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Memory of affective responses to physical activity (study 1) and a pilot intervention to reduce negative memory bias (study 2) in adults with overweight or obesity

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ABSTRACT

Background: Automatic, affective processing of exercise can influence exercise behavior. Study 1 compared regular exercisers (≥150 min/wk) and non-exercisers (<30 min/wk) on affective responses, memory of these responses, and anticipated response to future exercise. Study 2 pilot-tested a brief intervention for non-exercisers to improve exercise-related affect and memory bias (i.e., discrepancy between remembered and experienced affect).

Methods: 59 weight-loss seeking individuals with overweight/obesity (Age = 47.1 ± 10.3 years; BMI = 32.1 ± 3.3 kg/m^2; 79.7 % Female; 91.5 % White) completed two sessions of moderate-intensity walking for 30 min. Participants reported anticipated affect prior to exercise and affective response before, during, and after exercise. On days 1, 3, and 7 following the exercise session, remembered affect was assessed to determine possible memory bias. In Study 2, the non-exercisers were randomly assigned to an affect-based intervention (n = 15) or comparator condition (n = 15) and completed a third exercise session.

Results: In Study 1, negative memory bias was present in both exercisers and non-exercisers, but was greater among non-exercisers (p = 0.04). For both groups, remembered affect more closely resembled post-exercise affect (versus 'during'; p = 0.001). Exercisers anticipated feeling better during exercise compared to non-exercisers (p = 0.002), with a similar trend for anticipated 'post-exercise' affect (p = 0.073). In Study 2, non-exercisers receiving the affect-based intervention demonstrated significantly less memory bias (p = 0.04) and more positive affect post-exercise (p = 0.05). **Conclusions**: Both exercisers and non-exercisers experienced negative memory bias toward prior exercise, which was greater in non-exercisers. A pilot intervention to reduce negative memory bias and improve exercise-related affect among non-exercisers showed promise, warranting further study of these novel intervention targets.

Approximately two-thirds of the US population has overweight or obesity, with greater risk for chronic health conditions such as diabetes and cardiovascular disease (National Institute of Diabetes and Digestive and Kidney Disease, 2021). This major public health problem could, in part, be ameliorated by increased physical activity (PA). Despite the clear health benefits of PA for chronic disease control and prevention, many individuals, particularly those with overweight/obesity, paradoxically choose to avoid PA (Spees et al., 2012). Individuals with overweight/obesity have, overall, been shown to have more negative affective responses to PA compared to those in the healthy weight range thus it is possible that negative affect contributes to reduced PA behavior (Ekkekakis et al., 2010; Ekkekakis & Lind, 2006). Naturally, some individuals with overweight or obesity do engage in PA regularly, while others do not, however it is not yet clear if affect may play a role in this individual difference. Further understanding affective response to exercise would be helpful for designing future interventions aimed at

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increasing PA in this population.

The Affect and Health Behavior Framework (AHBF) is based on hedonic motivation theory which suggests individuals often engage in behaviors that maximize pleasure and minimize displeasure (e.g., continue watching TV [pleasurable] instead of engaging in PA [unpleasurable]; LaRowe et al., 2024; Rhodes & Kates, 2015; Stevens et al., 2020; Williams et al., 2019). The AHBF asserts that health behaviors are largely governed by one's affective response (i.e., how one feels while performing and/or immediately after completing a target behavior) to an experience, which impacts subsequent affective processing, motivation, and ultimately, their behavior (Williams & Evans, 2014). Consistent with dual-process models of PA including Affective Reflective Theory, which proposes that decisions to initiate activity are shaped by the interplay of automatic affective valuations and reflective evaluations (Brand & Ekkekakis, 2018), and the Dual Mode Theory, which suggests that affective responses to PA are influenced by both interoceptive physiological cues and cognitive appraisals (Ekkekakis, 2009), this framework posits that PA elicits two related but distinct affective processes; 1) an initial affective response which occurs while engaging in PA, and 2) a post-behavior affective response occurring at the cessation of exercise. These affective responses are often of opposing valence, with the initial affective response typically holding negative valence (i.e., feeling bad *during* exercise) while the valence of the post-behavior affective response is often positive (i.e., feeling good immediately *after* exercise; Stevens et al., 2020). The AHBF suggests these discrete affective responses lead to different forms of affect processing, with the initial affective response triggering reflexive and unconscious automatic affect processing and, conversely, the post-behavior affective response eliciting more contemplative and deliberate reflective affect processing. While much of the extant literature has focused on manipulating initial affective response and the resultant automatic affect processing, less attention has been paid to the role of reflective affect processing and its role in determining future exercise behavior (Dunton et al., 2023; Rhodes & Kates, 2015; Williams, 2008).

One possible explanation as to why some individuals exercise more than others may relate to such reflective affective processing via remembered affect (i.e., how one remembers feeling) and anticipated affective response (i.e., the expectation of how one will feel in response to engaging in (or avoiding) a target behavior, in this case PA (Stevens et al., 2020). Drawing from the Feedback Theory of Emotions, which suggests that emotions serve as a source of feedback that informs future decisions about whether to re-engage in a behavior based on anticipated emotional outcomes (Baumeister et al., 2007; Feil et al., 2023), within the AHBF, one's previous affective experience with an activity (be it driven by initial affective responses, post-activity responses, or a combination) influences how they *anticipate* they will feel in response to that activity in the future (Williams & Evans, 2014). This anticipated affective response can be either positive or negative, with positive anticipated affect giving rise to motivation to repeat a behavior, and negative anticipated affect leading to desire to avoid a behavior. Although individuals often believe they can accurately predict their anticipated affective response to a future event, in general people tend to overestimate the intensity of their future affective response. In the context of exercise, this effect is particularly pronounced among those who are insufficiently active, as inactive individuals have been found to underestimate the pleasantness of a future exercise session. This misjudgment can bias their subsequent in situ affective responses to PA, potentially creating a negative feedback loop. As a result, individuals who do not exercise regularly may develop negative anticipated affect towards future PA, which can serve as an additional barrier to PA adoption and maintenance (Feil et al., 2023).

Furthermore, individual differences in memory of affective responses during previous exercise (i.e., remembered affect) may contribute to more negative or more positive anticipated affective response and ultimately lead to engagement or avoidance of exercise. Research suggests that reports of remembered affect often deviate from experienced affect, as the affective valence of memories of a previous exercise experience fluctuate over time and are prone to biases (Bastos et al., 2025; Slawinska & Davis, 2020; Slawinska et al., 2025; Stevens et al., 2020). For some individuals the most negative aspects of exercise (often occurring *during* exercise) may be the most salient and influence their memory of the experience most heavily, whereas others may be more inclined to remember the most positive aspects of exercise (often occurring at PA's end or 10–15 min *post*-exercise; Fredrickson, 2000). Such differences in the hedonic valence of remembered affect are likely determined in part by individual characteristics, including current levels of exercise engagement among other traits, and could influence the choice to engage in PA in the future. Support for this hypothesis is guided by basic research on biases and heuristics stemming from behavioral economics (Fredrickson & Kahneman, 1993; Tversky & Kahneman, 1974). For instance, prior studies show how affect first becomes more negative during PA, then becomes more positive after PA (i.e., during the cool down and up to 20-min after the session concludes; Backhouse et al., 2007; Ekkekakis et al., 2008); therefore negativity bias, (i.e., the tendency to focus on the most negative aspect of an experience; Kanouse, 1972; Rozin & Royzman, 2001) could lead non-exercisers to shape their memory of PA based upon affect experienced during PA, rather than after PA. The idea that memory biases may shape further PA intentions and behavior is supported by research from cognitive science. Studies indicate that individuals' willingness to reengage with aversive or unpleasant experiences is influenced more by their memory of their affective response to the event than by the experience itself (Levine et al., 2012; Urban et al., 2019). Investigating how these affective constructs relate to one another and interact to inform PA behavior among regular exercisers vs. non-exercisers may help understand processes supporting exercise engagement vs. avoidance, and may provide the first step in translating such theories into applications for increasing PA.

This study contributes to the limited body of evidence connecting reflective affective processing constructs, specifically anticipated and remembered affect, to PA behavior across two studies (Bastos et al., 2025; Feil et al., 2023). Study 1 compares regular exercisers and non-exercisers on affective response to moderate-intensity exercise, the memory of that affective response (remembered affect), and anticipated affective response towards an upcoming exercise session. Due to the critical importance of PA in weight control, all exercisers and non-exercisers were within the overweight-obese BMI range and were seeking weight loss. It was hypothesized that non-exercisers would have a negative memory bias (i.e., remembered affect would be more negative than actual affect). It was further hypothesized that exercisers and non-exercisers would differ in their anticipated affective response for moderate-intensity exercise (particularly during exercise), with non-exercisers reporting more negative anticipated affective response compared to exercisers.

Study 2 piloted a brief intervention for non-exercisers aimed at improving exercise-related affect and memory bias to make remembered affect more positive. It was hypothesized that, relative to those randomized to a brief, educational control intervention, non-exercisers receiving the affect intervention may be trained to have either more positive affective responses to exercise, more positive anticipated affective response towards exercise, more positive remembered exercise affect, and/or less negative memory bias, which may lead to increased PA.

1. Methods

1.1. Participants

A total of 59 individuals with overweight/obesity (BMI 25–40 kg/m^2), who were weight loss seeking, and between the ages of 18–60 were recruited via self-referral from advertisements, predominantly via social media (e.g., Facebook) as well as physical flyers posted in the community. Interested individuals completed a phone screen questionnaire to determine initial eligibility. During this screening, trained research assistants queried potential participants on their moderate-to-vigorous intensity PA (MVPA) over the previous 6 months and a recent ‘typical’ week. Specifically, they asked individuals to report any activity (walking or sport/recreational activities) that were done for the purpose of exercise or transportation and performed for at least 10 continuous minutes, that was intense enough to get their heart thumping and to work up a sweat. If average MVPA over the past 6 months and during a typical recent week was <30 min/week, the individual was classified as a ‘non-exerciser’. If average MVPA was ≥150 min/week, the individual was classified as an ‘exerciser’. The MVPA threshold for ‘non-exerciser’ is consistent with previous definitions of physical inactivity which have been used in population surveillance and epidemiologic studies (Adult Physical Activity, 2023; Chau et al., 2017). The threshold for ‘exerciser’ is consistent with the recommended level of MVPA as stated within the national PA guidelines (Piercy et al., 2018). Individuals reporting an intermediate amount of MVPA (30 to <150 min/week) were ineligible for this study as the goal was to target distinctive groups of exercisers vs. non-exercisers.

Additional exclusion criteria included conditions limiting ability to exercise, history of coronary artery disease (i.e., myocardial infarction), stroke, diabetes, pulmonary disease (e.g., COPD), uncontrolled hypertension (i.e., resting BP ≥ 140/90 mmHg), use of any medication that would affect heart rate (HR; e.g., beta blocker), current enrollment in a weight loss treatment program, history of bariatric surgery, or women who were nursing/pregnant.

1.2. Procedures

1.2.1. Overview of study 1 and study 2

Study overviews are shown in Fig. 1. Individuals deemed eligible based upon the phone screen attended an in-person orientation session to learn about the studies in greater detail and to provide informed consent in accordance with guidelines set forth by the Internal Review Board of the institution at which the present work was conducted. Upon consenting, participants completed a baseline assessment, which included measures of BMI, fitness, and 1 week of objective PA monitoring. Participants then returned to the laboratory for Exercise Session 1, in which they walked on a treadmill for 30 min at a moderate intensity. Prior to exercise they reported on anticipated affect (i.e., how they expect the upcoming exercise bout to make them feel), and momentary affective response was assessed before, during, and after exercise (Feil et al., 2023; Williams & Rhodes, 2023). In days 1, 3, and 7 following the exercise session, participants were asked to report on their remembered affect via text messaging (see Fig. 2 for a visual depiction of the assessment of anticipated affective response, actual momentary affective response, and remembered affect). They then returned to the laboratory to complete an identical exercise session (Exercise Session 2; Slawinska & Davis, 2020). Following the completion of Exercise Session 2 within Study 1, ‘non-exercisers’ proceeded to Study 2 and were randomly assigned to receive one of two PA interventions (affect intervention vs. control). Following this brief, single-session intervention, participants completed additional study measures and a third exercise session (Exercise Session 3), 1–2 weeks later (described in detail below). ‘Exercisers’ who completed Study 1, were not eligible for Study 2 (Urban et al., 2019).

1.2.2. Baseline visit: BMI, fitness test, objective PA measurement

Prior to participating in Exercise Sessions 1 and 2, participants completed the following baseline assessment measures.

BMI. Weight was measured to the nearest .1 kg using a calibrated digital scale and height was measured to the nearest .1 cm using a wall-mounted stadiometer. Body mass index (BMI) was calculated as kg/m^2.

Fitness Test. Fitness was measured via a sub-maximal graded exercise test (GXT). Participants walked on the treadmill at 3.0 mph and the speed and incline were increased every 3 min until 75 % of age-predicted maximal HR was achieved (Tanaka et al., 2001). Total time spent on the treadmill (in seconds) was used as an indicator of fitness. The purpose of this GXT was to allow participants to gain familiarity with walking on a treadmill and assist in determining the starting treadmill grade for the following exercise visit.

Objective PA Measurement. While participants were deemed eligible for this study based upon self-report measures of PA (see ‘Participants’

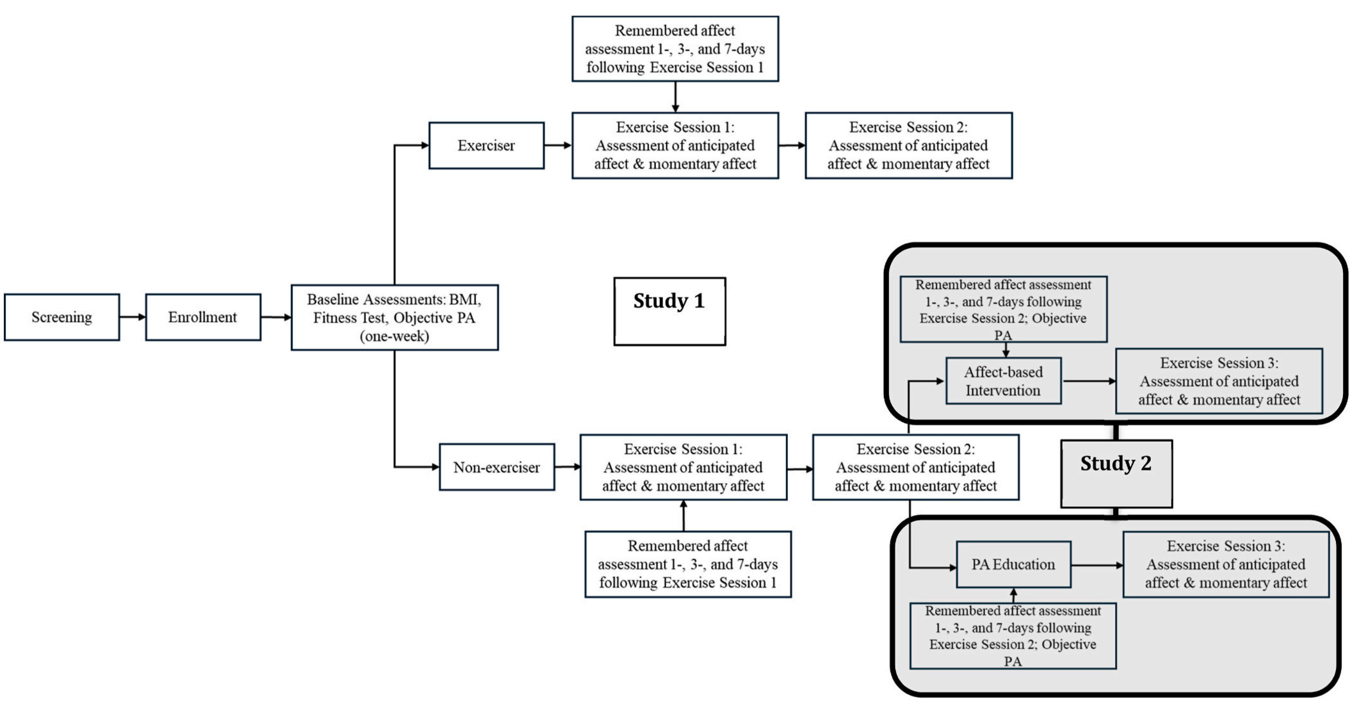

Fig. 1. Timeline. Study timeline for ‘exercisers’ vs ‘non-exercisers’ in Study 1, followed by the timeline for ‘non-exercisers’ only in Study 2 (Affect-based Intervention, ‘INT’ vs PA Education, ‘CON’).

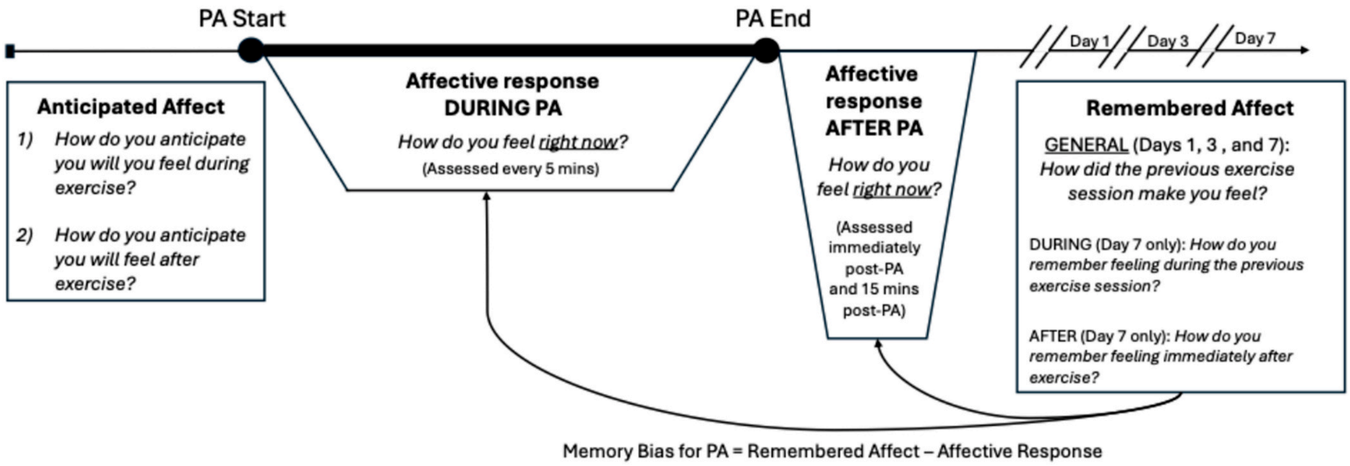

Fig. 2. Visual Depiction of timing for affect assessment. Participants were queried on Anticipated Affect prior to beginning their PA session via Visual Analog Scale (VAS), Affective Response was assessed in the moment throughout the PA session and 15-min post-PA using the Feeling Scale, and Remembered Affect was assessed at 1, 3, and 7 days post-PA session via VAS. Memory Bias was calculated as the difference between what was remembered and what was actually experienced.

section of the Methods), direct PA monitoring was also performed to confirm that 'exercisers' and 'non-exercisers' significantly differed on MVPA. All participants wore a previously validated activity monitor (Sensewear Armband, Body Media Inc., Pittsburgh PA; Jakicic et al., 2004; Johannsen et al., 2010) for 1 week and were asked not to alter their activity levels during this period. The monitor was worn on the upper arm and assessed movement and energy expenditure; however, the device did not provide any information or feedback to participants. Minute-by-minute data were collected, and using proprietary algorithms, metabolic equivalent values (METs) were computed for each minute the device was worn. Exercise groups were compared on time spent engaging in bout-related MVPA ($\geq$3 METs, $\geq$10 min).

1.2.3. *Exercise session 1*

Exercise Protocol. Following completion of all assessment measures, participants returned to the laboratory for Exercise Session 1. Upon arrival, participants were given a detailed description of the upcoming exercise protocol and were equipped with a heart rate (HR) monitor. Immediately prior to the start of the exercise bout, participants were asked to report their pre-exercise *momentary* affect using the Feeling Scale (FS; Hardy & Rejeski, 1989) and their *anticipated affect* towards the upcoming exercise bout using a visual analog scale (VAS; see below for additional detail on affect measures). They then completed the exercise protocol which consisted of a 2-min warm-up, followed by 30 min of moderate-intensity walking (70–75 % of age-predicted maximal HR), and a 2-min cool-down. This exercise duration and intensity was chosen because it is consistent with the American College of Sports Medicine's exercise guidelines which recommend 30 min of moderate-intensity exercise (64–76 % of maximal HR), 5 days a week (American College of Sports Medicine, 2013), and is feasible for individuals with overweight/obesity. Starting exercise intensity was estimated using HR data from the baseline fitness test. Heart rate was monitored every minute, and the treadmill grade or speed was adjusted by trained research staff if the subject's HR fell outside the target range for two consecutive minutes. Momentary affect was assessed every 5 min during exercise, immediately post-exercise, and 15 min following the completion of the exercise bout.

Assessment of momentary affect. The Feeling Scale (FS; Hardy & Rejeski, 1989) was used to assess momentary affect before, during and after exercise. This single-item measure asks participants to rate how they feel 'at the present moment' on an 11-point scale ranging from −5 (very bad) to +5 (very good). The FS has been shown to be related to other measures of affective valence (Hall et al., 2002), is ideal for assessing affect during exercise given that it is a single item measure, and it has been used as a measure of affective valence in numerous PA studies (Ekkekakis, 2003). *Pre-exercise* affect was assessed as individuals stepped onto the treadmill but before the exercise was started. *During* exercise affect was assessed every 5 min during the exercise bout (excluding warm-up), and *post-exercise* affect was assessed immediately after the conclusion of the exercise protocol and exactly 15 min later.

Assessment of anticipated affect. Prior to the exercise sessions *anticipated affect* was assessed using a 100 mm VAS. This method for assessing anticipated affect requires participants to denote their response on a continuous line (anchored by 'very bad' and 'very good' similar to the FS used for measuring current affect) but does not quantify affect with a numerical response (e.g., "2"), thereby eliminating potential for participants to provide subsequent affect ratings that are simply repetitions of their predictions. Participants were specifically asked "How do you anticipate feeling during exercise?" and "How do you anticipate feeling after exercise?".

1.2.4. *Remembered affect and memory bias*

In the week following Exercise Session 1, all participants were asked to maintain their typical daily routines of either exercising or not exercising and respond to an online questionnaire assessing their memory of their own affective responses to the exercise session. These questionnaires were completed 1, 3, and 7 days following the exercise session, and participants responded to the questionnaire by clicking on a link provided via text message. In order to avoid direct recall of responses provided on the FS, a VAS was used. On days 1, 3, and 7, participants were asked to reflect upon their Exercise Session 1 by responding to following question; "How did the previous exercise session make you feel?" and this was considered an indicator of *general* remembered affect. Following this response on day 7 only, participants were asked to further delineate how they remembered feeling during exercise, and post-exercise. Memory bias was assessed by first converting VAS values of remembered affect to corresponding FS values via linear transformation (e.g., -5 on the FS corresponded to 0mm on the VAS, 0 on the FS corresponded to 50mm on the VAS, and +5 on the FS corresponded to 100mm on the VAS). Then the discrepancy between remembered and actual FS values during and post-exercise was calculated (e.g., remembered during exercise affect [assessed 7 days post-exercise] minus actual during exercise affect [average of FS scores every 5 min during exercise]. A negative number indicates that participants remembered feeling less positive during exercise than they actually felt. Memory bias for post-exercise affect was computed in a similar manner.

1.2.5. Exercise session 2

In order to collect data on anticipated affect after participants had experienced one laboratory exercise session, all participants were asked to return to the laboratory for a second exercise session, identical to the first, which was at least 1 week following Exercise Session 1. Following completion of this second exercise session, exercisers were compensated $50 for participation in the study, while non-exercisers were randomized, and received a brief PA intervention (described below).

1.2.6. Study 2

Immediately following Exercise Session 2, all non-exercisers were randomized to a brief affect-based PA intervention (INT; n = 15) or an educational PA intervention, which served as the control condition (CON; n = 15).

Components common to both the Affect Intervention and Control Condition. Participants in both arms were informed of the national PA guidelines (150 min/wk of MVPA) and were encouraged to meet these guidelines. They were also provided with general information regarding the physiological and psychological health benefits of regular exercise. They were educated on what types of activities were considered moderate-intensity and how to gauge this intensity on their own. Finally, they were asked to reflect on their reasons for wanting to become more physically active. INT and CON sessions were each conducted as a single one-on-one session with a PhD-level interventionist lasting approximately 45–60 min in total.

Affect Intervention. In addition to the educational content described above, participants assigned to the INT group received a brief, affect-based intervention with a doctorate-level interventionist in which they were taught cognitive strategies designed to make their remembered affect more positive. Intervention delivery included the following steps: 1) normalizing negative affective response during PA, 2) reporting back to participants their own actual experienced affect before, during, and after PA, 3) (Individualized) highlighting positive affect wherever it may have occurred throughout the entire PA experience for that individual and highlighting discrepancies between what was experienced and what was recalled, and 4) discussing strategies to reduce this memory bias. First, each participant was shown a graph of normative data from studies using the FS during and post-exercise. This practice of using normative data has been shown to positively impact perception and behavior in other fields (Perkins, 2002; Perkins & Craig, 2006). This was used in the current study specifically to normalize the experience of reductions ("dips") in positive affect during exercise and to highlight the general positive affect produced by MVPA. The interventionist then shared a graph illustrating the participant's own affective trajectory from Exercise Session 1. The interventionist discussed this trajectory with the participant, pointing out the moments that were most positive, and using open-ended questions to probe the participants' feelings about these moments and these data. Participants were then shown on the graph their remembered affect for the same exercise session. A Cognitive-behavioral approach was used to point out discrepancies between experienced and recalled affect and draw attention to thoughts and feelings that contribute to the experience of PA and the memory of it. Participants were asked specific questions aimed at increasing their awareness of their remembered affect (e.g., why do you think you remembered exercise in this way? When you report on how you remember feeling in response to exercise, what do you think sticks out most in your mind and contributes to your response? Do you think you are focusing more on how you felt during or after exercise?). Finally, using a practice adopted from positive psychology (Csikszentmihalyi, 2014), participants were asked to write down any positive feelings they experienced during or as a result of the previous exercise session (e.g., improved mood, feeling energized, feeling accomplished/proud, or feeling good about doing something beneficial for the body). They then shared their responses with the interventionist and participants were encouraged to think about these positive experiences, feelings, and motivations for engaging in exercise often, and specifically during the next exercise session. These strategies were designed to orient non-exercisers to another motivating factor for engaging in exercise, the positive feelings they have in response to exercise, and to reduce dissonance between reported affect, remembered affect, and overall attitudes toward exercise. Motivational interviewing techniques were used to elicit individual participant-driven discussion and brainstorming of strategies to reduce bias. Common strategies covered include deliberate focus on feelings after exercise, thinking about the positive outcomes of exercise during the most negative moments of a PA session, acceptance of negative affect during exercise, and practice with self-assessment of affect associated with PA.

1.3. Post-intervention assessment

Non-exercisers in both arms were informed they could increase their PA following Exercise Session 2 if they desired, and they were given the Sensewear armband to wear for 1 week to objectively assess whether there was an intervention effect on bout-related MVPA. Further, during the week following Exercise Session 2, all non-exercisers were asked to complete remembered affect questionnaires for Exercise Session 2 at 1, 3, and 7 days following the session, as was done previously.

1.3.1. Exercise session 3

One to two weeks following Exercise Session 2, non-exercisers from both the control and intervention groups returned to the laboratory for a third exercise session (Exercise Session 3). This session was identical to the previous exercise sessions and measures of anticipated affect, pre-, during, and post-exercise affect were obtained. All non-exercisers attending Exercise Session 3 (INT and CON) were compensated $50 for their time.

1.4. Power and sample size estimates

This study was powered based upon the primary aim for Study 1: to compare exercisers and non-exercisers on memory bias of affect in response to PA (general, during, and post-exercise). Using previously observed standard deviation (SD) = 1.652, and assuming correlation between actual and recalled affect, with n = 60 (30 exercisers & 30 non-exercisers), it was estimated that we would have 80 % power to detect a large effect (Cohen's $d \geq .80$). Given the pilot nature of the study, we chose a large effect size to ensure we had sufficient power given a limited sample size. This also allowed us to focus on practical significance of the results. This effect size is equivalent to a clinically meaningful 1-point difference in memory bias between groups in a two-sided test with the type I error $\alpha = 0.05$. Study 2 was a pilot study to explore differences in intervention vs. control. Since this was exploratory in nature, we were not powered to detect significant differences.

1.5. Statistical analysis

Preliminary analyses were conducted to compare the groups (exercisers vs. non-exercisers) with respect to demographic variables including age, BMI, and biological sex. Chi-squared tests were used to assess between-group differences in categorical variables and independent two-sample t-tests were used for continuous variables. Using a series of longitudinal linear mixed effects models, we examined between-group (exercisers vs. non-exercisers) differences in remembered affect over time (1, 3, and 7 days post-exercise). Models included a subject-specific intercept and adjusted for repeated measures within participant over time. The goal was to determine the degree to which 'general' remembered affect was associated with (i.e. biased toward) affective responses during or after PA (and whether bias was more in favor of affect during or post exercise) and whether this differed between exercisers and non-exercisers. Correlation analysis was used to examine associations between affective memory bias and anticipated affect towards future exercise. Finally, analysis of variance (ANOVA) was used for

Study 2 to compare non-exercisers receiving the brief cognitive intervention to those in the control group on anticipated affect, affective response to exercise session 3, remembered affect for exercise session 2, and minutes/week spent in MVPA (assessed via the armband). All analyses were carried out in SAS 9.3 with significance level set at .05 a priori. Mixed effects models use a likelihood-based approach to estimation, thus making use of all available data without directly imputing missing value.

2. Results

2.1. Participants

A total of 59 participants with a mean age of 47.1 ± 10.3 years and mean BMI of 32.1 ± 3.3 kg/m^2 were included in this study. Participants were predominately female (79.7 %), non-Hispanic (94.9 %), and White (91.5 %). As shown in Table 1, based on self-reported exercise over the past 6 months, exercisers engaged in significantly more MVPA compared to non-exercisers ($p < 0.001$) and a similar magnitude of difference between groups was observed when verified via the armband (mean difference ± SEM: 252.1 ± 63.5 min/week; $p < 0.001$). Although all participants had BMI within overweight-obese ranges, there was a significant difference in BMI observed between exercisers vs. non-exercisers.

2.2. Study 1 – comparison of exercisers and non-exercisers on anticipated affect and affective responses to exercise

At Exercise Session 1, anticipated *during* exercise affect was more positive for exercisers than non-exercisers (exercisers = 71.3 ± 18.7, non-exercisers = 54.1 ± 21.3, p = 0.002), and there was a similar trend for anticipated *post-exercise* affect (exercisers mean = 81.0 ± 15.3, non-exercisers = 73.5 ± 16.4, p = 0.073). No significant differences were observed at Exercise Session 2 (p's > .14). Moreover, the pattern of momentary affective response during to post-exercise was examined. Compared to non-exercisers, affect was more positive among exercisers at every time point within Session 1 (b = .30, SE = .12, p = 0.056) (Fig. 3).

2.3. Study 1 – comparison of exercisers vs. non-exercisers on remembered affect and memory bias

We first examined whether *general* remembered affect more closely resembled *during* exercise or *post-exercise* affect among exercisers and non-exercisers on days 1, 3 and 7 following Exercise Session 1. Model results indicate that across days, remembered affect more closely resembled affective response 15-min *post* exercise (compared to *during* exercise affect; r = .57 vs. r = .46 p = 0.001), among the aggregate sample of exercisers and non-exercisers and separately within group (i.e., within exercisers and within non-exercisers). Next, using *general* remembered affect, we assessed whether memory bias differed between exercisers and non-exercisers. Findings indicate memory bias was greater among non-exercisers compared to exercisers (76.36 vs. 74.07, p = 0.04).

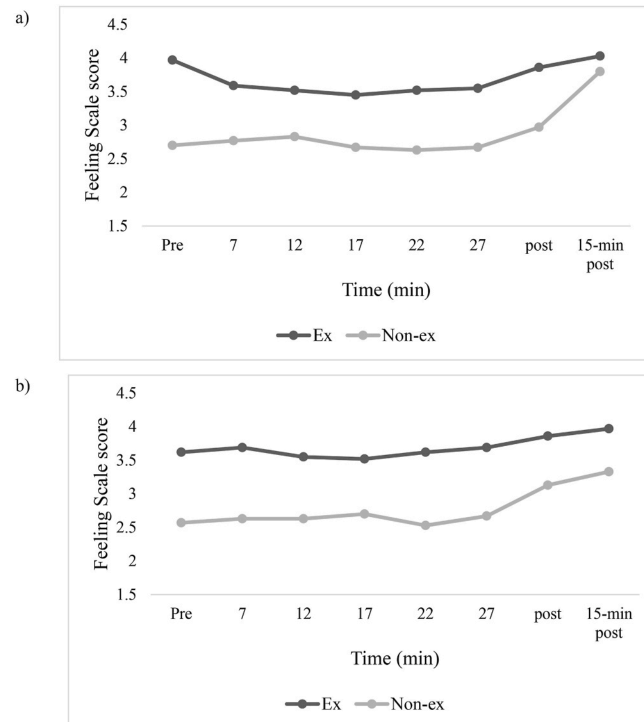

Fig. 3. Study 1 Affective Response. Affective responses assessed via Feeling Scale scores before, during and after exercise stratified by exercise status for Exercise Session 1 (a) and Exercise Session 2 (b).

We then examined whether negative memory bias was present when asked specifically to remember one's *during* exercise and *post-exercise* affect on Day 7. Model results indicate that, among the aggregate sample, participants' remembered *during* exercise affect was significantly more negative than their actual *during* exercise affect (mean difference = −.78, $p < 0.001$), indicating a negative memory bias. A similar pattern was seen when comparing remembered *post-exercise* affect and actual *post-exercise* affect (mean difference = −.92, $p < 0.001$). There were no significant differences between exercisers and non-exercisers in bias for *during* exercise affect (mean difference = −.80 vs. −.77, p = 0.93) or *post-exercise* affect ((-.76 for non-exercisers vs. −1.07 for exercisers, p = 0.44).

Finally, we examined whether *during* and *post-exercise* memory bias scores were correlated with anticipated affect towards future exercise (as measured prior to Exercise Session 2) among exercisers and non-exercisers. Greater negative bias for *post-exercise* affect was associated with lower anticipated affect scores among exercisers (r = .42, p = 0.03). No other significant correlations were observed.

Table 1
Participant baseline demographics.

	Exercisers (n = 29)	Non-exercisers (n = 30)	Difference (p-value)
Age (years)	49.2 ± 8.9	45.0 ± 11.3	.12
BMI (kg/m^2)	31.2 ± 3.6	33.0 ± 2.7	.03
% Female	75.9 %	83.3 %	.48
% White	89.7 %	93.3 %	.61
% Non-Hispanic	96.6 %	93.3 %	.57
MVPA (min/wk)*	285.9 ± 148.8	14.0 ± 15.2	<.001

Note: *Represents average self-reported moderate-to-vigorous physical activity over the previous 6 months prior to enrolling in the trial.

2.4. Study 2 – comparison of affect-based intervention (INT) vs. control (CON)

The effect of the intervention was examined by comparing INT vs. CON on 1) anticipated affect, during exercise, and post-exercise affect at Exercise Session 3, 2) remembered affect and memory bias from Exercise Session 2 (assessed 7 days following the exercise session), and 3) objectively-measured PA levels for one week following the intervention. Intervention and control groups did not differ on *anticipated* affect (b = .62, SE = .56, p = 0.46), or *during* exercise affective response from pre-to minute 17 (b = −.50, SE = .67, p = 0.60). However, between minute 17 and the end of the exercise session, results indicate a trend for the between group effect with CON showing decreases in FS scores compared to sustained FS scores among INT (p = 0.08). Models controlling for during exercise affect indicate significant differences favoring INT *immediately post-exercise* (b = .47, SE = .22, p = 0.05), but these effects were no longer significant *15-min post-exercise* (b = .23, SE = .24, p = 0.35).

When considering intervention effects on *general, during, and post-exercise* remembered affect, there were no significant differences between INT and CON (p's > .13). However, when considering the intervention effects on memory bias, INT had a significantly lower memory bias *during* exercise compared to CON (.88 vs. −.72, p = 0.04), and this bias was positive, indicating that participants remembered exercise as more favorable than it was, whereas CON had a more negative memory bias on average. The pattern of results was similar for *post-exercise* memory bias (i.e., less bias for INT and more positive vs. negative bias compared to CON), although this was not statistically significant (1.41 vs. −.91, p = 0.10). Finally, the effect of intervention on armband-measured PA 1 week after the intervention was examined with no significant effects on bout-related MVPA (F = 1.33, p = 0.27).

A complete summary of study results can be found in Table 2.

Table 2
Summary of main findings for comparisons between a) exercisers vs. non-exercisers, and b) affect-based.

a. Exercisers vs. Non-Exercisers	
Exercise Session 1	Key finding
Anticipated 'during exercise' affect	EX more positive than Non-Ex
Anticipated 'post exercise' affect	Trend for EX more positive than Non-Ex
During exercise affect	EX more positive than Non-Ex
Immediately post-exercise affect	EX more positive than Non-Ex
15-min post-exercise affect	No effect
General remembered affect	Remembered affect more similar to 15-min post-exercise vs. during exercise affect for both groups. Memory bias was greater among Non-Ex compared to EX.
Overall memory bias	Negative memory bias observed in both groups
Memory bias for 'during exercise' affect	No effect
Memory bias for 'post-exercise' affect	Negative bias observed in both groups, no difference between EX and Non-Ex
<u>**Exercise Session 2**</u>	
Anticipated 'during exercise' affect	No effect
Anticipated 'post exercise' affect	No effect
During exercise affect	EX more positive than Non-Ex
Immediately post-exercise affect	EX more positive than Non-Ex
15-min post-exercise affect	EX more positive than Non-Ex
b. Intervention vs. Control	
Exercise Session 3	Key finding
Anticipated affect	No effect
During exercise affect	No difference during first 17 min; Minute 17 to 30: Trend for INT to maintain affect vs. a worsening in affect in CON
Immediately post-exercise	INT more positive than CON
15-min post-exercise affect	No effect
General remembered affect	No effect
Overall memory bias	No effect
Memory bias for 'during exercise' affect	INT had lower memory bias vs. CON (Positive memory bias in INT and negative in CON)
Memory bias for 'post-exercise' affect	Trend for INT to have lower bias vs. CON (Positive memory bias in INT and negative in CON)
Physical activity 1-week post-intervention	No effect

Note: EX = exercisers, Non-Ex = Non-exercisers, INT = affect-based intervention, CON = control condition; 'Trend' was considered p = 0.05–.10.

3. Discussion

The primary objective of Study 1 was to compare exercisers and non-exercisers on anticipated affect, remembered affect, and memory bias related to a bout of exercise. Consistent with hypotheses, anticipated affect towards the first exercise session was more positive among exercisers than non-exercisers. Across all participants, remembered affect more closely resembled post-exercise affect than during exercise affect, with no significant difference between exercisers and non-exercisers. Furthermore, exercisers and non-exercisers exhibited general, overall negative memory bias, which was greater in non-exercisers compared to exercisers. Negative memory bias was also present for both during and post-exercise affect, with no difference by exercise status. Among exercisers only, a greater post-exercise negativity bias was related to lower anticipated affect scores for a future PA session.

In the current study, participants generally remembered affect as being worse than it actually was, with overall, negative memory bias being greater among non-exercisers. Although there is limited research on remembered affective experiences of PA, one study asked inactive and active adults to remember positive and negative memories of previous PA experiences and to rate them for phenomenological characteristics (Anderson et al., 2023). The researchers concluded that in general, exercisers reported more positive memories of PA compared to non-exercisers and that recalling these positive memories elicited a more intense emotional reaction for exercisers. Furthermore, exercisers reported remembering positive experiences of PA as more positive than their inactive counterparts. The notion that regular exercisers may be prone to positive memory biases which could serve as a mechanism sustaining their PA behavior seems to be supported by evidence from marathon runners. In their study, Bąbel (2016) found that marathon runners consistently underestimated the unpleasantness and pain incurred while running a marathon with no effect found for the length of recall delay (3- or 6-months post marathon compared to assessments of pain and unpleasantness obtained at the finish line), indicating a positive memory bias for this group of presumably regular exercisers. Taken together, these results suggest that remembered affect could be a mechanism supporting PA engagement among habitual exercisers or avoidance among insufficiently active individuals.

The current study also found that greater post-exercise negativity bias was related to lower anticipated affect scores for a future PA session among exercisers only. That negative memory bias is associated with more negative anticipated affect is consistent with the original hypothesis, however, it is interesting this was significant only amongst habitual exercisers. Even among habitual exercisers there is a range of affect experienced and remembered. Objective PA data indicate this group of habitual exercisers, on average, engaged in 285.9 ± 148.8 min of MVPA per week at baseline. It is possible that for these regular exercisers, interoceptive cues which typically result in negative affective evaluations of the PA task, may function as reliable indicators of PA intensity, with greater exertion possibly leading to heightened post-exercise satisfaction. Alternatively, the intensity, mode, or duration of the laboratory exercise session may have been different than usual PA behaviors in this group, which could have also contributed to their affective responses. Nonetheless, it's important to note that a crucial difference between this study and previous literature is that the participants in this study had overweight/obesity and were weight loss seeking. In general, the literature suggests individuals with overweight or obesity typically report more negative affective evaluations of PA compared to normal weight adults (Ekkekakis & Lind, 2006; Elsangedy et al., 2018). The less favorable affective evaluations of PA typically reported by those with overweight or obesity may explain why exercisers in this study had a negative memory bias and reported a more negative anticipated affective response towards a future exercise session. However, prior research has also shown significant intra and inter-individual variability in affective evaluations of PA among this population (Unick et al., 2012). More work is needed to understand why some exercisers engage in regular PA despite self-reported negative affective evaluations.

In Study 1, remembered affect most closely resembled post-exercise affect. This is, in part, aligned with one popular theory of affective memory bias, the Peak-End Rule. The Peak-End Rule (or bias) postulates affective memories for an experience are influenced predominantly by the peak (i.e., most intense moment) and the end of that experience, with remembered affect often being the average of the two (Fredrickson, 2000). This theory stems from the idea that we do not tend to remember the entire affective profile of an experience but recall rather summarized "snapshots." (Alaybek et al., 2022; Kahneman et al., 1993). The results of the present study suggest that affective experiences at the end of a PA session (i.e., after exercise concludes and up to 15-minuts post-session completion) may be more salient when subsequently retrieved from memory than any affective evaluations during a PA session. This is evidenced by the closer correlation between *post-exercise* affective response and remembered affect (versus *during* exercise affective response and remembered affect) in the aggregate sample. Research by Zenko et al. (2016) corroborates this conjecture as they found a more pleasant ending to a PA session had significant and lasting effects on how that experience was remembered up to 7 days later (Stevens et al., 2020; Zenko et al., 2016, 2024). Approaches in which intensity is varied strategically across an exercise session may also effectively promote positive recall of PA via the same theory of the peak-end rule. For instance, interval training, wherein short bursts of higher intensity activity are followed by less intense recovery periods has been shown to be more enjoyable than continuous intensity PA. Based on the premise of the peak-end rule, interval training provides multiple instances of 'the end' of intense activity which may in turn provide greater opportunity for the positive affect associated with that peak and end (Luo et al., 2024; Oliveira et al., 2018). Similarly, in resistance training, a PA session in which intensity is manipulated to start high and decrease over time was shown to yield more positive affective response during the session and more positive affective recall (Hutchinson et al., 2020, 2023). In this way it may be possible to favorably modify memory bias by altering the structure of an exercise session to ensure a pleasurable end.

Study 2 was a pilot study to determine if non-exercisers could be trained to have more positive affective evaluations of PA. Although no differences were observed between conditions for scores on anticipated affect or remembered affect, several interesting trends emerged. First, in the exercise session following the brief intervention, during exercise affective response remained stable throughout the PA session among intervention participants whereas affective response grew increasingly more negative as the PA session progressed for control participants. Furthermore, intervention participants reported significantly less memory bias for during exercise affect and their memory bias was positive indicating they remembered the PA session as being more pleasant than it actually was. While not statistically significant, a similar trend emerged for post-exercise affective response with intervention participants exhibiting less memory bias and their memory bias was positive compared to control participants.

Although the literature on affect-related memory bias for physical activity is limited, the results of the present study are consistent with the current empirical evidence. The intervention component of Study 2 revealed that memories of affective experiences of PA can be manipulated and thereby impact future in-task affective evaluations of PA which could impact subsequent PA behavior. Study findings align with those from a prior study which found that being instructed to recall a positive motivational memory of past PA led to increased activity during the following week compared to being instructed to recall a negative motivational memory or not recalling a PA-related memory. These results suggest that manipulating the type of PA-related memories recalled could have a favorable impact on PA behavior (Biondolillo and Pillemer, 2015). Similarly, other studies have found that manipulating anticipated affect by providing counseling about the importance of PA for health and well-being, and remembering a previous PA session as more positive than it actually was, can all alter the affective experience of exercise (Kwan et al., 2017; Karnaze et al., 2017). The present investigation supports and expands on the current literature, demonstrating that a brief (<30 min) affect-based intervention led to a more stable affective response throughout a subsequent PA session, versus a decline in positive affect, similar to that observed in the control condition. Collectively, results from Study 2 coupled with the extant literature suggest providing education and setting expectations regarding PA experiences can positively impact remembered and in-task affect, leading to less memory bias and more positive affective evaluations of the PA task. Fully powered trials in this area are warranted, particularly given the exploratory nature and limited sample size within Study 2.

4. Limitations & future directions

Although Study 1 was one of only a handful of studies to evaluate the impact of remembered affect and memory bias on subsequent PA evaluations, it is not devoid of limitations. First, participants voluntarily enrolled in this study; thus, it is possible those who agreed to participate already had more favorable impressions of PA prior to study enrollment than those who saw the study advertisement but opted not to participate. Self-selection into the study could result in selection bias challenging the tenability of the study results. Future work should seek to identify if similar trends in memory bias and affective evaluations emerge among those with less favorable impressions of PA and/or whether study findings would be replicated. Additionally, both studies recruited only those whose BMI classification was overweight or obese. Participant's weight status may have impacted their affective evaluations of the exercise sessions, potentially limiting the generalizability of the research findings to those outside the BMI range of the current study. Nonetheless, given the significant health benefits associated with PA in this population, future research efforts focused exclusively on this population are warranted. Similarly, participants in this study were weight loss seeking. This may have also impacted their affective evaluations of the exercise task given potential motiviation to use exercise as a mechanism to support their weight loss efforts. Future research in non-weight-loss-seeking popultations is needed to confirm generalizability of the results. These studies also lacked a nuanced exploration of how individuals were using their memories of PA to inform PA-related decisions. Future research should build upon this study and the findings of Anderson et al. (Anderson et al., 2023) to explore how exercisers and non-exercisers use their memories of PA when making activity-related decisions. Finally, these studies were limited in that they were conducted primarily in a laboratory setting and they did not employ any long-term follow-up; therefore, it is unknown whether findings from each study could be replicated within a naturalistic setting, and it is not known for how long the effects of the affect-based intervention may persist. Future research will be needed to address these limitations.

5. Conclusions

Results of the present studies suggest that in general, individuals' affect-related memories of exercise more closely resemble their post-exercise affective response independent of exerciser status. Therefore, attempts should be made to maximize positive affective evaluations of the PA task toward the end of the PA session and immediately after activity concludes. Furthermore, both exercisers and non-exercisers display negative memory bias; however, non-exercisers remembered PA as being less positive, suggesting that remembered affect may be important for sustaining PA behavior. Finally, pilot findings demonstrate that remembered affect can be manipulated among non-exercisers by providing them with information about personal and normative affective responses to exercise and asking them to reflect upon and identify the most positive aspects of exercise. Providing this type of information may result in more positive affect-related assessments of the

PA task.

CRediT authorship contribution statement

Kathryn E. Demos McDermott: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Katrina M. Oselinsky:** Writing – review & editing, Writing – original draft. **Shira I. Dunsiger:** Writing – review & editing, Writing – original draft, Formal analysis. **David M. Williams:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Rena R. Wing:** Writing – review & editing, Supervision, Resources, Project administration, Conceptualization. **Jessica L. Unick:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the authors used Microsoft Copilot and Perplexity AI in order to find relevant peer-reviewed articles, which the authors then reviewed and incorporated relevant study findings within the manuscript without the use of AI. These tools were used in a limited capacity to check for reference duplication and to proofread specific sentences, but the manuscript was not comprehensively reviewed or edited using AI. After using these tools/services, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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Data availability

Data will be made available on request.

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