significant placebo effect, therefore, this cannot be discounted in the current study (Halson & Martin, 2013). A further limitation is that we did not assess immediate post-recovery performance. However, the study was designed to replicate an ath-

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lete's typical experience following evening exercise or competition, whereby athletes would usually train/compete, perform various recovery strategies and then go home to bed. This is why we opted for a 12 h-post follow-up measure, as we felt that this is more realistic to the team-sport setting.

Results from the current study provide evidence-based support for the practical application of FLOAT in the exercise recovery setting. We would suggest that minimal instructions and only one induction/familiarisation FLOAT session are required, before beneficial effects can be seen from a 45 min FLOAT. Coaches and practitioners working with athletes should consider FLOAT as a recovery modality to implement into the periodised training and recovery program. As evidenced in the current study, the use of FLOAT later in the evening (~7:00pm) following training, may help to alleviate the issues usually faced by athletes trying to sleep following intense night-time exercise (Driller et al., 2018; O'Donnell, Bird et al., 2018).

The current study has extended the findings of previous research into FLOAT, showing that perceived muscle soreness, physical fatigue, and perceived sleep quality can be significantly improved when integrating it into a recovery program following high-intensity exercise. The use of FLOAT following exercise in the late afternoon/early evening may be an effective strategy to enhance relaxation and subsequent sleep. Furthermore, this is the first study to our knowledge to show the benefits of FLOAT on next-day performance recovery, specifically in measures of power and speed. Future research should attempt to control for the possible placebo effect of such a treatment, or include the comparison of other post-exercise recovery strategies (e.g. cold water immersion).

The authors report no conflicts of interested are associated with the current study. All float sessions were paid for by the researchers and took place at a commercial float studio (Serenity Float, Hamilton, New Zealand). The owners of the float facility had no input into the design, data collection or analysis of the research.

Declaration of Competing Interest

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