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ORIGINAL ARTICLE

Adult Attachment Is Not Associated With Conditioned Pain Modulation in Healthy Females in a Neutral Social Context

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ABSTRACT

Background: Individuals with chronic pain are both more likely to have an insecure adult attachment style and impaired conditioned pain modulation (CPM) than pain-free individuals. This study investigated whether impaired CPM is seen in pain-free individuals and determined associations with attachment.

Method: A CPM test paradigm was used to determine the differences in the measures of pain across attachment anxiety and avoidance dimensions in pain-free females in a neutral social context. First, static (heat pain threshold, heat pain tolerance, and cold pain intensity) and dynamic (cumulative pain load) measures of pain were explored.

Results: One hundred and three females were recruited (median [IQR] age: 21 [20–23] years). We found no associations between attachment dimensions and static measures of pain (*ps* >0.05). Higher attachment anxiety, but not avoidance, was associated with an increase in pain intensity over time (Estimate [95% CI] = 0.15 [0.06–0.25], *p*-value = 0.002), and increased average test stimulus pain intensity rating both before (Estimate [95% CI] = 0.15 [0.07–0.23], *p*-value <0.001) and during (Estimate [95% CI] = 0.36 [0.23–0.48], *p*-value <0.001) conditioning. In the 78% (80/103) who completed the full CPM procedure, there was no association between CPM effect and attachment anxiety (Estimate [95% CI] = −3.79 [−8.62 to 1.03], *p* = 0.122) or avoidance (Estimate [95% CI] = 0.25 [−4.88 to 5.38], *p* = 0.923). Effective CPM was seen in 90% (72/80).

Conclusion: Impaired CPM was not seen in pain-free individuals suggesting that impaired endogenous analgesia may develop from chronic pain, rather than cause chronic pain.

Significance Statement: Individuals with chronic pain are both more likely to have an insecure adult attachment style and impaired conditioned pain modulation (CPM) than pain-free individuals. This is the first study to investigate a link between attachment and experimental pain using a conditioned pain modulation (CPM) paradigm in a neutral social context. Impaired CPM was not seen in pain-free individuals, suggesting that impaired endogenous analgesia may develop from chronic pain, rather than cause chronic pain.

1 | Introduction

Pain perception, subsequent pain-coping behaviours, and pain burden, are theorised to be influenced by adult attachment (Meredith et al. 2008). Attachment theory is a theory of emotional regulation in times of perceived threat, comprising two dimensions: attachment anxiety, an individual's anxiety over seeking support and/or attachment avoidance, an individual's avoidance of intimacy in those times of perceived threat (Bartholomew and Horowitz 1991). High anxiety and/or high avoidance deem an individual to be more insecurely attached (Bartholomew and Horowitz 1991). Studies investigating attachment style and pain have found that insecurely attached individuals with chronic burn injuries and insecurely attached women in labour required significantly more analgesia than their securely attached counterparts with similar injuries and labours, respectively (Costa-Martins et al. 2014; Nyland et al. 2022). Furthermore, in individuals with chronic pain, those with an insecure attachment style have a higher number of pain sites when compared to individuals with secure attachment (Davies et al. 2009; Stamp et al. 2025).

In samples with chronic pain, individuals are more likely to have an insecure attachment style (55%–66%) than a secure attachment style (34%–45%) (Davies et al. 2009; Kowal et al. 2015; Meredith et al. 2006a). Similarly, we recently found that in a general population, there was an increased presence of chronic pain in individuals with insecure (38%; 211/547), compared with secure (23%; 424/1824), attachment (Stamp et al. 2025). Although the presence of chronic pain, and pain-related psychological variables [including depression, anxiety and pain catastrophising] (Andersen 2012; Ciechanowski et al. 2003; Kowal et al. 2015), appear to be increased in individuals with an insecure attachment, the possible mechanisms underlying these associations remain unexplored.

Limited studies have investigated the association between adult attachment and experimental pain (see (Meredith 2013) for review). While the results of these studies suggest an association between adult attachment and experimental pain, the direction of the reported associations varies depending on the study protocol, including social context (empathy from partner, empathy from stranger, presence of partner, presence of stranger, affective touch or social threat) and outcome measures of pain (threshold, tolerance and intensity). Accordingly, the relationship between adult attachment style and measures of the experimental pain experience, including pain threshold, tolerance and intensity, remains unknown.

Endogenous analgesia is a term used to refer to the inhibitory central pain modulation mechanisms (Nir and Yarnitsky 2015) and it is reported to be impaired (i.e., reduced endogenous analgesia) in individuals with chronic pain and idiopathic pain syndromes when compared to healthy individuals (Damien et al. 2018; Nir and Yarnitsky 2015; Ossipov et al. 2010). Brain regions that are involved in attachment system activation overlap with brain regions involved in generating the experience of pain and also those involved in both endogenous analgesia and placebo analgesia (Stamp et al. 2024). As such, we believe that differing attachment system activation (dependent on attachment dimensions) may affect both the perception and modulation of pain.

The conditioned pain modulation (CPM) test paradigm provides a reliable method of measuring endogenous analgesia in an experimental setting (Kennedy et al. 2016; Ramaswamy and Wodehouse 2021; Sirucek et al. 2023). The CPM paradigm essentially assesses the 'pain-inhibits-pain' effect, which is evaluated by examining how the perceived intensity of one noxious (test) stimulus is affected by the simultaneous application of another noxious (conditioning) stimulus (Yarnitsky et al. 2010). In a physiologically healthy state, the intensity of the test stimulus is reduced when the conditioning stimulus is present, demonstrating the presence of endogenous analgesia. It remains unclear whether impaired CPM is a potential predictor for the development of chronic pain (Damien et al. 2018; Yarnitsky et al. 2008) or a consequence of compromised neural mechanisms associated with chronic pain (Nir and Yarnitsky 2015). Individuals with chronic pain are both more likely to have an insecure adult attachment style (Davies et al. 2009; Kowal et al. 2015) and impaired CPM (Damien et al. 2018); thus, investigating whether impaired CPM is seen in pain-free individuals with insecure attachment may provide insight into the relationship between these three variables. For example, finding an association between CPM and attachment in pain-free individuals may suggest that impaired CPM comes first; yet if there is no association, it may suggest that it is the presence of chronic pain that comes before the impaired CPM.

In this study, we hypothesised that impaired (reduced) endogenous analgesia (as measured by CPM) may be associated with greater attachment anxiety and avoidance. We conducted a cross-sectional study of experimental pain measures in healthy, pain-free women and looked for associations with attachment dimensions. Our main study objectives were to determine whether there is an association between adult attachment dimensions and (1) static measures of pain (threshold, tolerance and single-point intensity), (2) dynamic measures of pain (cumulative pain load from contact heat) and (3) CPM, in pain-free women in a neutral social context.

2 | Methods

2.1 | Ethical Clearance

The protocol was approved by the University of the Witwatersrand's Human Research Ethics Committee (Medical), which adheres to the principles of the Declaration of Helsinki and the Declaration of the World Medical Association (Clearance certificate number: M211003).

2.2 | Participants

The present research was initiated with a nationwide online survey (details described elsewhere [Stamp et al. 2025]); here we describe only the details relevant for this experimental study. From the survey responders, females who reported having no 'chronic pain' (defined as pain most days for at least the last 3 months [Treede et al. 2015]) and who lived locally were invited to partake in the in-person experimental procedure—the current study. Additionally, to increase our sample size, we encouraged participants to inform others about the study. All additional volunteers were required to complete the same survey to ensure that they met the inclusion criteria before being permitted to participate in the experimental study.

Since there are known biological and psychological differences between males and females that influence pain perception (Myers et al. 2003; Wiesenfeld-Hallin 2005), and since sex differences in experimental pain are not consistent, or predictable, in the literature (Racine et al. 2012), to avoid any potential sex-related confounding factors, only female participants were included in the current study. Volunteers were excluded from the experiment if they had chronic pain, as defined by a positive response to the question 'Have you had pain most days for the last three months?' (Treede et al. 2015). Volunteers were also excluded if they had any co-morbidities (diabetes, obesity, hypertension), as well as if they had any physical disability. Those with physical disabilities were excluded due to the high prevalence of co-morbidities (e.g., hypertension, diabetes, post-traumatic stress disorder, substance use disorder, heart disease) and chronic pain (Anderson et al. 2014; Rana et al. 2024; Scott et al. 2009). To partake in the experiment, participants were also required to be pain-free on the day of the CPM procedure. Lastly, to minimise the possibility of psychological variables specific to experimenter manner (or relationship with the experimenter) affecting pain perception (Andrews et al. 2011), volunteers were also excluded if they were friends or family of the experimenter.

To ensure unbiased data collection, the experimenter was blinded to the attachment style of the participants (data previously obtained from the completion of the survey). Since the association between adult attachment style and mechanisms of endogenous analgesia (CPM) has not, to the authors' knowledge, been previously investigated, there was no estimate of standard deviation from past literature, and hence, a power analysis could not be run. Previous studies examining the association between adult attachment and experimental pain had sample sizes ranging from 30 (Sambo et al. 2010) to 95 (Rowe et al. 2012) and previous studies using the CPM test paradigm had sample sizes ranging from 20 to 62 (Kennedy et al. 2016). As such, we chose the upper end of these sample sizes and recruited 100 participants.

Demographic and socio-economic factors known to be associated with pain were assessed during the survey, including age, race, sex, education and annual household income (Stamp et al. 2025). Socioeconomic status was categorised according to each participant's reported annual household income, defined as low- (ZAR 1–ZAR 19 200), middle- (ZAR 19 201–ZAR 307 200) or high-income (> ZAR 307 200) categories (Statistics South Africa 2011). Psychosocial factors and pain-related variables were also assessed using other standardised questionnaires that were included in the survey. As detailed below, the psychological factors assessed were adult attachment style, stress, anxiety and depression, and the specific pain-related psychological variable assessed was pain catastrophising.

2.2.1 | Assessment of Adult Attachment Style

Adults have a network of attachment figures, which can vary throughout various stages of adulthood (Doherty and Feeney 2004; Tian and Freeman 2024). To account for attachments with the four most common attachment figures in adulthood (rather than focusing on a single attachment figure), we used the Experience in Close Relationships—Relationship Structures (ECR-RS) questionnaire to assess adult attachment style (Fraley et al. 2011). The ECR-RS was adapted from the Experiences in Close Relationships—Revised questionnaire (Fraley et al. 2000) and shares a smaller number of the same questions. It is a standardised 9-item questionnaire with a 6-item subscale for avoidance and a 3-item subscale for anxiety, and has been previously validated in a non-clinical sample (Fraley et al. 2011). The 9 items are repeated four times, each with respect to a different relationship (a relationship with a mother/mother-like figure, father/father-like figure, romantic partner, and best friend). The questionnaire is scored on a 7-point Likert scale anchored at 1 (representing 'strongly disagree') to 7 (representing 'strongly agree'). The mean scores for the six avoidance items and three anxiety items for each relationship were calculated, and the mean of these scores over the four relationships gave the global dimensions for attachment anxiety and avoidance (Fraley et al. 2011).

2.2.2 | Assessment of Depression, Anxiety and Stress

The Depression, Anxiety and Stress Scale 21 (DASS-21) was used to assess depression, anxiety and stress (Lovibond and Lovibond 1995). The DASS-21 has been validated in a South African non-clinical population (Dreyer et al. 2019) and has been found to be an effective measure of depression in patients with chronic pain due to the absence of questions about somatic symptoms (Taylor et al. 2005). The DASS-21 is a 21-item questionnaire with three 7-item subscales assessing depression, anxiety and stress. The questionnaire was scored on a 4-point Likert scale anchored at 0 (representing 'never' applies to the individual) to 3 (representing 'almost always' applies to the individual). The total score for each subscale was 21, with scores above 13, 9 and 16 indicating extremely severe depression, anxiety and stress, respectively.

2.2.3 | Assessment of Pain Catastrophising

The Pain Catastrophising Scale (PCS) questionnaire was used to measure the participant's tendency to adopt pain catastrophising thoughts (Sullivan et al. 1995). The PCS is a 13-item questionnaire assessing pain rumination, pain magnification and helplessness, and has previously been validated in a non-clinical sample (Sullivan et al. 1995). The PCS was scored on a 5-point Likert scale anchored at 0 (representing 'not at all') to 4 (representing 'all the time'). The highest possible score for the PCS questionnaire is 52 (Sullivan et al. 1995), and a score > 30 indicates a clinically relevant level of catastrophising (Sullivan 2009).

2.3 | Overall Experimental Pain Procedure

Given the evidence that pain sensitivity follows an endogenous circadian rhythm (Daguet et al. 2022), eligible volunteers were required to book a timeslot to complete the experiment within a 4 h window; specifically, between 10:30 am and 14:30 p.m. Following informed consent, participants completed an electronic pre-experimental pain procedure questionnaire to ensure that they were not experiencing any acute pain on the day of the experiment and that they had not taken any analgesic medication less than 6 h prior to the CPM procedure (Sobieraj et al. 2019). The consent form and questionnaire data were collected and captured using REDCap electronic data software hosted at the University of the Witwatersrand (Harris et al. 2009, 2019).

To control the social context, the experimenter maintained a professional (providing accurate and clearly communicated information) and neutral (trying neither to be warm nor cold/distant towards participants) manner. To do this, a pre-determined standardised script (see Supporting Information) was used to ensure that the same language was used each time. Since all data were collected by the same experimenter, a 10 min recess between participants was imposed to allow the experimenter to collect herself, reducing the effect of daily stressors or successes on the experimenter's manner.

2.3.1 | Experimental Pain Procedure

Endogenous pain modulation was assessed with a CPM model. There are variations in the CPM protocols published and currently no gold standard for the CPM test paradigm, particularly with regard to which stimulus to use for the test stimulus and which for the conditioning stimulus (Sirucek et al. 2023). We chose to follow a previously validated test paradigm (Lie et al. 2017) that uses a tonic heat test stimulus (the second most used test stimulus [Kennedy et al. 2016]) with cold pain as the conditioning stimulus (the most commonly used conditioning stimulus [Kennedy et al. 2016]).

2.3.1.1 | Equipment Setup. Participants were seated on a comfortable chair between the testing laptop and the cold-water bath with their feet resting on a foot stool. The participants were positioned such that they were close enough to comfortably lower their arms into the water bath while seated. The testing laptop was placed in a wooden cabinet to ensure that the testing data were not visible to the participants. The testing laptop was used to run the procedure using software Sense652 (SENSELab, Somedic Sales AB, Sweden) by connecting the SENSELab Modular Sensory Analyser thermode machine (MSA thermal stimulator, Somedic, Sösdala, Sweden). A separate laptop was used to capture the heat thresholds and tolerances as well as all reported heat and cold pain intensities throughout the procedure. Pictures of the equipment setup and layout can be found in the Supporting Information.

2.3.1.2 | Static Measures of Pain. Described in detail in the following sections, the static measures of pain assessed in the study were: heat pain threshold (HPT), heat pain tolerance level (HPTL) and single-point cold pain intensity. The HPT and HPTL measures were taken and recorded during the CPM pre-test procedure. HPT was determined as the temperature at which the participant felt that the temperature from the thermode on the volar aspect of their left forearm changed from feeling warm to feeling painful. HPTL was determined as the temperature at which the participant could no longer tolerate the pain from the thermode on the volar aspect of their left forearm. The single-point cold pain intensity measure was taken and recorded immediately following the conditioning stimulus procedure. Participants were asked to rate the intensity of the pain (on an 11-point NRS anchored at '0, no pain' to '10, worst pain imaginable') in their left hand from the cold water bath.

2.3.1.3 | CPM Pre-Test Procedure—Static Measures of Heat Pain. As a pre-test, the participants' test stimulus intensity was determined by strapping a 25 × 50 mm Peltier thermode onto the participant's left thigh, such that the thermode plate (where the temperature will change) was facing upwards. The position of the thermode on the thigh needed to be such that the participant could comfortably rest the middle-to-distal volar aspect of their left forearm on the thermode. As such, the position of the thermode on the thigh varied slightly between participants, but all participants had their left arm positioned the same on the thermode. The thermode was initially at its baseline temperature of 32°C, while participants had their left arm resting on the thermode. The temperature of the thermode would increase gradually from 32°C to a maximum of 50°C. First, the participants' HPT was assessed. To eliminate any anticipatory effects, participants were told when the temperature of the thermode would start increasing. Participants were given a button to hold in their right hand and were instructed to push the button the moment that the temperature from the thermode changed from feeling 'warm' to feeling 'painful', and *that* temperature was recorded. The heat threshold procedure was repeated a total of three times, with a 10 s break between each stimulus, and an average of the three thresholds was calculated and recorded as each participant's HPT.

Next, the participants' HPTL was assessed. The same procedure as described above was performed but here participants were instructed to only push the button when the temperature from the thermode became unbearable. The participants were told when the temperature would start increasing and were reminded that the thermode would not cause any tissue damage, harm or lasting pain. The pain tolerance procedure was repeated a total of three times, with a 60 s break between stimuli and the average of the three values was calculated and recorded as HPTL. The HPT and HPTL measures were analysed for pain comparisons during our statistical analyses, and were also used to calculate an estimated test stimulus temperature for the CPM procedure using the following equation: ([HPTL − HPT]/2) + HPT (Lie et al. 2017).

The final test stimulus temperature was determined by assessing the temperature of the calculated estimated test temperature as well as temperatures 1°C above and below the estimated test temperature, creating three estimated test temperatures. Each estimated test temperature was tested three times for 5 s with a 10 s interval between each test. For this procedure, participants were asked to keep their left arm (that they previously had resting on the thermode) off the thermode while the thermode temperature was set. Once the thermode was at the required temperature, participants were instructed to rest the left proximal volar aspect of their forearm on the thermode until they were instructed to lift it again after 5 s. Participants were asked to rate the pain from the thermode during each 10 s break on an 11-point NRS anchored at '0, no pain' to '10, worst pain imaginable'. The NRS ratings for each temperature were recorded and their averages were calculated. The stimulus that had an average NRS rating closest to 6/10 was used as the final test stimulus (Lie et al. 2017). If the NRS rating for all three temperatures did not fall within 4–9, additional estimated temperatures were tested until the NRS rating fell within these parameters. The final test temperature was recorded and used as the participant's test stimulus. The CPM pre-test procedure is summarised in Figure 1.

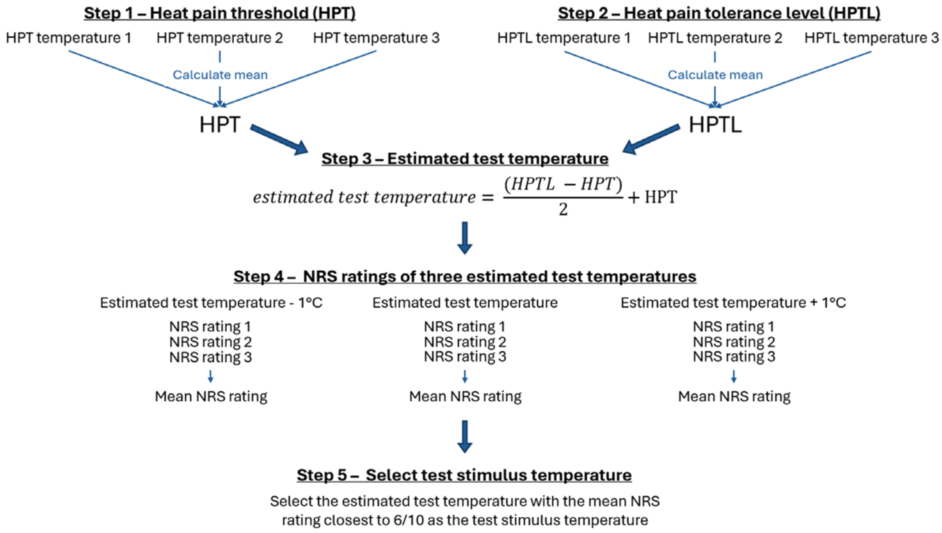

FIGURE 1 | Overview of the conditioned pain modulation pre-test procedure process. NRS, numerical rating scale.

2.3.1.4 | CPM Test Stimulus Procedure—Dynamic Measure of Pain (Cumulative Pain Load). For the test stimulus procedure, the same 25 × 50 mm Peltier thermode was placed on the right leg of the participant, face up, such that the participant could comfortably rest the distal volar aspect of their right arm on the thermode. Since the thermode was already set to the test temperature, the participant was asked not to touch the mental plate of the thermode. The participant was then instructed to rest the right volar aspect of their forearm on the thermode for 120 s, as determined using a stopwatch. The temperature of the thermode remained at the predetermined test temperature for the duration of the procedure. Every 10 s, when the word 'thermode' was spoken by the experimenter, the participant was asked to rate the pain intensity from the thermode on the 11-point NRS. A mean NRS rating was calculated and recorded for the entire 120 s period (Lie et al. 2017).

2.3.1.5 | CPM Test Stimulus With Conditioning Stimulus Procedure—Measure of the CPM Effect. Five minutes after concluding the test stimulus procedure described above, participants were asked to immerse their left hand, up to the wrist, in a water bath (ThermoFisher Scientific 19L Circulating Water Bath, Massachusetts, United States of America) of circulating 7°C water (painful cold stimulus). All participants were reminded that the cold water would not cause any tissue damage, harm or lasting pain. Participants were asked to keep their hand relaxed with slightly spread fingers to allow water contact with their whole hand. This cold water bath stimulus was the conditioning stimulus. At the same time, participants were also asked to place the distal volar aspect of their right forearm back on the thermode (the test stimulus), just as they had done for the test stimulus procedure. Participants were asked to keep both their right arm on the thermode and their left hand in the water for the full duration of 120 s, although the experimenter made it clear that they may choose to withdraw from either stimulus if they felt that they absolutely could not keep either their right arm on the thermode or left hand in the water bath. The moment that both stimuli were in position, the test stimulus procedure, as described above, was repeated in parallel with the cold water conditioning stimulus. Participants were asked to rate the pain intensity from the thermode every 10 s when the experimenter said 'thermode'. The test stimulus pain intensity ratings were recorded and then averaged in the same manner as done for the test stimulus procedure. These thermode ratings obtained from this procedure will be referred to as the test stimulus pain intensity ratings during the conditioning procedure.

2.3.1.6 | CPM Post-Test Procedure—Static Measure of Cold Pain and Measure of Experimenter Manner. After the participant's hand was withdrawn from the water at 120 s, the conditioning stimulus average pain intensity (the pain intensity in response to the cold water) was rated by the participants using the 11-point NRS (Lie et al. 2017). The intensity of the cold pain stimulus was only rated once, following the completion (or partial completion) of the CPM procedure. During the data collection, the experimenter observed that some participants seemed more apprehensive about putting their hands in the cold water than others. Since expectation is known to influence pain perception (Bjørkedal and Flaten 2012; Fields 2018) and since expectation differs across adult attachment styles (Mikulincer and Shaver 2007), part-way into data collection (after 44 participants had already completed their CPM procedure), an additional question following their rating of the cold water pain intensity was added to the protocol. The new question asked participants to rate (using the 11-point NRS) what they expected the pain intensity from the cold water to be.

2.3.2 | Post-Experiment Questionnaire

Participants were asked to fill in a customised electronic 'qualitative questionnaire' on the laptop. The questionnaire (see Supporting Information) assessed aspects of the participants' overall experience of the experiment, including open-ended questions to describe the sensations from both stimuli. These questions were added in to somewhat conceal the main aim of this post-experiment questionnaire: to determine how participants experienced the manner of the experimenter (the participants were able to choose from three options: 'Friendly', 'Neutral/Professional', 'Aloof'). This question essentially served as a check that participants perceived the experimenter's manner as neutral/professional, as was the intention. Without knowledge of the true reason for this assessment, participants were encouraged to complete this entire questionnaire with honesty.

This post-experiment questionnaire was also used to assess additional questions that were added after data collection had already started (after 44 participants had already completed the procedure). Questions were added to assess whether the heat or cold stimuli were perceived as 'threatening', together with open-ended questions asking the participants to describe their experience of both the hot and cold stimuli. During the data collection process, we realised that such questions may provide some valuable insight into any potential associations during data analysis.

2.4 | Data Analysis

All data processing and analyses were performed in the R statistical environment (v4.2.1) (R Core Team 2022), using the following packages: DHARMa (Hartig 2022), emmeans (Lenth 2022), lme4 (Bates et al. 2015), pscl (Jackman 2020), psych (Revelle 2022), sjPlot (Lüdecke 2022), tidyverse (Wickham et al. 2019) and VGAM (Yee et al. 2015). A p-value of <0.05 was considered to be statistically significant for all analyses. All data, analysis scripts and analysis script outputs are available at Figshare: 10.6084/m9.figshare.25479397.

Before calculating a general attachment score for both attachment anxiety and attachment avoidance, to ensure that there were no significant differences in attachment dimensions between the attachment figures, we used a repeated measures ANOVA (F(df_between, df_within) = F-value) to assess the difference in the attachment dimension scores for both attachment anxiety and attachment avoidance between the four attachment figures. We conducted a factor analysis (see Supporting Information) to determine the best method with which to handle the ECR subscales and determined that a two-factor solution, that is using anxiety and avoidance dimensions, was best.

Descriptive data were reported as total number (N) and percentages (%) for categorical data and median [IQR] for skewed continuous data. For analysis between attachment dimensions (attachment anxiety or attachment avoidance) and categorical variables (including completion of the CPM procedure and experimental manner), a logistic regression was run. Results from the logistic regression models were reported as odds ratios and crude estimates (95% confidence interval [CI]). Additionally, linear regressions were run between the attachment dimensions (attachment anxiety or attachment avoidance) and continuous variables (including depression, anxiety, heat pain threshold and tolerance temperatures, pain intensity ratings and the CPM effect percentage). The linear regression model results were reported as Estimate [95% CI].

Data from all participants ($n = 103$) were analysed in the models run between attachment dimensions (either attachment anxiety or attachment avoidance) and psychological variables, experimenter manner, single-point pain measures (heat pain threshold, tolerance and cold pain intensity) and pain intensity of the test stimulus (both the average pain intensity as well as the pain intensity over time for the cumulative pain load). Only data from participants who had completed the full CPM procedure ($n = 80$) (kept their hand submerged in the cold water bath for the full duration of 120 s) were analysed in the models run between adult attachment dimension and the CPM effect (defined efficacy of endogenous analgesia, taken as the difference between the test stimulus pain intensity rating prior to conditioning and the test stimulus pain intensity ratings during conditioning, as described in more detail below).

Prior to assessing the CPM effect, univariate analyses were run by performing a linear regression to compare the heat pain thresholds and tolerances and average intensity over 120 s between the secure and insecure adult attachment styles. Since the CPM effect is calculated as the difference between the test stimulus thermode pain intensity before and during the conditioning stimulus procedure, a difference in the perception of the pain intensities was determined before investigating the efficacy of the descending pain inhibiting pathways by looking at the CPM effect. The average pain intensity rating from the thermode test stimulus prior to the conditioning procedure was determined by calculating the mean of each individual rating, which was given every 10 s for 120 s.

A linear regression model was first run with pain intensity prior to conditioning as the outcome and time as the predictor, to estimate the cumulative pain load of the test stimulus. The adult attachment dimensions (anxiety and avoidance) were then added to the model, and a multiple linear regression was conducted to examine whether attachment moderated the relationship between time and cumulative pain load.

Following a predefined protocol, the absolute CPM effect was defined as the difference in pain ratings from the thermode test stimulus pain ratings before the conditioning procedure compared to the thermode test stimulus pain ratings during the conditioning procedure (Absolute CPM effect = pain rating from thermode test stimulus prior to the conditioning procedure—pain rating from thermode test stimulus during the conditioning procedure) (Lie et al. 2017). The CPM effect was further calculated as a percent change of the thermode test stimulus rating prior to conditioning (CPM effect percentage = [absolute CPM effect/thermode test-stimulus rating prior to conditioning] × 100) (Lie et al. 2017). The calculation of CPM effect in this manner has been recommended by pain researchers (Yarnitsky et al. 2015). The CPM percentage was used for analyses and linear regression was run to determine the association between adult attachment dimension (attachment anxiety or attachment avoidance) and the CPM effect.

A linear regression model was also run between the thermode test stimulus pain intensity ratings every 10 s prior to conditioning and the thermode test stimulus pain intensity ratings every 10 s during the conditioning procedure. This linear regression was used to determine whether there was an overall pain inhibition in the participants and whether the adult attachment dimensions moderated the relationship between the thermode test stimulus pain intensity ratings prior to and during the conditioning procedure.

We examined the relationship between the adult attachment dimensions (attachment anxiety and avoidance) and threat perception (using a logistic regression) as well as the CPM effect (using a linear regression). Additionally, we aimed to determine if there was any difference in the range of attachment dimensions (attachment anxiety and avoidance) between healthy females in a general population and those who participated in the experimental study. We compared the attachment dimension scores between the participants from this present study and the chronic pain-free female participants from our previous nationwide online survey (Stamp et al. 2025). Welch Two Sample *t*-tests were run to determine the difference in the attachment anxiety scores and the difference in the attachment avoidance scores between the two samples.

3 | Results

The process of recruitment and exclusion is summarised in Figure 2. A total of 103 participants were included in the analyses of the static measures (heat pain threshold and tolerance, and cold pain intensity) and the dynamic measure of cumulative heat pain intensity from the CPM procedure. Only 80 participants completed the entire CPM procedure (kept their hand in the cold water bath for the full duration of 120s) and were included in all primary analyses of the CPM effect.

The age of the participants ranged from 18 to 44 years, with a median [IQR] of 21 [20–23] years. All participants included in the analyses ($N = 103$) had, at least, completed secondary education, with 44% (45 of 103) of the participants having completed their undergraduate university degree. The annual household income was greater than ZAR19 200,00 (considered as middle and high-income households (Statistics South Africa 2011)) for 73% (75/103) of the participants. More details of the sample are described in Table 1.

No difference in attachment anxiety dimension scores was found between the four attachment figure types ($F(3, 404) = 1.864$, $p = 0.135$). There was a main effect of attachment figures on the attachment avoidance dimension scores ($F(3, 404) = 5.95$, $p < 0.001$), but the main effect size was small ($\eta^2 = 0.0423$) with 4.23% of the variance in the attachment avoidance dimensions explained by the attachment figure type. As such, global attachment dimensions were used for analysis.

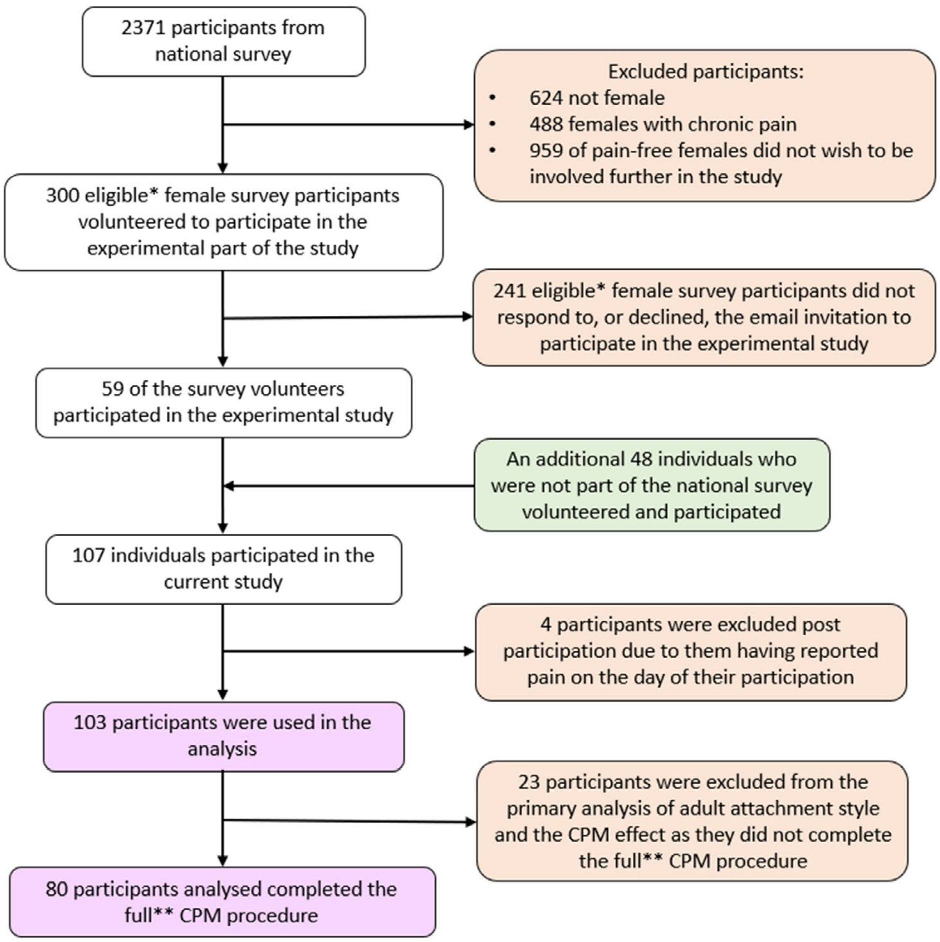

FIGURE 2 | Outline of the process and numbers of volunteers, details of screening exclusion, the final number of participants in the study, and those participants included in the analyses. CPM, conditioned pain modulation. *To be eligible for participation in the study, volunteers needed to be female, 18 years old or above and not have chronic pain. **Only data from participants who had completed the CPM procedure (kept their hand in the conditioning cold water bath pain stimulus for the full 120s) were included in the primary analysis between adult attachment style and the CPM effect.

TABLE 1 | Demographic frequency data and adult attachment style proportions in the female participants who participated in ($N=103$), and completed ($N=80$), the conditioned pain modulation procedure.

Characteristic	Total sample *N* (%)	Completed CPM sample *N* (%)
Race/Ethnicity		
Asian	2 (2)	2 (3)
Black	61 (59)	42 (53)
Indian	12 (12)	10 (12)
Mixed race	4 (4)	4 (5)
White	23 (22)	21 (26)
Other	1 (1)	1 (1)
Annual household income		
No income (ZAR 0,00)	4 (4)	4 (5)
Low income (ZAR 1,00–ZAR 19 200,00)	24 (23)	21 (26)
Middle income (ZAR 19 201,00–ZAR 307200,00)	46 (45)	34 (43)
High income (> ZAR 307 200,00)	29 (28)	21 (26)
	Total sample	**Completed CPM sample**
	Median [IQR]	**Median [IQR]**
Attachment dimensions[a]		
Attachment anxiety	2.67 [1.83–3.54]	2.62 [1.81–3.50]
Attachment avoidance	3.08 [2.35–3.79]	3.08 [2.33–3.73]

Abbreviations: IQR, Interquartile range; ZAR, South African Rand.
[a]Adult attachment style was assessed using the Experience in Close Relationships—Relationship Structures (ECR-RS) Questionnaire (Fraley et al. 2011).

3.1 | CPM Completion, Perception of Experimenter's Manner and Psychological Variables

Before assessing the pain variables, we explored whether attachment anxiety and attachment avoidance dimensions were predictors for the (i) number of individuals who completed the CPM procedure, (ii) the assessment of the experimenter's manner, and (iii) psychological variables of depression, anxiety and pain catastrophising. The experimenter manner was rated as 'Neutral/Professional' by 81% (83 of 103) of the participants, while the remaining 19% (20 of 103) rated the experimenter manner as 'Friendly'. None of the participants rated the experimenter as 'Aloof'. Neither attachment anxiety (Odds Ratio [95% CI] = 0.93 [0.60–1.46], $p=0.747$) nor attachment avoidance (Odds Ratio [95% CI] = 0.84 [0.52–1.36], $p=0.469$) were predictors of experimenter manner. Similarly, neither attachment dimension predicted the completing of the CPM procedure (Anxiety: Odds Ratio [95% CI] = 0.94 [0.61–1.44], $p=0.765$; Avoidance: Odds Ratio [95% CI] = 0.88 [0.55–1.39], $p=0.571$). For the psychological variables, both attachment dimensions were associated with depression (Anxiety: Estimate [95% CI] = 3.63 [1.75–5.51], $p<0.001$; Avoidance: Estimate [95% CI] = 3.17 [1.08–5.27], $p=0.003$) and anxiety (Anxiety: Estimate [95% CI] = 3.15 [1.70–4.59], $p<0.001$; Avoidance: Estimate [95% CI] = 2.56 [0.93–4.19], $p=0.002$), while only the attachment anxiety dimension was associated with pain catastrophising (Anxiety: Estimate [95% CI] = 2.59 [0.65–4.54], $p=0.009$; Avoidance: Estimate [95% CI] = 1.81 [−0.35 to 3.97], $p=0.099$).

3.2 | Were the Pain Stimuli Considered 'Threatening'?

Of the additional questions added to the post-experimental pain procedure questionnaire partway into the data collection (after 44/103), two questions asked whether the participants perceived the heat and cold pain stimuli as 'threatening'. Of the 59 participants who answered the questions about perceived threat, 22% (13/59) found the heat pain to be threatening and 76% (45/59) found the cold pain to be threatening. Attachment dimension, however, was not a predictor of perceiving either the heat stimulus (Anxiety: Odds Ratio [95% CI] = 1.05 [0.59–1.83], $p=0.872$; Avoidance: Odds Ratio [95% CI] = 0.90 [0.45–1.66], $p=0.737$) or cold stimulus (Anxiety: Odds Ratio [95% CI] = 0.72 [0.41–1.24], $p=0.237$; Avoidance: Odds Ratio [95% CI] = 0.64 [0.34–1.15], $p=0.137$) as threatening. There was no interaction between attachment anxiety and attachment avoidance for either perception of heat pain (Odds Ratio [95% CI] = 0.81 [0.40–1.47], $p=0.509$) or perception of cold pain (Odds Ratio [95% CI] = 1.31 [0.74–2.49], $p=0.379$).

3.3 | Static Measures of Pain (Heat Threshold, Heat Tolerance and Cold Pain Intensity)

Heat pain threshold temperature was not associated with attachment anxiety (Estimate [95% CI] = −0.06 [−0.61 to 0.49], $p=0.837$) or attachment avoidance (Estimate [95% CI] = −0.00 [−0.60 to 0.59], $p=0.992$) (Figure 3a). Heat pain tolerance temperature was also not associated with attachment anxiety (Estimate [95% CI] = 0.04 [−0.24 to 0.33], $p=0.761$) or attachment avoidance (Estimate [95% CI] = −0.07 [−0.38 to 0.24], $p=0.651$) (Figure 3b). There was no association between single-point cold pain intensity and either attachment anxiety (Estimate [95% CI] = 0.01 [−0.23 to 0.25], $p=0.907$) or attachment avoidance (Estimate [95% CI] = −0.18 [−0.44 to 0.07], $p=0.161$) (Figure 3c).

In the participants who answered the expected cold pain question (59/103 [57%]), there was also no association between expected cold pain intensity rating and either attachment anxiety (Estimate [95% CI] = 0.12 [−0.29 to 0.53], $p=0.553$) or

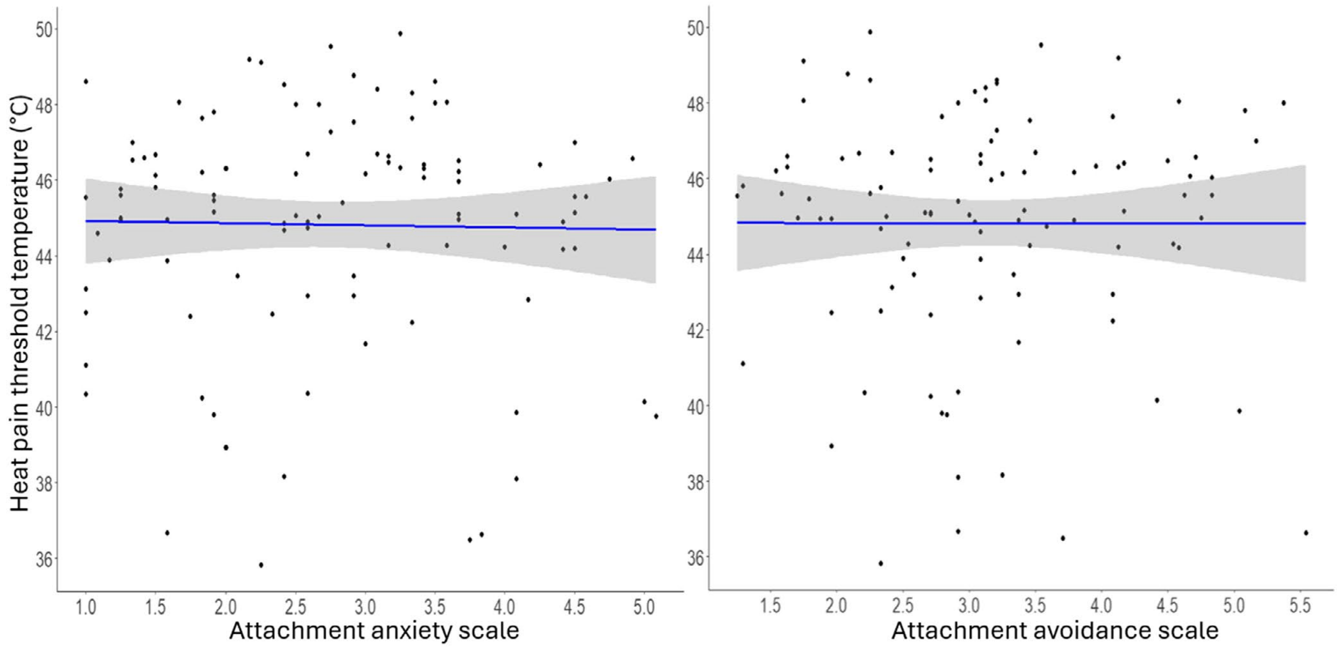

FIGURE 3 | Heat pain threshold temperatures for the attachment anxiety (left) and attachment avoidance (right) dimensions ($N = 103$). A blue regression line with a grey band representing the 95% confidence interval is shown on the scatterplot.

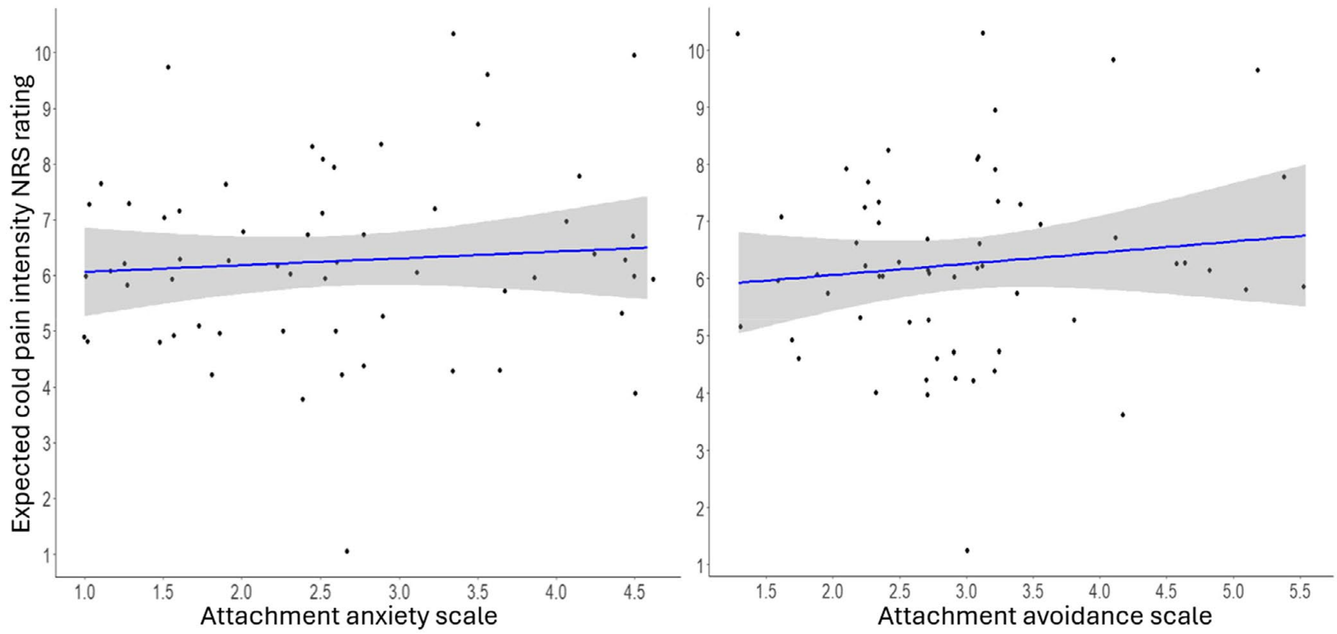

FIGURE 4 | Expected cold pain intensity ratings for the attachment anxiety (left) and attachment avoidance (right) dimensions ($N = 103$). A blue regression line with a grey band representing the 95% confidence interval is shown on the scatterplot. NRS, numerical rating scale.

attachment avoidance (Estimate [95% CI] = 0.20 [−0.26 to 0.65], $p = 0.392$) (Figure 4).

3.4 | Dynamic Measures of Pain (Cumulative Pain Load and Conditioned Pain Modulation)

Before investigating the relationship between adult attachment style and endogenous analgesia (using the CPM effect), we explored the possible relationships between the two attachment dimensions and the cumulative pain load of the test stimulus heat pain intensity over the 120 s of the test stimulus procedure.

For the participants overall, the reported test stimulus pain intensity increased over time (Estimate [95% CI] = 0.01 [0.00–0.01], p-value < 0.001). Higher attachment anxiety was associated with an increase in pain intensity over time (Estimate [95% CI] = 0.15 [0.06–0.25], p-value = 0.002), but attachment avoidance was not associated with pain intensity over time (Estimate [95% CI] = 0.03 [−0.08 to 0.13], p-value = 0.631).

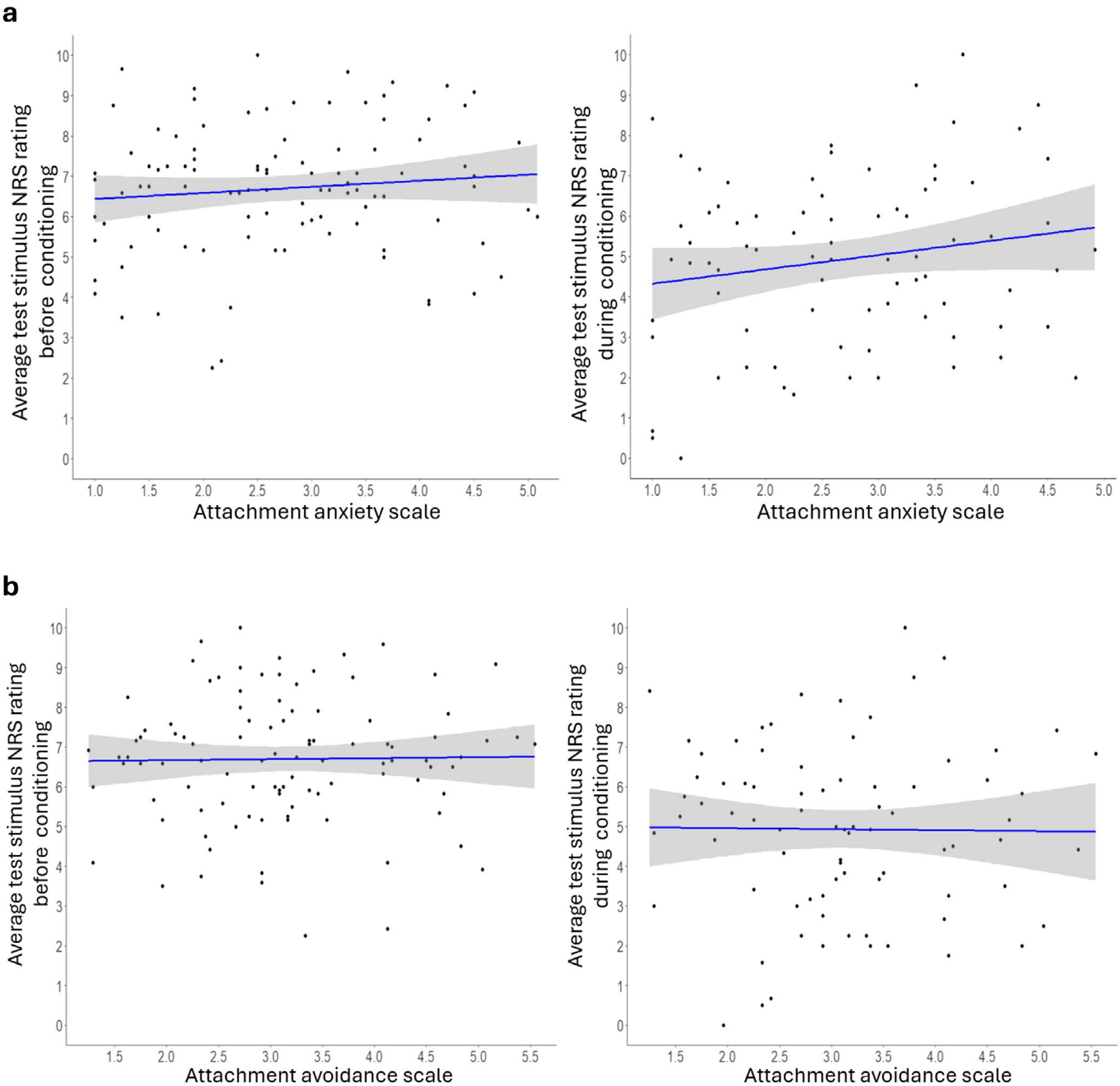

FIGURE 5 | Average test stimulus pain intensity rating before (left) [$n=103$] and during (right) [$n=80$] conditioning across the anxiety (a) and avoidance dimensions (b). The average test stimulus pain intensity rating prior to conditioning was calculated by finding the mean for each test stimulus rating prior to conditioning over the 120 s test stimulus prior to conditioning phase. A blue regression line with a grey band representing the 95% confidence interval is shown on the scatterplot. NRS, numerical rating scale.

Moreover, higher attachment anxiety was associated with an increased average test stimulus pain intensity rating both before (Estimate [95% CI] = 0.15 [0.07–0.23], *p*-value < 0.001) and during (Estimate [95% CI] = 0.36 [0.23–0.48], *p*-value < 0.001) conditioning (Figure 5a). However, attachment avoidance was not associated with test stimulus pain intensity ratings, either before (Estimate [95% CI] = 0.03 [−0.06 to 0.11], *p*-value = 0.574) or during (Estimate [95% CI] = −0.02 [−0.16 to 0.11], *p*-value = 0.709) conditioning (Figure 5b). Attachment anxiety and attachment avoidance displayed an interaction for the test stimulus pain intensity rating before (Estimate [95% CI] = −0.12 [−0.21 to −0.04], *p*-value = 0.003) but not during (Estimate [95% CI] = 0.11 [−0.01 to 0.23], *p*-value = 0.080) conditioning.

Out of the 80 of 103 (78%) participants who had completed the CPM procedure and, therefore, had a calculated CPM effect, eight participants (10%, 8/80) had a CPM facilitatory effect (pain rating from the thermode increased in the CPM test stimulus with conditioning stimulus procedure, i.e., when the cold pain from the water bath was simultaneously added to the heat pain from the thermode) rather than an inhibitory effect. Thus effective CPM was seen in 90% (72/80). All participants were still included in the analysis, regardless of the direction of the CPM effect, since the CPM effect variable was analysed as a continuous variable. As such, these 80 participants formed a complete-case model on which the CPM analysis was run. There was no association between the CPM effect and either

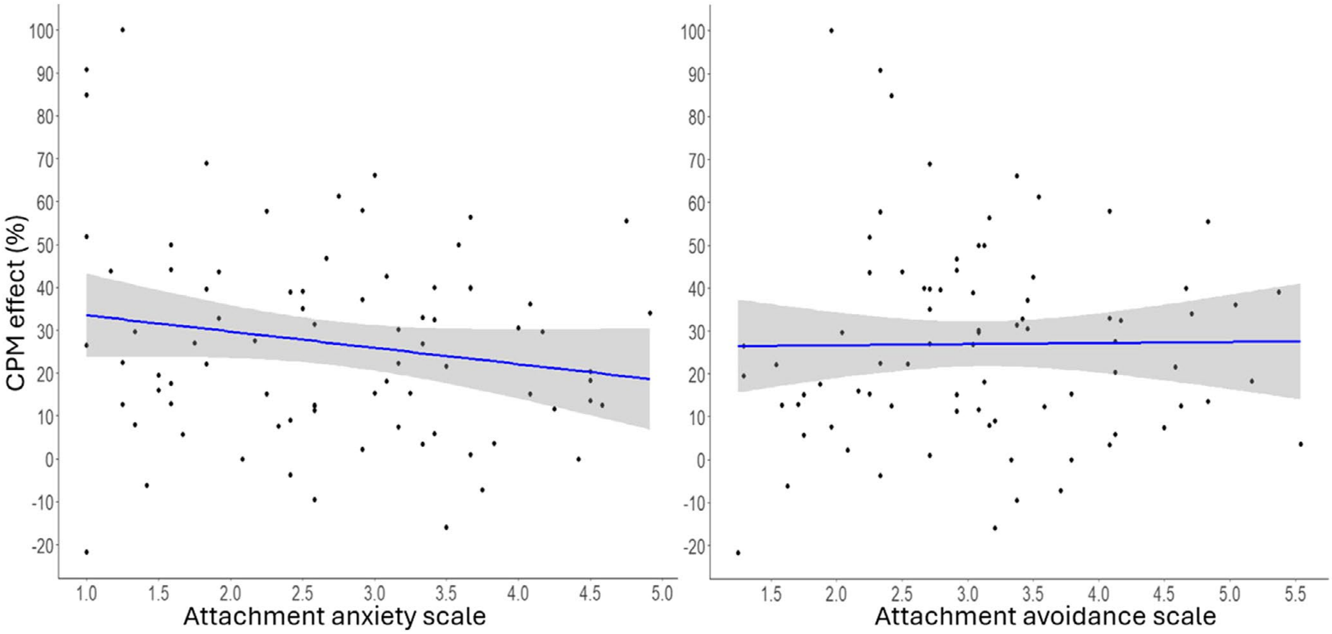

FIGURE 6 | Conditioned pain modulation (CPM) effect as a percentage for the attachment anxiety (left) and attachment avoidance (right) dimensions ($n=80$). A blue regression line with a grey band representing the 95% confidence interval is shown on the scatterplot.

attachment anxiety (Estimate [95% CI] = −3.79 [−8.62 to 1.03], $p=0.122$) or attachment avoidance (Estimate [95% CI] = 0.25 [−4.88 to 5.38], $p=0.923$) (Figure 6). Additionally, no interaction between attachment anxiety and attachment avoidance was found for the CPM effect (Estimate [95% CI] = −1.27 [−6.05 to 3.52], $p=0.600$).

3.5 | Analysis of Attachment Dimensions of Who Participated in the Study

Between the participants who participated in the present study ($n=103$) and the chronic pain-free female participants from our previous survey study ($n=1259$) (Stamp et al. 2025), we noted significant differences in the scores for the attachment anxiety dimension ($t(119.52)=2.25$, $p=0.026$, mean difference [95% CI] = 0.25 [0.03–0.48]). The attachment anxiety scores for the survey sample ranged from 1 to 7, compared with the CPM sample attachment anxiety scores that ranged from 1 to 5.1. Moreover, between the two samples, there was also a significant difference in the scores of the attachment avoidance dimension ($t(116.41)=2.07$, $p=0.041$, mean difference [95% CI] = 0.21 [0.01–0.42]). The attachment avoidance scores for the survey sample ranged from 1 to 6.1, compared with the CPM sample attachment avoidance scores that ranged from 1.3 to 5.5 (Figure 7).

4 | Discussion

Our study on experimental pain and adult attachment aimed to determine whether, in a neutral social context, there is a difference between anxious and avoidant attachment dimensions in healthy, pain-free females for (i) static measures of thermal pain (heat pain threshold, heat pain tolerance, and cold pain intensity), (ii) cumulative pain load, (iii) the CPM effect (a dynamic measure of endogenous analgesia and pain inhibitory pathways). Our study is the first to assess the association between adult attachment style and CPM and has a larger sample size than other CPM studies. We controlled the social context by creating an engagement that was professional and neutral (neither warm nor cold, and with a standardised script). We also accounted for the known effects of experimenter sex on the perception of pain by ensuring that both the experimenter and participants were female (Levine and De Simone 1991). We found no associations between attachment dimensions and static measures of pain. We did find higher attachment anxiety to be associated with increased cumulative pain load; however, there were no associations between attachment dimensions and the CPM effect. Indeed, 90% of individuals displayed a CPM effect demonstrating the success of the CPM test paradigm and showing effective inhibitory pain pathways.

We found no association between adult attachment style and static experimental measures of thermal pain (heat pain threshold and tolerance or cold pain intensity). No consistent relationship or consistent direction of effect is evident between adult attachment and experimental pain perception in healthy pain-free participants [see (Meredith 2013) for review]; likely due to varying experimental protocols, each with different social contexts. For example, insecurely attached individuals with low belief in self to cope with challenges, reported reduced heat pain intensities in the presence of an empathetic stranger (Sambo et al. 2010), but increased cold pain thresholds when socially excluded (MacDonald 2008). We used a neutral social context and found no difference in threshold or tolerance to heat or intensity of cold pain. Our negative findings may support the idea that associations between attachment and pain may be more dependent on social context than the stimulus, and this hypothesis warrants further research.

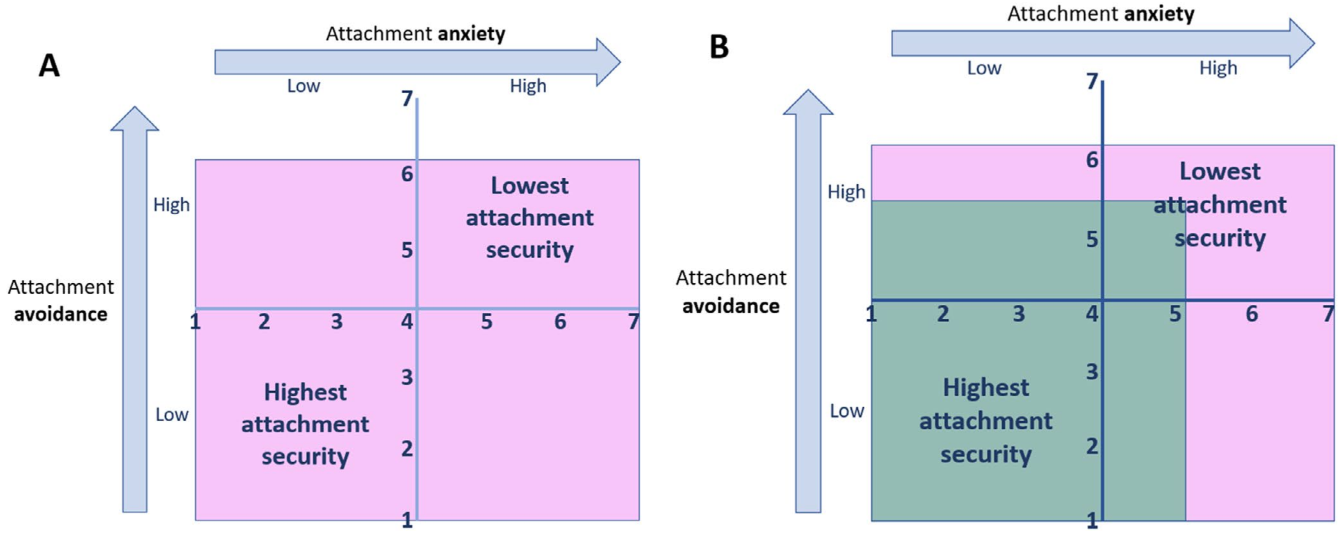

FIGURE 7 | Comparison in the attachment dimensions scores for the chronic pain-free females in the general population from the survey data (Stamp et al. 2025) and the pain-free females that participated in our present experimental study. Panel A shows the standard attachment dimension scores ranging from 1 to 7 (x-axis: attachment anxiety, y-axis: attachment avoidance) and attachment style quadrants. Panel A also shows a visual representation (pink square) of the distribution of attachment dimensions scores for the chronic pain-free females from the general population who completed the survey (Stamp et al. 2025) (maximum anxiety score: 7; maximum avoidance score: 6.1). Panel B has the same components of panel A but overlaid with the range of dimension scores for the pain-free females who participated in the experimental study (green) (maximum anxiety score: 5.1; maximum avoidance score: 5.5).

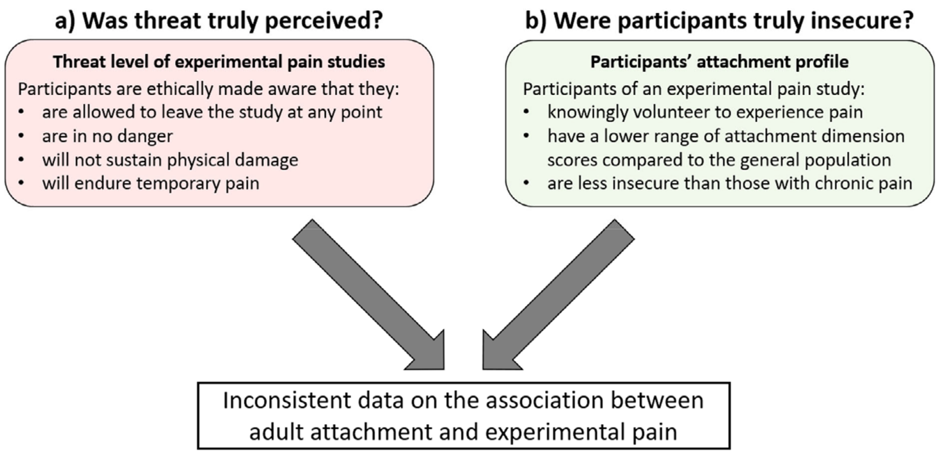

FIGURE 8 | Summary of the potential reasons for the absence of associations in the present experimental pain study, and most likely other experimental pain studies. Reason (a) Since perceived threat is a requirement for the activation of the attachment system (Bowlby 1969; Mikulincer and Shaver 2007), there is a possibility that the participants did not feel 'threatened' or 'stressed' during the experimental pain procedures (whether the threat perception originated from the experimental pain, the social (laboratory) environment or the experimenter's manner). Reason (b) suggests that even if a threat is perceived and the attachment system is activated, healthy pain-free participants partaking in experimental pain studies may not be as 'insecure' as those in the general and chronic pain populations (Mohr et al. 2018).

We found no association between adult attachment dimensions and CPM. It is, therefore, possible that there is no difference in endogenous analgesia across attachment anxiety and avoidance dimensions in healthy, pain-free individuals. Since individuals with chronic pain have been found to have an impaired CPM effect (Damien et al. 2018; Nir and Yarnitsky 2015), and an insecure adult attachment style is associated with greater chronic pain prevalence (Stamp et al. 2025), our results may support impaired endogenous analgesia not as the cause, but rather the result, of chronic pain development. In addition, we did find higher attachment anxiety to be associated with cumulative pain load suggesting that attachment may modulate pain. Therefore, we believe that impaired endogenous analgesia should not be ruled out as a potential mechanism underlying the relationship between insecure attachment and chronic pain, as there may be subtleties in the relationship between the attachment anxiety dimension and other pain outcomes, such as chronicity and severity of chronic pain. Given that this is the first study of its kind, it would be worth replicating a similar protocol in both a neutral and more threatening social context before excluding endogenous descending pain inhibition as a mechanism underlying the increased prevalence of chronic pain in people with an insecure attachment style.

We propose two hypotheses explaining the absence of significant differences between attachment styles and pain in this study (Figure 8). Firstly, the threat level of our experimental study may have been insufficient to activate the attachment system (Bowlby 1969; Mikulincer and Shaver 2007). Less than a quarter of the participants perceived the heat pain as threatening, and just over three quarters of the participants perceived the cold-water stimulus as threatening. More specifically, most (76%) of the participants only felt threatened in the last 5 min of the CPM procedure rather than during the entire protocol (approximately 40 min), suggesting a possible delayed activation, if any, of the attachment system. Moreover, we found no difference in the threat perception across attachment anxiety and avoidance dimensions for either stimulus. As such, our protocol may not have been 'threatening enough' to activate the attachment system. We hypothesize that experimental pain protocols like ours—not threatening enough to activate the attachment systems—may prevent the detection of an association between attachment and pain perception. Probably unlike chronic pain, our data support the notion that experimentally induced pain may not consistently evoke perceived threats, thereby not ensuring activation of the attachment system (Bedwell et al. 2022). The use of subjective or, even better, objective measures of threat like heart rate, heart rate variability, blood pressure or salivary cortisol (Kim et al. 2018; Kirschbaum et al. 1993; Smeets et al. 2012; Yao et al. 2016) has not been used in previous studies investigating attachment and experimental pain (Hurter et al. 2014; Krahé et al. 2015, 2016; MacDonald 2008; Meredith et al. 2006b; Mohr et al. 2018; Rowe et al. 2012; Sambo et al. 2010), and we suggest this is an important methodological consideration.

Our second hypothesis for the absence of significant findings involves the profile of attachment dimensions in our participants, and their relative 'security'. Other studies have shown samples participating in experimental pain studies to be more securely attached than those of similar, but separate, samples from the general population (Krahé et al. 2015; Mohr et al. 2018). The advantage of our study was that we invited women from our national survey (Stamp et al. 2025) to the experimental study and so, whilst there were additional people who participated only in the experiment, the comparison of attachment dimensions gives us a clearer picture of who remained, and who exited, the study; specifically in terms of attachment style, compared with other studies that used representative but separate samples. An exploratory analysis comparing the attachment dimensions (attachment anxiety and attachment avoidance) of the sample of pain-free females that completed the survey ($N = 1259$), with those that participated in the experimental study here ($N = 103$) showed that the women who participated in the experimental study had greater attachment security than those who completed the survey (Figure 7).

Clearly experimentally-induced pain is vastly different from chronic pain, where chronic pain is commonly accompanied by co-morbidities and poorer psychosocial factors, but we highlight two significant factors for future studies: (i) in the context of attachment in pain research, even if experimental pain protocols are threatening enough to activate the attachment system, those who volunteer and who proceed to experimental pain studies may not be 'insecure enough' (have sufficient range of attachment dimensions) to detect differences in responses to painful stimuli across attachment styles. Secondly, (ii) in the broader context of experimental pain studies, the differences between experimental and clinical studies may be due to experimental study participants being more securely attached than those with chronic pain participating in clinical studies. Given the overlapping brain regions involved in both attachment activation and pain processing (Stamp et al. 2024), and given the consistent association between chronic pain and attachment style (Meredith and Strong 2019), further research is needed to understand the relationship between pain and adult attachment and whether this understanding can provide useful information in the clinical setting (Stamp et al. 2024). We believe, therefore, that assessing and reporting attachment style is important in all pain studies (Stamp et al. 2024).

4.1 | Limitations

It is worth noting that there is an absence of validation of the standardised questionnaires, specifically the ECR-RS, in a South African population. Additionally, the ECR-RS is not frequently used in attachment and experimental pain literature, which may hinder cross-literature comparisons; however, the ECR-RS is a condensed version of the ECR-R and so is comparable to the ECR-R (Fraley et al. 2011). Additionally, we felt the ECR-RS was the best option for an early-adult sample, as it assesses four key attachment relationships rather than relying on participants to imagine a romantic relationship, that they might not yet have had. The experimental sample consisted predominantly of undergraduate university students who were familiar with the campus and the building where the experiment took place. This poses two factors worth considering: (1) the sample was homogenous and not representative of the general population, and (2) the familiar environment may have further reduced the overall threat value of the experiment. It could be argued that the cold pain stimulus may have acted as a distraction, thus simulating a CPM effect without engaging physiological mechanisms independent of distraction (Moont et al. 2010). However, a previous study (that used contact heat as the test stimulus and cold water as the conditioning stimulus) showed an additive effect of distraction and CPM (Moont et al. 2010).

In conclusion, this was the first study to explore CPM and attachment in healthy, pain-freefemales. We found no associations between static measures of pain or CPM effect, and attachment dimensions in a neutral social context. A CPM effect was demonstrated in 90% of the cohort completing the procedure showing effective inhibitory pain pathways. The direction of effect between the presence of chronic pain and impaired CP is unknown, but these results suggest that impaired endogenous analgesia may develop from chronic pain, rather than cause chronic pain. Also, in light of a recent, and we believe important, call to consider attachment style in pain research (Stamp et al. 2024), we offer a nuanced perspective into the constraints of current experimental pain and attachment studies, namely the skewed attachment dimensions of those volunteering to take part in pain experiments.

Author Contributions

G.E.S. analysed all the results, created all tables and figures, and compiled the manuscript. S.I. and A.L.W. discussed the results and extensively commented on and edited the manuscript. All authors made substantial inputs to the study design.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** ejp70172-sup-0001-supinfo.docx.