BMC Complementary Medicine and Therapies

SYSTEMATIC REVIEW Open Access

A systematic review of flotation-restricted environmental stimulation therapy (REST)

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Abstract

Background Restricted Environmental Stimulation Therapy (REST) is a therapeutic technique that involves immersing an individual in an environment with minimal sensory input or stimulation. The goal of REST is to induce a state of relaxation that is deeper than what can be achieved through other forms of relaxation techniques. Research suggests that REST can help reduce anxiety, alleviate chronic pain, improve sleep, and enhance creativity and cognitive function. Flotation-REST is a popular type of REST that utilizes an enclosed tank filled with buoyant saltwater to facilitate relaxation. This study aimed to synthesize the evidence on studies that investigate the effects of flotation-REST.

Methods We used Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to survey the flotation-REST literature starting from the earliest papers we could find, in 1960, until May 2024. This search was conducted on 23 May 2024 within the Google Scholar and PubMed databases. Journal and conference papers, as well as electronic preprints, that used flotation-REST in their methods, and that were written in English were included; non-original research papers (e.g., review papers, book chapters, and papers solely on types of REST other than flotation-REST (e.g., chamber-REST) were excluded. From each eligible paper, we extracted information regarding the participant sample, application of flotation-REST, experimental design, treatment delivery method, questionnaires and tools, and study results.

Results In total, we found 63 studies that included 1,838 participants. We propose that the application of flotation-REST can be divided into nine main categories: pain, athletic performance, physiology, stress, consciousness, psychology, creativity, clinical anxiety, sleep, smoking cessation, and other miscellaneous applications. In general, flotation-REST was found to bring about positive effects on pain, athletic performance, stress, mental well-being, and clinical anxiety, while having limited to no effect on sleep-related disorders and smoking cessation.

Conclusion This paper provides a comprehensive overview of the current research on flotation-REST, highlights ongoing limitations in the literature, and outlines potential areas for future research. While flotation-REST appears to induce various benefits for physical and mental well-being, particularly when it comes to managing states like pain and stress, more research is needed to better understand the mechanisms underlying these effects and to identify optimal treatment protocols for different populations. A limitation of this paper is the relatively small number of studies available for review, which limits the generalizability of certain findings and highlights the need for additional research in this area.

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Keywords Restricted environmental stimulation therapy, Float pod, Flotation, PRISMA

Introduction

Restricted Environmental Stimulation Therapy (REST) is a therapeutic technique that involves immersing an individual in an environment with minimal sensory input or stimulation. Flotation-REST refers to a type of REST that involves floating in a tank filled with saltwater, also known as a float pod, float tank, or sensory deprivation tank. During flotation-REST, an individual is enclosed in a soundproof and lightproof chamber, floating in a shallow pool of water that is saturated with Epsom salt, which makes the water dense and enables the individual to float effortlessly. This environment is designed to minimize any sensory input from the outside world and thus to lead to a state of deep relaxation and reduced brain stimulation [1]. The goal of all forms of REST is to induce a deep state of relaxation [2]. As detailed below, previous research suggested that REST can help reduce anxiety, alleviate chronic pain, improve sleep, and enhance creativity and cognitive function. In clinical settings, REST has been proposed as a treatment for various conditions, including anxiety disorders, chronic pain, and post-traumatic stress disorder (PTSD) [3]. REST has also been used in sports therapy to help athletes recover from injuries and improve performance [4].

An early pioneer of flotation-REST research was John C. Lilly at The National Institute of Mental Health in the 1950s. It appears that Lilly created the first sensory deprivation tank in 1954 [5]. While Lilly played a significant role in popularizing the use of flotation tanks and exploring the concept of sensory deprivation in the 1950s and 1960s, it seems that he did not publish any specific scientific papers on the topic during that time. This early research on REST focused on elucidating the effects of reduced environmental stimulation on a range of psychophysiological, motoric, perceptual, cognitive, and emotional outcomes by placing people in sensory deprivation chambers for extended periods of time. The research eventually transitioned into an attempt to gain in-depth understanding of consciousness in the absence of external stimuli [6].

While Lilly was researching the effects of sensory deprivation through deep-water immersion, Donald Hebb investigated the effects of dry-REST, more commonly known as chamber-REST [7]. Chamber-REST occurs in a soundproof and lightproof room. The participant lies on a bed and is encouraged to limit movement. The experimental sessions tend to be long, lasting up to 24 (consecutive) hours. Researchers believed that after experiencing sensory deprivation, people became more vulnerable to external suggestions and influences. To test this, anxiety-inducing elements such as panic buttons and medical trays were sometimes introduced to see how individuals would react [8]. These results suggest that flotation therapy promotes deep relaxation and may hold promise for treating mental health conditions like anxiety and depression [9].

In 1968, Peter Suedfeld started conducting research on flotation-REST and eventually coined the term "Restricted Environmental Stimulation Therapy" (or REST). More extensive academic research then began globally, the majority taking place in the 2000s by Annette Kjellgren from Karlstads Universitet in Sweden [10–17]. In more recent years, Justin Feinstein and his team, then at the Laureate Institute of Brain Research in the United States, conducted the first functional magnetic resonance imaging (fMRI) study on the effects of flotation-REST [18]. Recent fMRI studies by Justin Feinstein and his team at the Laureate Institute for Brain Research explored the neural effects of Flotation-REST. Their findings revealed decreased activity in the default mode network (DMN), associated with reduced self-referential thinking, and increased interoceptive awareness, enhancing focus on internal bodily sensations. Additionally, reduced activation in stress-related brain regions, such as the amygdala, indicated flotation's potential for alleviating anxiety. These results suggest that flotation therapy promotes deep relaxation and may hold promise for treating mental health conditions like anxiety and depression [18].

Several review papers have been published on the effects of flotation-REST, focusing on either stress [19, 20] or sleep [21]. These papers and others provide insight into the potential benefits that have been claimed for flotation-REST, including reducing stress and anxiety, improving sleep and relaxation, and promoting general well-being. However, these previous reviews are relatively narrow in scope, discussing specific applications of flotation-REST. In other words, although several systematic reviews have been conducted on flotation-REST, they have focused on specific applications, such as its effects on anxiety, pain relief, or athletic recovery. However, a comprehensive, systematic review that considers all the potential applications and examines multiple aspects of flotation-REST is still lacking. What is more, to our knowledge, there has been no recent review of the flotation-REST literature, despite progress in recent years. The aim of this systematic review is therefore to provide a comprehensive and up-to- date analysis of all the scientific literature, comparing and contrasting its effects across various domains and applications. Our review encompasses all fields of float pod applications, offering a comprehensive view of its potential across various domains, such as creativity, smoking cessation, and

athletic performance—areas that have not been fully addressed in previous reviews. This broad scope provides researchers with a valuable starting point by summarizing treatment methods, key findings, and the results of questionnaires used in each study, presented in an accessible abstract format for each field. This will help guide future research by giving an overview of existing studies and suggesting potential directions for new investigations. Additionally, our review is timely, as most existing reviews are several years old and do not incorporate the most recent studies or advancements in the field.

Hence, this systematic review provides a comprehensive and up-to-date analysis of the scientific literature, comparing and contrasting its effects across various domains and applications. To achieve this, we outline the methods employed in our review in Sect. 2, adhering to the systematic PRISMA guidelines. Section 3 presents our results, followed by a bias assessment in Sect. 4. In Sect. 5, we discuss the design of the float pod, while Sect. 6 offers an in-depth discussion of our findings. Section 7 addresses the limitations of our review, and Sect. 8 highlights potential future directions for research in this area.

Methods

Search strategy

This systematic literature review follows the preferred reporting items for systematic review and meta-analysis (PRISMA 2020) guidelines [22]. PRISMA provides a transparent and structured framework for researchers to follow when conducting a systematic review, enhancing the transparency, reproducibility, and quality of the review.

During identification (Phase 1), we used keywords to search for potentially relevant papers. This search was conducted on 23 May 2024 within the PubMed and Cochrane Library databases along with the Google Scholar search engine using the following group of keywords: "Restricted Environmental Stimulation Therapy" OR "Float pod" OR "Flotation REST" OR "Flotation pod" OR "Flotation Tank" OR "Sensory isolation". The search yielded 2,489 papers (PubMed: 179, Cochrane Library: 50, and Google Scholar: 2,260). Microsoft Excel (v.16.57) and JASP (v.0.18.3) were used to track relevant results during this search.

Study selection

During screening (Phase 2), we screened the papers identified in Phase 1 for relevance. After reviewing the title and abstract of each paper, 2,163 papers were removed because they were not relevant, resulting in 326 remaining papers. We then further reviewed those 326 papers for duplicates; of those, 134 were duplicates. Thus, Phase 2 yielded 192 articles. The remaining 192 papers were examined in detail to meet the criteria set by the researchers.

Eligibility criteria

During the inclusion phase (Phase 3), authors EL and JG conducted independent and manual reviews of the remaining papers to assess their eligibility for inclusion in this review (refer to Table 1). We set the inclusion criteria with the purpose of reviewing high-level, scientific literature of floatation-REST. Hence, the inclusion criteria that we set were for the papers to be peer-reviewed, professional journal or conference publications that were written in English and focused on floatation-REST. Screening the full texts of the remaining 192 papers, revealed that 129 of them did not meet the eligibility criteria for this review. Reasons for exclusion included papers where relevant keywords were included only in the references rather than within the body of the paper, papers that were not published in English, studies that utilized only dry-chamber REST, pre-prints, undergraduate journal publications, theses, or repositories.

Consequently, we identified 63 papers that met the criteria for inclusion in this analysis (Fig. 1).

Data extraction and presentation

For each selected article, authors EL, JG, and EC independently extracted 30 features, covering 7 categories: article origin; data sample; application of flotation-REST; experimental design; treatment delivery; questionnaires and tasks; and results (see Table 2 for details).

Results

Origin of the selected studies and different applications of float pod

The research methodology returned a total of 63 journal papers on flotation-REST. The majority of studies (48 out of 63, 76.2%) were conducted either in the United States (27 studies, 42.9%) or in Sweden (21 studies, 33.3%), with smaller numbers of studies conducted in Canada (7 studies, 11.1%), Japan (3 studies, 4.8%), Australia, Germany,

Table 1 Predetermined inclusion and exclusion criteria for reviewed papers

Inclusion criteria	Exclusion criteria
• Peer-reviewed journal, written in English	• Non-original research papers (e.g., review papers)
• Uses flotation-REST in methods	• Book chapters, pre-prints, undergraduate journals, theses, or repositories.
	• Papers solely on types of REST other than flotation-REST (e.g., chamber-REST)

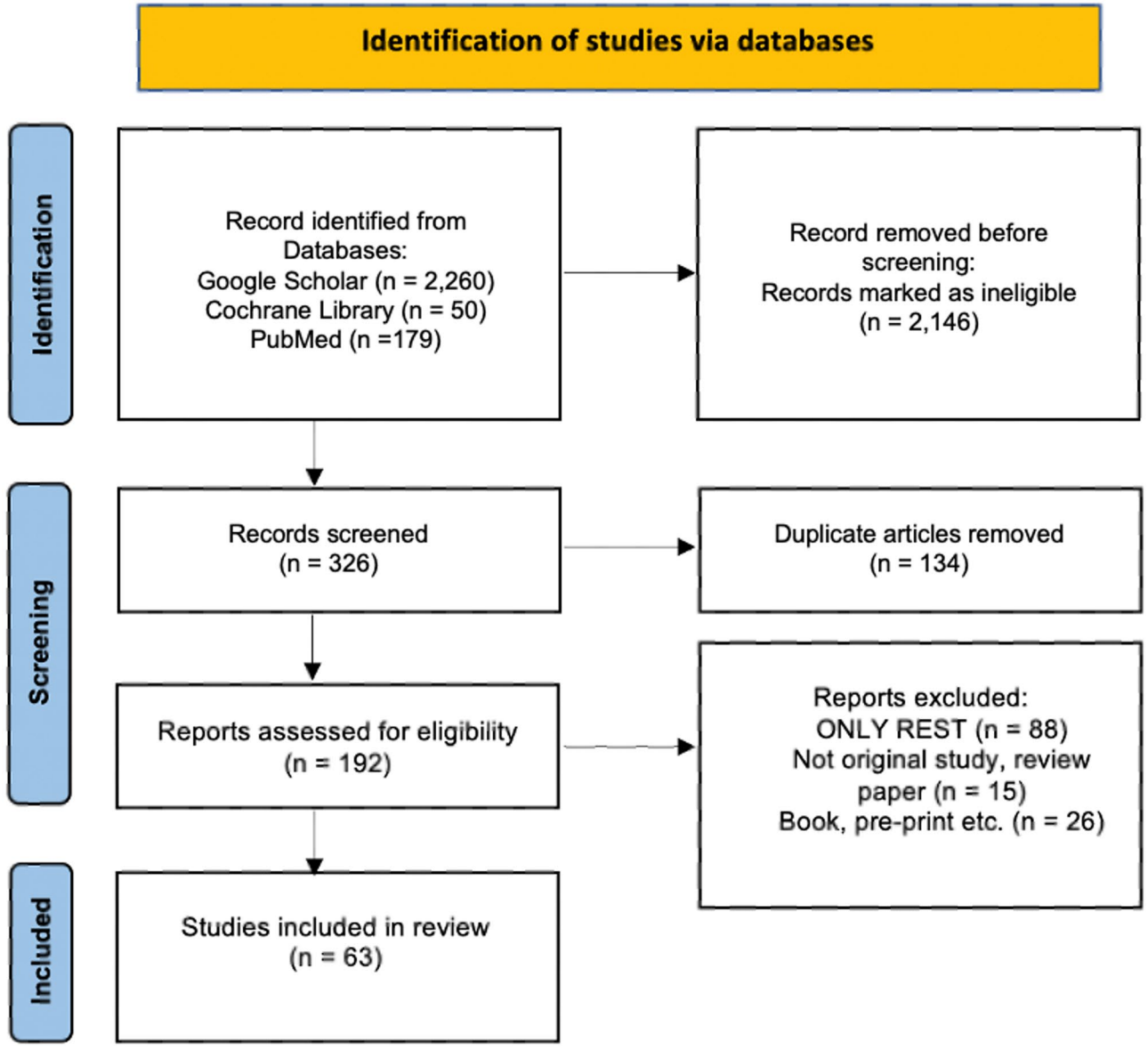

Fig. 1 Selection process for the papers to include in the review paper

Table 2 Data items extracted for each Article selected

Category	Data item
Article origin	Type of publication (journal article, conference article, or manuscript in an electronic preprint repository), location where the study took place
Data sample	Number of participants, age, selection method, conditions
Application of flotation-REST	Type of treatment carried out with flotation-REST
Experimental design	Description of randomization or pre/post design
Treatment delivery	Number of sessions, duration of sessions
Questionnaires and tasks	All the measurements taken during the study
Results	The effect of flotation-REST on the participants

Switzerland, the United Kingdom, and New Zealand (1 study each, 1.6%). These findings suggest that research on flotation-REST spans many countries, though it consists only of developed countries or members of the "global north". The distribution of studies may also reflect differences in the availability and popularity of float pods in different regions, as well as varying levels of research interest and funding.

The reviewed papers were categorized into groups based on their application of flotation-REST (Fig. 2). The following groups were identified: pain (11 studies), athletic performance (8 studies), physiological effects (8 studies), stress (6 studies), consciousness (6 studies), psychology (7 studies), creativity (5 studies), clinical anxiety (4 studies), sleep (2 studies), smoking cessation (2 studies), and other (4 studies). These categories reflect the diverse range of flotation-REST applications explored in the literature, highlighting the float pod's potential utility across different fields of research.

After exploring the applications of float pods, it is beneficial to examine the Chronological Development of Float Pods for Various Applications (Fig. 3). As illustrated in this figure, the evolution and application of float pods have progressed over several decades, marked by notable shifts in research focus. In the early years, from 1960 to the mid-1980s, studies primarily concentrated on consciousness, stress, and relaxation, reflecting the initial interest in sensory deprivation for mental well-being. By the late 1980s, research expanded to encompass more diverse applications, including smoking cessation and creativity enhancement. From the 1990s onward, the focus shifted toward stress relief, pain management, and enhancements in athletic performance, with intermittent spikes in studies addressing anxiety and physiological outcomes. A significant surge in publications occurred in 2018, particularly highlighting the psychological and anxiety-related benefits of float therapy, indicating a renewed interest in its applications for both mental and physical health. In the most recent years (2020–2022), research

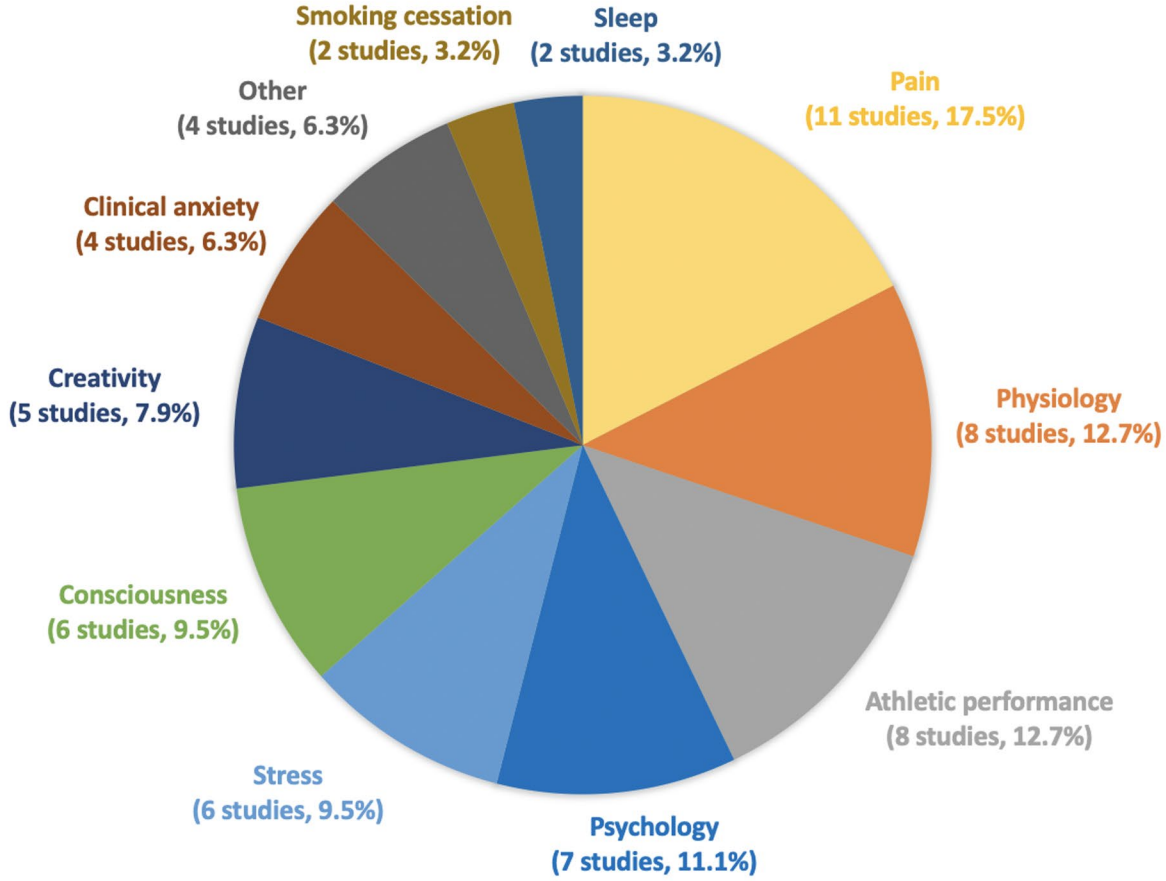

Fig. 2 The percentage of flotation-REST studies in different flotation-REST applications across 63 reviewed studies. The following groups were identified: pain (17.5%, 11 studies), athletic performance (12.7%, 8 studies), physiology (12.7%, 8 studies), stress (9.5%, 6 studies), consciousness (7.9%, 6 studies), psychology (11.1%, 7 studies), creativity (7.9%, 5 studies), clinical anxiety (6.3%, 4 studies), sleep (3.2%, 2 studies), smoking cessation (3.2%, 2 studies), and other (6.3%, 4 studies)

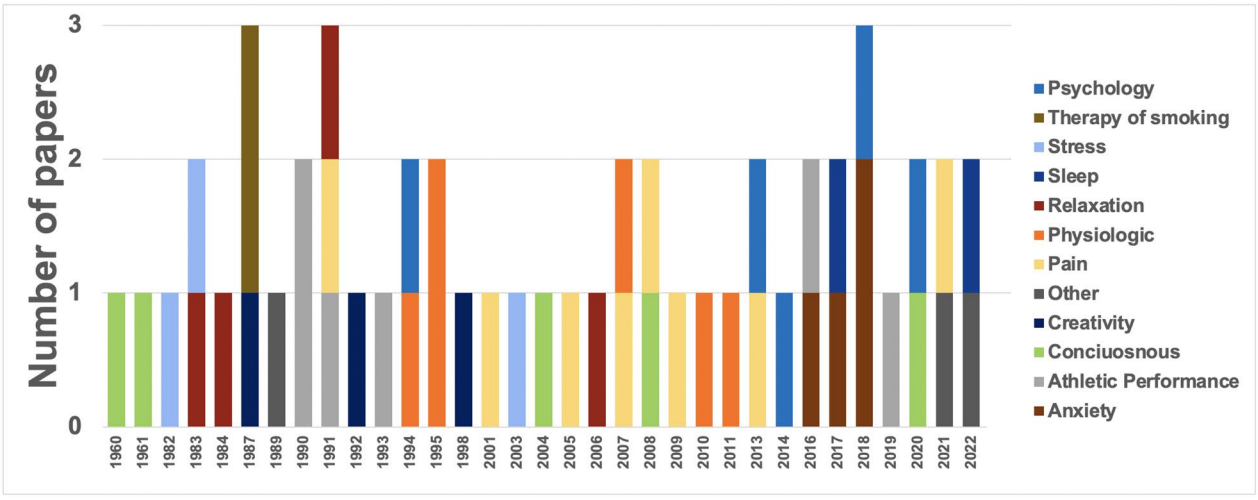

Fig. 3 Chronological Development of Float Pods: Evolving Applications and Research Focus (1960–2022)

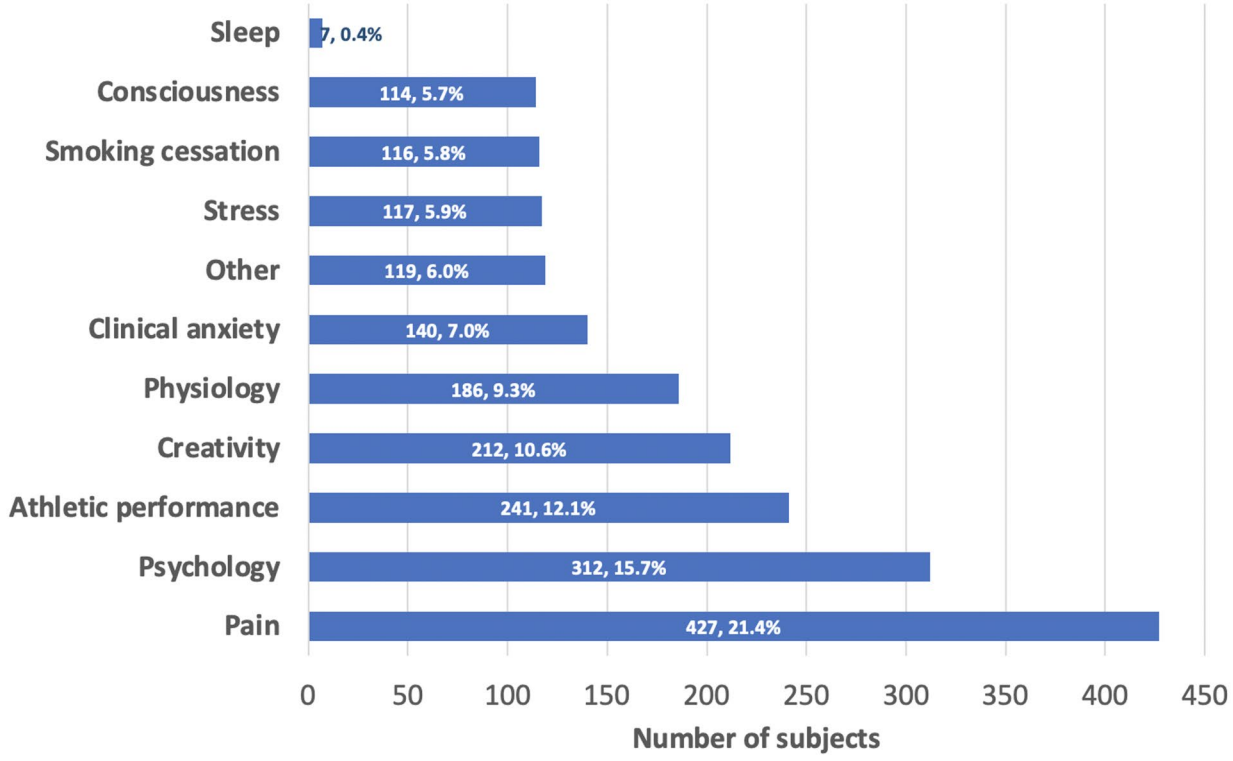

Fig. 4 Total number of participants for different types of flotation-REST studies and the percentage of participants in each type of study from the overall 1,838 participants across all 63 reviewed studies

has continued to diversify, with an increasing number of studies focusing on sleep and pain management, further showcasing the expanding scope of float pod usage across various disciplines.

Sample characteristics

The number of recruited participants in the 63 reviewed studies ranged from 1 to 99, with an average of 31.6 ± 25.8 (mean ± standard deviation) participants per study. These findings suggest that research on flotation-REST is characterized by moderate sample sizes, similar to those common in neuroimaging studies. In total, the studies included 1,991 participants. Figure 4 displays the overall number of participants in each category. The pain category has the largest number of participants. The preponderance of participants in the pain category as well

as that same pain category serving as the plurality among the percentages of studies among the different categories (Fig. 2) suggests a special interest in float pods as tools for pain management. Another category receiving a lot of attention, relatively, are psychology and athletic performance (2nd and 3rd largest number of participants, Fig. 4).

Experimental design

The reviewed studies used a variety of experimental designs (Fig. 5). Three categories of experimental design were identified: (1) randomized designs, which included both within-group designs and randomized controlled trials (42 studies); (2) pre-test/post-test measurement design (11 studies); and (3) semi-structured interviews (7 studies). The remaining 3 studies did not fit into these categories. A range of experimental designs have therefore been used to investigate the effects of flotation-REST. The frequent use of randomized designs, in particular, reflects a rigorous research standard among flotation-REST studies. In contrast, pre/post measurement and semi-structured interview designs offer valuable insights into the effects of flotation-REST in more realistic, everyday contexts.

Treatment delivery

The delivery of flotation-REST as treatment can vary depending on its intended therapeutic application. Here are some examples of how float pods have been used historically (see Sect. 3.6 for more details):

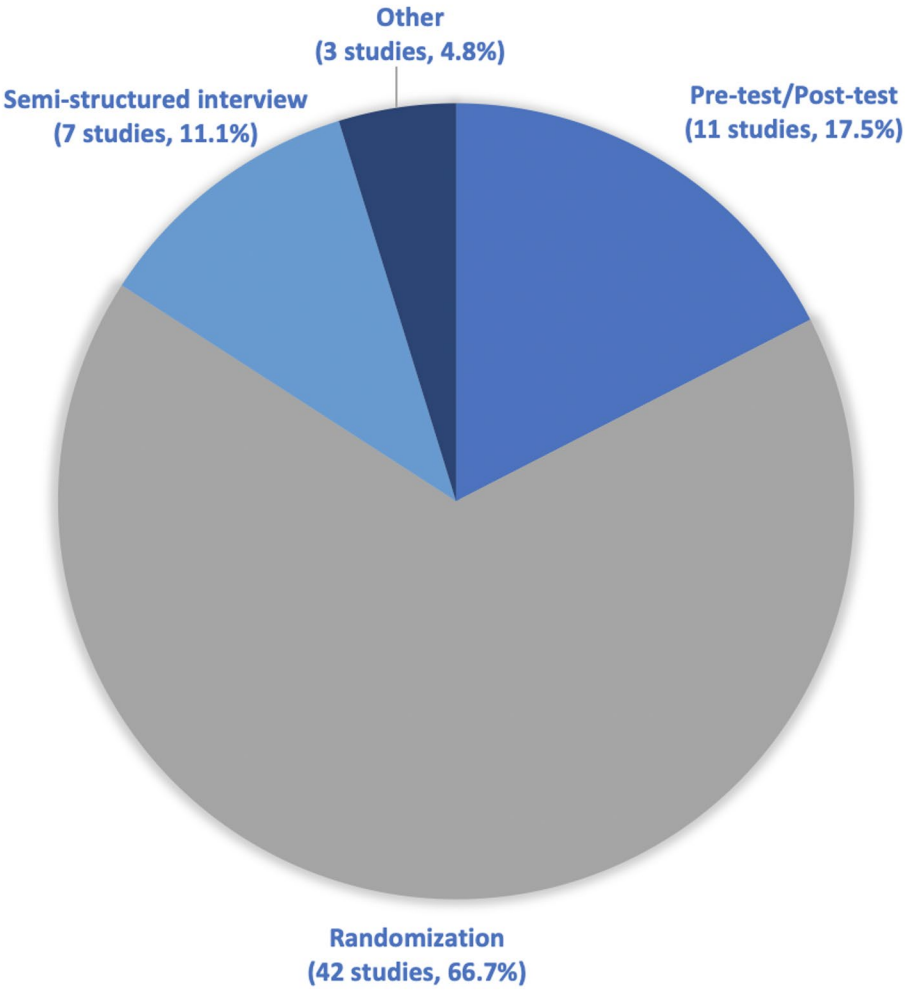

Fig. 5 The percentage of experimental designs across the 63 reviewed studies. Four categories of experimental design were identified: (1) randomization (66.7%, 42 studies); (2) pre-test/post-test measurement design (17.5%, 11 studies); (3) semi-structured interviews (11.1%, 7 studies), and (4) other (4.8%, 3 studies). In a randomization design, participants are randomly assigned to an experimental condition. In a pre-test/post-test design, participants complete assessments both before and after the experimental condition. Finally, in a semi-structured interview, participants respond to questions about their experience with the experimental condition

- Pain management: Flotation-REST may help manage chronic pain by providing a sensory-deprived environment that reduces stimulation and promotes muscle relaxation. Treatment may involve a series of flotation sessions over a period of weeks or months.
- Athletic performance: Athletes recovering from injuries or seeking to enhance performance may benefit from flotation-REST, which may reduce muscle tension and promote relaxation. Treatment may involve a series of flotation sessions before or after a competition or be part of an athlete's regular training program.
- Psychology and mental health: Float pod sessions may be used as a complementary therapy for a range of psychological and mental health conditions, such as anxiety, depression, and PTSD. Treatment may involve a series of flotation sessions over a period of weeks or months, combined with other therapies such as counseling and medication.
- Relaxation and stress reduction: Float pods may also be used in a nonclinical setting, to induce relaxation or to reduce stress in the general population, either through a single flotation session or a series of sessions over a period of time.

In general, flotation-REST typically involves a series of sessions over a period of time, with the number of sessions depending on the targeted therapy (Fig. 6). The duration of each session can also vary and typically ranges from 35 to 90 min (Fig. 7). Other therapies and interventions can be combined with flotation-REST to enhance its effects. For instance, integrating mindfulness practices or meditation sessions before or after flotation can deepen relaxation and self-awareness [23]. Cognitive Behavioral Therapy (CBT) may also be combined with flotation to address anxiety and depression, providing a calming environment for therapeutic discussions (Feinstein et al., 2014). Additionally, incorporating gentle yoga or stretching prior to flotation helps prepare the body and mind for relaxation (van Dierendonck & de Vries, 2019). Breathwork techniques can further induce calmness, while receiving a massage before a flotation session can release muscle tension and enhance the float experience [24]. Engaging in creative expression through art or music therapy can promote emotional release and combining acupuncture with flotation therapy may provide synergistic effects for stress relief [4]. Furthermore, biofeedback techniques can help individuals learn to control physiological responses during flotation, amplifying relaxation. Nutritional counseling can support holistic well-being when discussed in conjunction with flotation

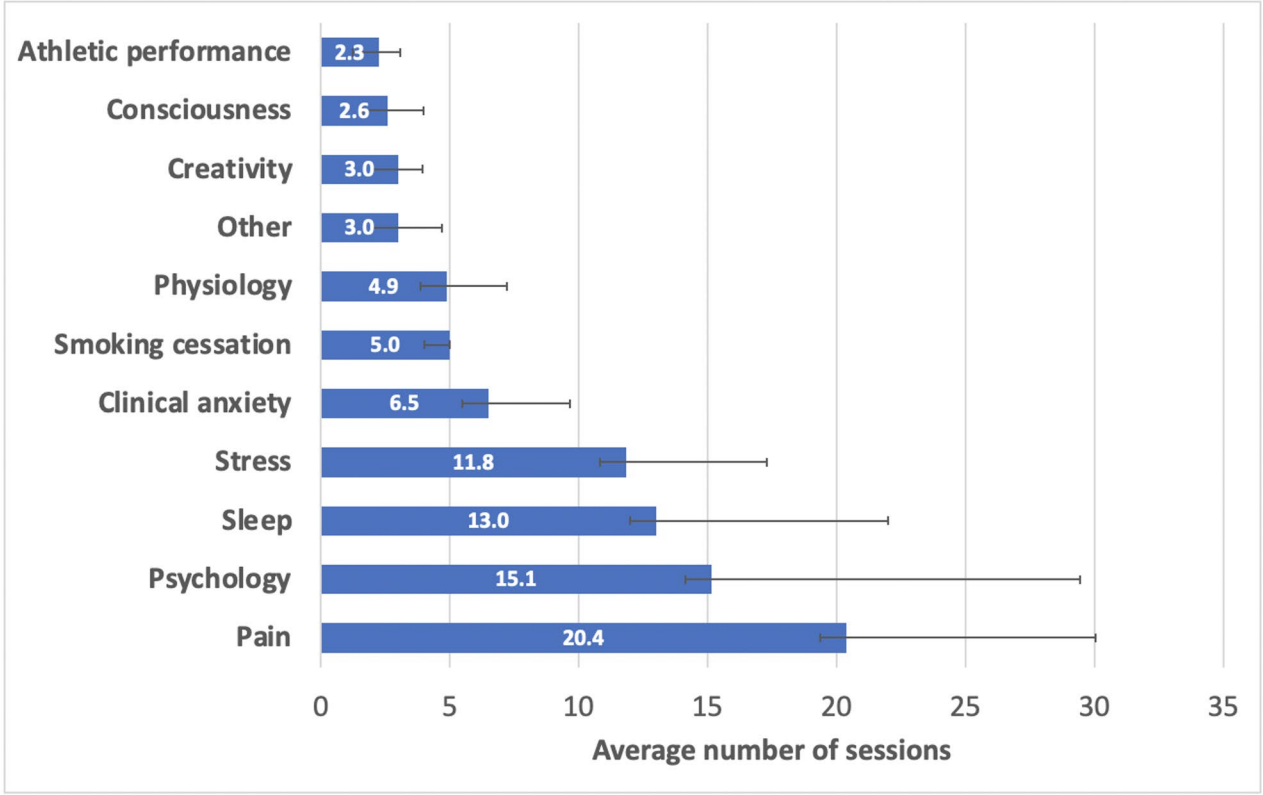

Fig. 6 Average number of sessions for different groups of flotation-REST across the 63 reviewed studies. Error bars represent 95% confidence intervals

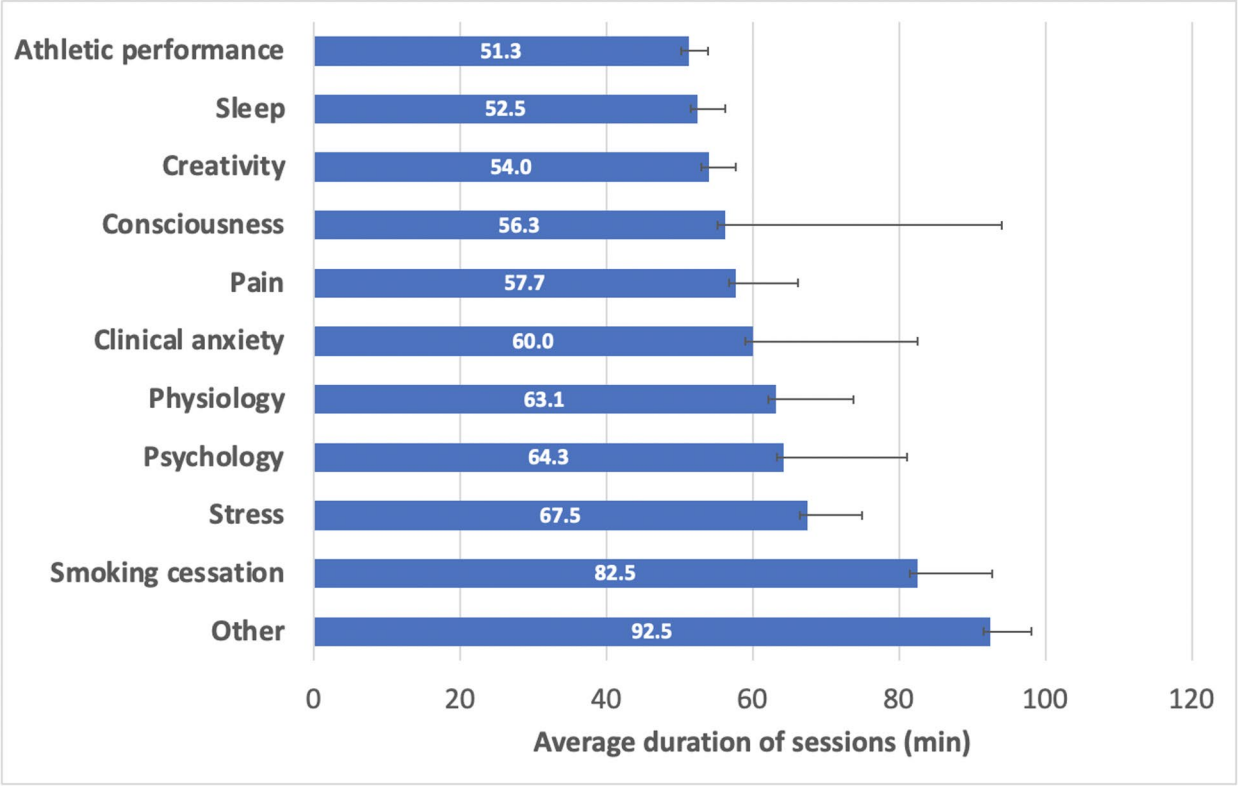

Fig. 7 Average duration of sessions for different groups of flotation-REST across 63 reviewed studies. Error bars represent 95% confidence intervals

therapy. Finally, integrating flotation with regular psychotherapy sessions creates a supportive environment for discussing emotions in a relaxed state [23]. Overall, these combined approaches can amplify the benefits of flotation-REST and address a broader range of physical and mental health issues.

Bayesian ANOVAs were performed to test for differences in the number and duration of sessions between different flotation-REST applications. These ANOVAs revealed anecdotal evidence ($BF_{10} = 0.353$) that the number of sessions between the different flotation-REST applications are the same and substantial evidence ($BF_{10} = 0.159$ that the duration of sessions between the different flotation-REST applications are also the same.

Figure 8 illustrates the treatment delivery metrics (number of sessions and duration per session) across various applications of flotation-REST, as depicted in Fig. 2 of the reviewed studies. Larger segments on the outer ring indicate that multiple studies shared similar treatment delivery parameters (Fig. 8).

Questionnaires

Questionnaires are commonly used in flotation-REST research to assess various outcomes, such as pain, stress, anxiety, mood, and cognitive performance. Questionnaires are a useful tool for assessing subjective experiences and outcomes in flotation-REST, and a range of validated questionnaires have been used to assess different outcomes. In addition to questionnaires, other measures such as heart rate, blood pressure, cortisol levels, and electroencephalography (EEG) have been used in flotation-REST research to assess various physiological and neurobiological outcomes. In the supplementary material, Table S1 shows the list of all tasks and questionnaires used as outcome measures (i.e., not for mere screening purposes) in the 63 studies. As is apparent from the table, the most common questionnaires were the HADS, PANAS/PANAS-X, and POMS, which were used as outcome measures across a total of 7 studies each. Other popular questionnaires included the STAI (used in 6 studies); EDN, LOT, SE, and VAS (5 studies); and PAI (4 studies). Additionally, 13 studies used unique questionnaires (i.e., original questionnaires that were made for the purpose of the study) while 21 studies did not use any questionnaire at all as an outcome measure.

On average, 1.9 ± 1.3 questionnaires were used per study. Studies in the psychology category had the highest average of 3.6 ± 3.6 questionnaires per study, followed by clinical anxiety (3.5 ± 2.6), pain (3.2 ± 2.6), creativity (2.8 ± 2.7), sleep (2.3 ± 2.1), stress (1.7 ± 1.6), physiology

Fig. 8 A sunburst plot of treatment delivery (number of sessions and duration per session) for the different applications of flotation-REST (see Fig. 2) across the reviewed studies. Larger slices on the outer ring represent multiple studies that shared the same treatment delivery parameters

(1.5 ± 2.0), athletic performance (0.8 ± 0.7), consciousness (0.6 ± 0.9), and other (0.5 ± 0.6). No study in the smoking category used any questionnaire (Table S1).

Float pod applications

We categorized the reviewed papers into various groups based on their application of flotation-REST (Figs. 2 and 6). Here is a brief summary of the main findings from each study category:

- Pain (11 studies): Flotation-REST can effectively reduce pain stemming from a variety of conditions, including chronic tension headaches, stress-induced muscle tension, and whiplash associated disorder.
- Athletic performance (8 studies): Flotation-REST may improve certain components (e.g., accuracy, precision) of athletic performance, especially when coupled with guided imagery tasks, as well as enhance performance recovery.
- Physiology (8 studies): Flotation-REST was generally found to have various physiological effects indicative of decreased sympathetic arousal, such as reduced blood pressure, slowed breathing rate, and decreased cortisol levels.
- Stress (6 studies): Flotation-REST was found to reduce levels of stress in both clinical and non-clinical participant samples.
- Consciousness (6 studies): Altered states of consciousness are frequently induced by flotation-REST, with participants reporting experiencing visual and auditory hallucinations, distorted time perception, out-of-body experiences, and personally profound and transformative visions.
- Psychology (7 studies): Flotation-REST was shown to induce positive effects on various psychological outcomes among both healthy and non-healthy participants, including improved mood, reduced anxiety, and decreased depression.
- Creativity (5 studies): In general, flotation-REST was found to enhance certain facets of creativity, including originality, divergent thinking, and aspects of technical musical ability, such as improvisation and composition.
- Clinical anxiety (4 studies): Specifically focusing on participants with a diverse range of anxiety-related

disorders, flotation-REST demonstrated significant anxiolytic effects, underscoring its targeted therapeutic potential in clinical settings.

- Sleep (2 studies): Flotation-REST was found to have limited potential as a treatment for sleep-related disorders (e.g., insomnia). Two studies found evidence of flotation-REST improving sleep latency, but one of these studies found that this improvement only reached significant levels three months after treatment completion, while the other study found that only half of the participants experienced improvement.
- Smoking cessation (2 studies): Compared to other, more established therapeutic interventions for smoking cessation, flotation-REST is not particularly effective in helping individuals reduce their smoking habits.
- Others (4 studies): The remaining studies explored components of flotation-REST protocol (2 studies), sought to investigate hypotheses about flotation-REST (1 study), or examined miscellaneous effects of flotation-REST (1 study).

Overall, the reviewed studies suggest that flotation-REST can have various benefits for physical and mental health, but more research is needed to better understand the mechanisms underlying these effects and to identify optimal treatment protocols for different populations.

Below we review the flotation-REST protocol, methods, and findings for each study, categorized by application. We have 11 categories spanning 63 papers that are discussed from 3.6.1. to 3.6.11. We hope that this review will be valuable for future flotation-REST research by serving as a reference for experimental design, helping elucidate existing gaps in knowledge, and inspiring new research directions. For a comprehensive understanding of the methodologies and findings, a detailed summary of each study is provided in the supplementary materials under "Float pod application".

Pain

We found eleven studies that investigated the effects of flotation-REST on pain stress-related [25–35] (Table S3). Based on these studies, flotation-REST appears to be an effective method for pain relief. All eleven studies found evidence in support of the analgesic effects of flotation-REST; notably, flotation-REST was found to alleviate pain stemming from a variety of disorders, including stress-related muscle tension (5 studies), WAD (2 studies), chronic pain disorder (3 studies), and tension headaches (1 study). Importantly, however, the only study in this category to compare flotation-REST to placebo found comparable results between the two treatments [34]. Out of the nine quantitative studies in this category, all studies (9 out of 9; 100.0%) found significant results in favor of flotation-REST reducing pain. If we assume that the probability of a study finding a significant result is 50% (i.e., a coin toss), a Bayesian binomial test shows that there is very strong evidence (BF_{+0} = 102.300) in support of the hypothesis that the likelihood of a study finding that flotation-REST can significantly improve pain is greater than chance. Given this and the high number of studies in this category relative to the other categories, we can reasonably assume that flotation-REST is capable of relieving pain across multiple disorders, although whether this benefit is partially due to the placebo effect remains unclear. We provide a summary of each of the ten studies in the "Pain" subsection of the Supplementary Materials.

Athletic performance

We found eight studies that investigated the effects of flotation-REST on athletic performance [36–43] (Table S3). Based on these studies, flotation-REST may be a useful therapeutic intervention for athletes. Seven out of eight studies found evidence in support of this conclusion; five of these positive studies found that flotation-REST, often coupled with an imagery task, can improve certain types of athletic performance, and the remaining two studies found that flotation-REST can enhance post-athletic performance recovery. Seven out of eight studies (87.5%) found significant results in favor of flotation-REST's athletic-related benefits. If we assume that the probability of a study finding a significant result is 50% (i.e., a coin toss), a Bayesian binomial test shows that there is moderate evidence (BF_{+0} = 6.972) in support of the hypothesis that the likelihood of a study finding that flotation-REST can produce athletic-related benefits is greater than chance. Given this and the high number of studies in this category relative to the other categories, we can reasonably assume that flotation-REST may help athletes improve and recover from their athletic performance. We provide a summary of each of the eight studies in the "Athletic performance" subsection of the Supplementary Materials.

Physiological effects

We found eight studies that investigated the physiological effects of flotation-REST. Based on these studies, flotation-REST may induce physiological change [18, 44–50] (Table S3). All eight studies found evidence in support of this conclusion, with two studies finding such evidence in regard to blood pressure (with one of these studies also finding evidence in regard to breathing rate and heart rate variability), two studies regarding cortisol, and one study each regarding right hemispheric processing, urinary VMA, EEG activity, and resting state functional connectivity. However, two studies found evidence

suggesting that flotation-REST had no effect on luteinizing hormone; one of these studies also found no evidence of flotation-REST affecting cortisol, contradictory to the other two aforementioned studies, along with a similar lack of evidence for a host of other neuroendocrine measures [48]. Despite this, all studies (8 out of 8; 100.0%) found at least one significant result in favor of flotation-REST's physiological effects. If we assume that the probability of a study finding a significant result is 50% (i.e., a coin toss), a Bayesian binomial test shows that there is very strong evidence (BF_{+0} = 56.778) in support of the hypothesis that the likelihood of a study finding that flotation-REST can produce physiological change is greater than chance. Given this and the high number of studies in this category relative to the other categories, we can reasonably assume that flotation-REST is capable of altering physiological functioning. We provide a summary of each of the eight studies in the "Physiological effects" subsection of the Supplementary Materials.

Stress

We found six studies that investigated the effects of flotation-REST on stress [2, 14, 19, 51–53] (Table S3). Based on these studies, flotation-REST appears to be effective at reducing levels of stress. All six studies found evidence in support of this conclusion, with two studies finding such evidence in regard to clinical samples while the other four studies were in regard to non-clinical samples. Out of the four quantitative studies in this category, all studies (4 out of 4; 100.0%) found significant results in favor of flotation-REST reducing pain. If we assume that the probability of a study finding a significant result is 50% (i.e., a coin toss), a Bayesian binomial test shows that there is moderate evidence (BF + 0 = 6.200) in support of the hypothesis that the likelihood of a study finding that flotation-REST can significantly reduce stress is greater than chance. Given this, flotation-REST may be an effective method for stress reduction, as evidenced by pre- and post-session electromyogram testing [4, 54–58]. We provide a summary of each of the six studies in the "Stress" subsection of the Supplementary Materials.

Consciousness

We found six studies that investigated the effects of flotation-REST on consciousness [16, 59–63] (Table S3). Based on these studies, flotation-REST commonly appears to induce altered states of consciousness. All six studies found evidence in support of this conclusion, with participants across these studies reporting experiences of deep relaxation, visual and auditory hallucinations, and altered perceptions of time. Only two of these studies used quantitative methods for their main analyses; thus, there are not enough studies in this category alone to run statistical analyses. However, given the uniform agreement in the results of all six studies for the consciousness-altering effects of flotation-REST, we can reasonably assume that flotation-REST is capable of inducing these changes. We provide a summary of each of the six studies in the "Consciousness" subsection of the Supplementary Materials.

Psychology

We found seven studies that investigated the effects of flotation-REST on psychology. Based on these studies, flotation-REST may induce positive psychological change [17, 64–69] (Table S3). All seven studies found evidence in support of this conclusion, with all of the studies finding evidence of reduced anxiety, four of decreased depression, and two of decreased arousal. Among the six quantitative studies in this category, which primarily focused on psychological outcomes, all (100%) reported significant findings indicating that flotation-REST also effectively reduces pain. If we assume that the probability of a study finding a significant result is 50% (i.e., a coin toss), a Bayesian binomial test shows that there is moderate evidence (BF_{+0} = 18.143) in support of the hypothesis that the likelihood of a study finding that flotation-REST can significantly alter one's psychological state is greater than chance. Overall, flotation-REST appears to lead to improvements in psychological well-being. We provide a summary of each of the seven studies in the "Psychology" subsection of the Supplementary Materials.

Creativity

We found five studies that investigated the effects of flotation-REST on creativity [9, 70–73] (Table S3). Based on these studies, flotation-REST appears to generally enhance creativity. One study found evidence that flotation-REST improves scientific creativity; one study found evidence that flotation-REST increases divergent thinking; one study found evidence that flotation-REST improves technical musical ability; and two studies found evidence that flotation-REST increases originality, although one of these studies also found that flotation-REST may impair creative problem-solving. Overall, however, all five studies (5 out of 5; 100.0%) found at least some significant result in favor of the creativity-enhancing effects of flotation-REST. If we assume that the probability of a study finding a significant result is 50% (i.e., a coin toss), a Bayesian binomial test shows that there is strong evidence (BF_{+0} = 10.500) in support of the hypothesis that the likelihood of a study finding that flotation-REST can significantly improve creativity is greater than chance. In conclusion, flotation-REST may enhance certain types of creative behavior, particularly those that rely on original thinking, while impairing other types of creative behavior, such as those that rely on problem-solving. We provide a summary of each of the

five studies in the "Creativity" subsection of the Supplementary Materials.

Clinical anxiety

We found four studies that investigated the effects of flotation-REST on clinical anxiety [10, 11, 74, 75] (Table S3). Based on these studies, flotation-REST appears to be an effective therapeutic intervention for a range of clinical anxiety disorders. All four studies found evidence in support of this conclusion, with two studies finding such evidence specifically in regard to GAD and the other two regarding a variety of anxiety-related disorders. Only three studies in this category used quantitative methods for their main analyses; thus, there are not enough studies in this category alone to run statistical analyses. Overall, flotation-REST may be a promising treatment for clinical anxiety. We provide a summary of each of the four studies in the "Clinical anxiety" subsection of the Supplementary Materials.

Sleep

We found two studies that investigated the effects of flotation-REST on sleep [76, 77] (Table S3). Based on these studies, flotation-REST may have limited benefits for individuals with sleep-related disorders. Flotation-REST appears to induce an acute state of restfulness similar to that experienced during stage I sleep. However, flotation-REST was found to improve sleep quality in only half of the participants in one of the studies. Unfortunately, there are not enough studies in this category alone to run statistical analyses. In conclusion, flotation-REST may not be particularly effective for sleep-related disorders, although it may still benefit non-clinical populations [21]. We provide a summary of each of the two studies in the "Sleep" subsection of the Supplementary Materials.

Smoking cessation

We found two studies that investigated the effects of flotation-REST on smoking cessation [78, 79] (Table S3). Based on these studies, flotation-REST may not be particularly effective as a therapeutic intervention for smoking cessation. Both studies in this category found evidence of other interventions, such as chamber-REST, being more effective at helping individuals reduce their levels of smoking than flotation-REST. Unfortunately, there are not enough studies in this category alone to run statistical analyses. In conclusion, flotation-REST may not facilitate decreased smoking behavior any better than other established interventions. We provide a summary of each of the two studies in the "Smoking cessation" subsection of the Supplementary Materials.

Other

In 1960, Jay Shirley sought to refine the procedural methods used in flotation-REST [80]. Specifically, Shirley wanted to standardize what he considered the three fundamental aspects of flotation-REST: the physical aspect, physiological aspect, and psycho-social aspect. For the physical aspect, Shirley noted that it was important to create an environment that obtained the maximum achievable reduction of ambient physical stimuli along with a dynamic maintenance of ambient temperature. To achieve these conditions, Shirley built a two-room laboratory, in which the float tank was housed, that substantially reduced incoming light, sound, vibration, and odor. Next, for the physiological aspect, Shirley sought to eliminate all sources of pain and discomfort stemming from body position, reduced blood flow, or abdominal distention. Thus, a float tank was designed that allowed participants to float upright while comfortably wearing both a stimulus-restricting oxygen mask and body weights that maintained neutral buoyancy and full immersion. Lastly, for the psycho-social aspect, Shirley speculated that certain types of persons were optimal participants for float-REST studies. Such participants were skilled in self-observation, memory, and attention to detail and were able to communicate their experience fully and freely with minimal distortion. Based on these criteria, Shirley recruited twelve participants, and each participant was free to choose the length of their flotation session, with the longest session lasting for four hours. In the form of anecdotal notes, participants reported experiencing emotions that shifted randomly from calm, contemplation, anxiety, elation, and depression. Some participants also experienced visual and auditory hallucinations along with hyperawareness of their bodily functions, such as being able to hear the sounds of their heartbeat. Overall, this study helped define the optimal conditions for flotation-REST and laid the groundwork for the float tank to be used as a tool for probing a wide range of psychophysiological phenomena.

In 1989, Turner et al. investigated whether light exposure might modulate the effects of flotation-REST [81]. 21 participants were recruited and randomly assigned into one of two groups: flotation-REST in the presence of light (REST-L) or flotation-REST in the absence of light (REST-D). All participants completed eight 40-minute flotation-REST sessions across four weeks. Eight blood samples were taken before the start of the flotation-REST program, and eight samples were taken during the last two weeks of the flotation-REST program, for a total of 16 blood samples per participant. Blood pressure measurements were also taken before and after each blood draw. At both baseline and after the completion of the program, participants completed the POMS scale. The results indicated that there were no significant

differences between the REST-L and REST-D groups, such that groups experienced comparable improvements in mood, decreases in plasma cortisol, and decreases in mean arterial pressure. Thus, the authors conclude that exposure to light during flotation-REST does not compromise the benefits of flotation-REST.

Suedfeld et al. (1994) conducted four studies to test a hypothesis aiming to explain the wide-ranging effects of flotation-REST [82]. The Dynamic Hemispheric Asymmetry (DHA) model proposes that flotation-REST increases activity in the side of the cortical hemisphere that tends to be less dominant (typically thought to be the left hemisphere in most people), and this increased activation is responsible for the perceptual and mood changes accompanied by flotation-REST. Under the model, the authors posit that flotation-REST should lead to the following four changes: (1) increased perceptual recognition of objects based on visually incomplete representations, (2) improved story-telling abilities (i.e., more creative, complex stories), (3) decreased asymmetry of finger-tapping speed between the dominant and non-dominant hands, and (4) increased EEG activity in the non-dominant brain hemisphere. Four studies were conducted to test each of the hypotheses; 25, 19, 25, and 10 participants were recruited for each study, respectively. For participants assigned to the flotation-REST group in each study, a single flotation-REST session that was either one hour long (studies 1, 2, and 4) or two hours long (study 3) was completed. Based on the results of each study, evidence was found in support of hypothesis 3, whereas contradictory evidence was found for hypotheses 1 and 4, and evidence for hypothesis 2 was inconclusive. Based on the mixed results, the authors conclude that the DHA model fails to adequately explain the effects of flotation-REST.

Sakata et al. (1995) tested the hypothesis that flotation-REST would enhance an individual's ability to generate random sequences [83]. 7 participants were recruited, and all participants completed two types of treatment sessions in a counterbalanced order: (1) flotation-REST), and (2) bed-REST, in which participants rested in a supine position on a bed within a dark, quiet room. Participants completed in a total of two float-REST sessions and one bed-REST session with each session lasting 40 min. Additionally, there was a one-week interval between each float-REST session and a month-long interval between the two treatment types. Prior to each treatment session, electrodes were attached to the participant in order to measure EEG, EOG, heart rate, and respiration. Before each session, participants completed a task in which they were asked to orally generate a list of numbers while attempting to be as random as possible. Participants completed this same task immediately after the end of the treatment session as well as 40 min after the REST session. Results indicated that randomization indices scores were lower (indicated greater randomness) immediately after flotation-REST and that these low scores persisted even at the 40-minute post-session mark. Conversely, randomization indices scores increased after the bed-REST and persisted into the post-REST mark. Thus, the authors conclude that random number generation was significantly enhanced by flotation-REST in comparison to bed-REST, and they hypothesize that the deep relaxation and hypnagogic state induced by flotation-REST is what facilitates enhanced randomness.

Bias assessment

In our paper, we systematically assessed several categories of bias for each study under review. Firstly, we evaluated the presence of selection bias, which pertains to potential systematic differences between participants selected for the study and those not included. This assessment will involve scrutinizing the methods used for participant recruitment and selection, as well as the adequacy of randomization procedures, to ensure the sample's representativeness. Secondly, we will consider performance bias, which addresses variations in the administration of interventions or treatments between groups. This analysis will involve examining the standardization and consistency of procedures across different study arms. Thirdly, we will assess detection bias, focusing on the consistency and blinding of outcome assessments to prevent biased measurement or interpretation of results. Additionally, we will explore attrition bias, which involves examining the differential dropout rates between study groups and the potential impact on outcome data completeness and validity. Finally, we will examine reporting bias, which concerns the selective reporting of outcomes and results. Our thorough evaluation of these bias categories will ensure a comprehensive understanding of the methodological rigor and validity of the studies under review in our paper. We provide a summary of the bias assessment for each study based on selection, performance, detection, attrition, and reporting in Table S2 of the Supplementary Materials.

Float pod design

Since its original conception in 1954, the float pod has undergone several revisions to its design (Fig. 9). The first float pod, created by physician John C. Lilly, required users to be vertically submerged underwater, necessitating the use of cumbersome breathing masks constantly monitored by a safety operator [84]. Although this first prototype already incorporated certain key features that are still used today– namely, a dark, soundproof enclosure filled with body-temperature water– the generally crude design made float pods largely inaccessible. To address this shortcoming, Lilly collaborated with

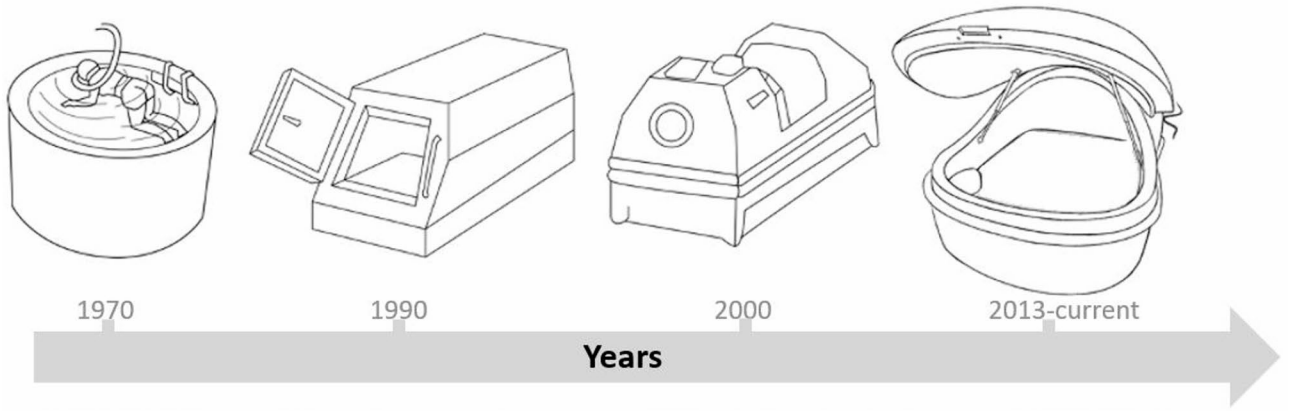

Fig. 9 Float pod design over time

engineer Glenn Perry to create a new design, one in which users could lie horizontally in a buoyant solution highly saturated with Epsom salt [85]. These updated float pods were released in the 1970s and primarily aimed to increase the device's convenience. Newer models were built to a much shallower depth and incorporated filtration systems, upgrades that made water maintenance much more efficient. Additionally, these float pods were smaller, lighter, and less costly to build, constructed of materials like fiberglass and acrylic rather than metals. Ultimately, these changes enabled the float pod to be widely disseminated, including for commercial (i.e., non-academic) use. From the 1990s and onwards, the traditional tank structure has been replaced by a smaller, sleeker enclosed pod. The modern float pod further maximizes user-friendliness by including additional features like temperature control, built-in audio speakers, and updated sanitation systems.

Some of the key changes to float pod architecture that have occurred since its conception include:

- Shape: Early float tanks were typically rectangular, while modern float pods are more likely to be rounded or oval in shape. The curved design helps to reduce the amount of external sensory input and create a more cocoon-like environment for users.
- Size: Early float tanks were historically quite large, taking up a significant amount of space in a dedicated flotation room. Modern float pods are typically more compact, allowing them to be installed in a wider range of settings. However, the corrosive nature of the salt used in float pods still necessitates special flooring and easy access to a shower.
- Lighting: Early float tanks typically had no lighting inside the tank, leaving users in complete darkness. Modern float pods may have optional, subtle internal lighting that helps contribute to a calming, relaxing environment without substantially adding to sensory input.
- Acoustics: Early float tanks were often noisy, with audible pumps and filtration systems. Modern float pods are designed to be as quiet as possible, with advanced soundproofing and quiet pumps that create a more peaceful sensory environment, deprived of sound.
- Materials: Early float tanks were typically made of metal, while modern float pods are more likely to be constructed from fiberglass, acrylic, or other high-tech materials. This allows for more precise control over the environment inside the tank and can help to create a more hygienic and low-maintenance experience for users.

Discussion

Flotation-REST has demonstrated a wide range of potential applications, as evidenced by the studies reviewed. A total of 63 studies were considered, spanning various domains such as pain management, athletic performance, physiology, stress, consciousness, psychology, creativity, clinical anxiety, sleep, and smoking cessation. Pain management was the most commonly studied area, with 11 studies (17.5%) examining flotation-REST as a treatment for chronic pain. The evidence from these studies suggests flotation-REST may be a beneficial intervention for pain of diverse origins, though more research is needed to confirm these findings. Similarly, eight studies (12.7%) focused on the impact of flotation-REST on athletic performance, with promising results indicating potential benefits for post-exercise recovery and certain types of athletic performance.

While the evidence for other applications, such as creativity, sleep, and smoking cessation, was mixed, it still offers valuable insights. In creativity (7.9%) and sleep (3.2%), the findings suggest potential benefits, though the evidence is not as robust, and further studies with larger

sample sizes and consistent methodologies are required. Smoking cessation (3.2%) also showed mixed effects, highlighting the need for more targeted research in this area.

The studies reviewed varied in methodological design, with a range of treatment delivery methods, including randomization, pre/post measurements, and semi-structured interviews. The majority of studies utilized subjective self-report measures, such as visual analog scales and questionnaires, to assess both psychological and physiological outcomes. However, there were several limitations across these studies, such as small sample sizes and the absence of control groups in some cases. Additionally, variations in the type of flotation pod used (e.g., traditional tanks vs. newer models) may also affect the generalizability of the findings. Despite these limitations, the current evidence supports the use of flotation-REST as a complementary treatment in various health domains, suggesting benefits for both physical and mental well-being.

However, there are also important considerations and limitations. For some individuals, flotation-REST may not be appropriate due to medical conditions such as open wounds, claustrophobia, or severe skin conditions. It is crucial that individuals consult with a medical professional before starting flotation-REST to ensure it is safe for them. Furthermore, flotation-REST should be seen as part of a broader wellness regimen rather than a standalone solution for health issues. While it can provide relaxation and rejuvenation, it is not a replacement for medical or psychological treatment. The cost and accessibility of flotation-REST may also limit its widespread adoption, as it can be expensive, and some individuals may need time to acclimate to the sensory deprivation experience.

When compared with other wellness practices, flotation-REST offers distinct advantages and drawbacks. Meditation, for example, is a versatile and cost-effective practice that can be performed anywhere, promoting mental health, focus, and emotional well-being. While meditation requires patience and a learning curve, it is accessible to everyone and does not require specialized equipment. Yoga, combining physical exercise and mental relaxation, offers benefits for both strength and mindfulness but may require a significant time commitment and carries a risk of injury. Massage therapy, on the other hand, provides immediate relief from muscle tension and stress but may require regular sessions for sustained benefits and can be costly and less accessible.

Ultimately, the choice between these techniques depends on individual preferences, needs, and lifestyle. While flotation-REST provides profound relaxation and potential health benefits, other practices such as yoga, meditation, and massage therapy may offer more accessible, cost-effective, and holistic approaches to wellness."

Limitations of this review

Some limitations of the current review should be noted. First, only a handful of studies have been published in certain categories of float pod application, so our review should not be used to conclude that flotation-REST is effective for certain understudied applications such as sleep or smoking cessation. The relatively small number of studies available for review limits the generalizability of certain findings and highlights the need for additional research in this area.

Further, the potential for publication bias in the existing literature cannot be ruled out. Researchers often submit predominantly positive results for publication due to a highly competitive publishing landscape. Thus, it is possible that studies reporting negative results were not published and thereby were not included in this review. To mitigate publication bias and increase the generalizability of results, future research should aim to implement study designs with adequate sample sizes, appropriate control groups, and long-term follow-up. Additionally, the development of standardized outcome measures would help to increase comparability across studies and enable more robust meta-analyses.

Despite these limitations, we hope that this review can inform future research on flotation-REST. In particular, this review may serve as a helpful tool for identifying current knowledge gaps in the flotation-REST literature, informing study design, and devising new applications for flotation-REST.

Future directions

Our survey of the literature suggests that there is still much to be explored in the field of flotation-REST. In particular, some potential areas for future research include:

- Long-term effects: Many of the studies reviewed in this analysis had relatively short treatment periods, ranging from a single session to several weeks. Thus, the long-term effects of flotation-REST on different conditions remains understudied.
- Mechanisms of action: While flotation-REST has been shown to have various positive effects, the mechanisms behind these effects are not yet fully understood [18, 42, 50]. Future research could explore the physiological and psychological mechanisms underlying flotation-REST, which could help to optimize treatment approaches and potentially identify new therapeutic targets.
- Optimization of treatment parameters: Further research could explore how the duration, frequency, and other parameters of flotation-REST affect

treatment outcomes. The variability of the methods used to collect, and report results across studies precludes us from the ability to conduct analyses in order to determine the effects of these parameters.

- Diverse populations: The majority of the studies reviewed in this analysis included predominantly female and/or healthy participants, which limits the generalizability of the findings. Future research could explore the effectiveness of flotation-REST in diverse populations, including individuals with different medical conditions, ages, and genders.

To gain a better understanding of the effects of the various applications of floatation-REST, we would need a meta-analysis on top of a systematic review of the literature. At this stage, given the limitations in the number and consistency of studies across categories, conducting a meta-analysis was not feasible. To enable future meta-analyses, we urge authors of flotation-REST studies to carefully and consistently report pre- and post-measurement data and use standardized protocols. Needless to say, larger sample sizes in each study and more studies in the various application areas of floatation-REST would certainly make future meta-analyses more feasible. Such meta-analyses would help explore the factors contributing to the diverse outcomes of flotation-REST, which is critical in understanding the underlying mechanisms and optimizing treatment approaches.

In conclusion, flotation-REST has shown promising potential as a therapeutic intervention for various conditions, and further research, particularly meta-analyses, could help optimize its use and identify new applications. Addressing the limitations of past research—such as implementing placebo conditions, including objective measures, and studying more diverse samples—will provide more robust and reliable evidence. We hope this review serves as a solid foundation for future research and encourages high-quality, reproducible results in the field.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12906-025-04973-0.

Supplementary Material 1

Acknowledgements
We thank Amir Raz for his guidance and support during the initial stages of this project.

Author contributions
Conceptualization, visualization and writing: ELwriting: EC, JG, ELSupervision, Review & Editing: UM.

Funding
The publication received support from a joint grant from the John Templeton Foundation and the Fetzer Institute. The views expressed herein are solely those of the author(s) and do not necessarily represent the opinions of NINDS, the John Templeton Foundation, or the Fetzer Institute.

Data availability
Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
NA.

Consent for publication
We confirm that there are no conflicts of interest to disclose related to this work. We also attest that this manuscript has not been published elsewhere and is not under consideration by any other journal or conference.

Competing interests
The authors declare no competing interests.

Registration and protocol
This study was not registered, and a review protocol was not prepared.

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Received: 16 June 2024 / Accepted: 11 June 2025
Published online: 03 July 2025

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