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ORIGINAL RESEARCH

Negative Emotional Influences on Pressure Pain Thresholds: Findings from a Quasi-Randomized Controlled Trial

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Objective: Human emotions could affect pain perception, but knowledge from well-powered experiments about how different emotions affect pressure pain thresholds (PPTs) in pain-free individuals are missing. The aim of this quasi-randomized control trial was to investigate the effect of different emotional states on PPTs in four different body locations (upper, right m. trapezius; upper, left m. trapezius; right m. tibialis anterior; left m. tibialis anterior).

Methods: Pain-free participants (n = 152) were assigned to four different emotional states (negative n = 38; positive n = 38; distraction control n = 38; control n = 38). Baseline PPTs in each group were measured after a neutral video clip following emotional state induction with video clips (negative; positive; distraction control; control). PPTs were again measured after emotion induction.

Results: The main finding was that negative emotion induction significantly lowered PPTs in the m. trapezius and m. tibialis anterior on the left side of the body after correction for multiple comparisons. PPTs were also significantly lower in the left m. tibialis anterior in the distraction control group. No other significant differences in PPT levels were found.

Conclusion: Negative emotions, but not positive emotions, could significantly lower PPTs in the left m. trapezius and the left m. tibialis anterior in healthy individuals. A practical implication may be that negative emotions might negatively affect pain states through descending pain modulation.

Keywords: pain, emotion, pressure pain thresholds, pain thresholds

Introduction

From a psychophysiology perspective, pain and negative emotions are intertwined, and negative emotions accompany painful experiences,[1,2] and the brain dynamically reflects clinical pain states, where emotional networks are related to the central mechanisms in chronic pain states.[3] The descending pathway from the brain to the spinal dorsal horn reflects the ability of higher brain centers to inhibit ascending pain signals. Thereby, the activity in the descending system could affect the perception of ascending nociceptive information by inhibiting less ascending pain signals, thereby increasing the ascending flow of painful signals.[4,5] The more anticipated anxiety for experimental pain, the higher the pain intensity ratings and the more activation in brain stem areas.[6] Negative emotions decreased pain tolerance and increased pain intensity ratings in pain-free individuals.[7] The nociceptive flexion reflex was significantly increased during negative emotions but inhibited during positive emotions, where pain ratings were also significantly decreased.[8,9] The nociceptive flexion reflex is a physiological, reliable and objective measure of pain perception.[10,11] Pain ratings (pain intensity, pain tolerance) were lower in response to positive emotions in some studies[12,13] but affected perceived unpleasantness but not pain intensity in another study.[14] Pain ratings were higher during a negative emotion condition compared to a positive emotion condition[15] Other studies reported that negative associations between depression, psychological distress variables and sensitized PPTs have been reported both in pain-free individuals and in individuals with chronic pain.[16,17] Concluding the above-mentioned studies, there is some support that emotions influence pain perception. In a meta-analysis it was concluded that positive emotions attenuated pain perception, while the link between negative emotions and pain

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exacerbation was less clear.[12,13] To the best of our knowledge, no earlier study has examined the effect of emotions on PPTs in a well-powered experimental setting. In an experimental setting, causation could be established and the reflection of sensory modulation from higher brain centers could be investigated when measuring PPTs.[4] We aimed to examine the effect of emotions on PPTs in a well-powered, experimental setting with two different control conditions (distraction control and control). We hypothesized that positive emotions would elevate PPTs to specific body locations m. trapezius and m. tibialis anterior within subjects (pre-post measure), and negative emotions would lower PPTs at specific body locations m. trapezius and m. tibialis anterior within-subjects (pre-post measure) in pain-free participants.

Materials and Methods

Participants

This study with a quasi-randomized trial (RCT) design targeted healthy individuals. Participants were university students and staff from a University in Southern Sweden. Inclusion criteria were above 18 years of age and fluency in Swedish. Exclusion criteria were pain anywhere in the body during the test session and known self-reported neurological disease. In total, 152 participants (128 students and 24 staff members) participated in this study. The majority 60.1% (n = 105) were female and 30.9% (n = 47) were male. The mean age was 27.7 (SD = 11.27, min-max 18–71 years). Participants were successively recruited from September 2023 to May 2024. They were informed that the study was about different emotional states and sensitivity to pressure in different body parts and inclusion and exclusion criteria were checked. If inclusion and exclusion criteria were met, a test session was scheduled. Each participant was assigned to the next condition in turn for their test session in a pre-fixed order. Conditions were in the following order: condition 1 negative emotion induction (n = 38); condition 2 positive emotion induction (n = 38); condition 3 distraction control (n = 38); condition 4 mind-wandering control (n = 38). The participants did not know that different conditions existed and therefore did not know to which condition they were assigned. The main author (female) of this article was the principal investigator and guided the test procedure. The principal investigator knew to which condition each participant was assigned. Therefore, the study was single blinded since the participants knew only that they would be watching short videos during the test session. They did not know that different videos existed or that different participants were assigned to watch different videos. Participants were recruited through digital and paper advertisements at a university in Southern Sweden. All scheduled participants completed the experimental session.

The study was approved by the Swedish Ethical Review Authority (code: 2023–03968-01). The study was registered in clinicaltrials.gov (ID: NCT06074575).

Experimental Protocol

At the test session, the participant was comfortably seated in a quiet laboratory setting, received written information about the study and signed the informed consent form. Information about age, gender and education/work title were collected. The algometer functions with the handheld signal button were demonstrated with instructions to press the signal button when the pressure turned into an uncomfortable sensation (clarified with a written sign on the table in front of the participant). Practice PPT measurements on the participants left hand between os metacarpale 2 and os metacarpale 3 were conducted until the participant had grasped the pain threshold sensation and the signal button function. Usually, 1–3 pressure trials were needed. To ensure a neutral mood in all participants at the baseline PPT measurement, a neutral one-minute video was presented to all participants. Immediately after, three consecutive PPT measurements were conducted in the following order: left m. trapezius, right m. trapezius, left m. tibialis anterior and right m. tibialis anterior. Directly after this, valence and arousal regarding the one-minute video-clip were estimated on the Self-Assessment Manikin Scale. The difference between valence and arousal was explained in text and writing to each participant to ensure a valid measurement. Following this, one of the videos matching each condition (condition 1 negative emotion; condition 2 positive emotion; condition 3 distraction control) was presented for 2.20 minutes. In the control condition, the participants were instructed to wait in silence for 2.20 minutes, without any instructions about how to engage their thoughts. Immediately following the presented video or waiting time, three consecutive PPT-values were again conducted in the body location order described above. Directly after this, another estimation of the valence and

arousal level regarding the 2.20 minutes video-clip on the self-assessment manikin scale was conducted. A short debriefing where the participant received a movie ticket for participating ended the session (Figure 1).

Pressure Algometry

A manual Somedic algometer (Somedic AB, Sweden), with a tip size area of 1 cm^2 and an application rate of 30 kPa/s was used to measure the Pressure Pain Thresholds (PPTs). The application rate and tip size area were chosen from an earlier study.[18] For every PPT measurement, three consecutive values were measured, and the mean of the three values was used in statistical analysis. Directly after the baseline and the induction video, the first of the three consecutive PPT values was measured in the left m. trapezius and the PPT value was written down in the protocol, then the second PPT of the consecutive values was measured in the left m. trapezius and the PPT value was written down in the protocol, and then the last PPT value for that location was measured and written down in the protocol. Then, the experimenter started to measure the three consecutive measurements at the right m. trapezius following the same routine; then the three consecutive measures were conducted on the left m. tibialis anterior following the same routine, and then the three consecutive measures were conducted on the right m. tibialis anterior following the same routine. The PPT measurements were conducted over the upper part of the left and right m. trapezius on the location of costae 1 where the m. trapezius muscle is thickest and in the medially thickest part of the left and right m. tibialis anterior. In total, six PPT measurements were conducted at each location (three after baseline and three after induction). The algometer tip was placed at the highest spot on m. trapezius over costa 1 location, and the three consecutive measures were placed beside the first one in a clock-wise circle spaced for 6 measures leaving a space of 1 cm in between the algometer tips. This could easily be done since the algometer tip leaves a light mark on the skin after the exerted pressure. The PPT measures were conducted on the left and right m. tibialis anterior by starting with the tip at the uppermost location over the thickest part of the m. tibialis anterior at the three consecutive baseline measurements. The tip was then moved downward for the next consecutive measure while leaving a place of 1 cm in between for the induction PPT measurement. The same procedure was conducted when measuring the last consecutive measure. In this way, it was possible to make sure that the algometer

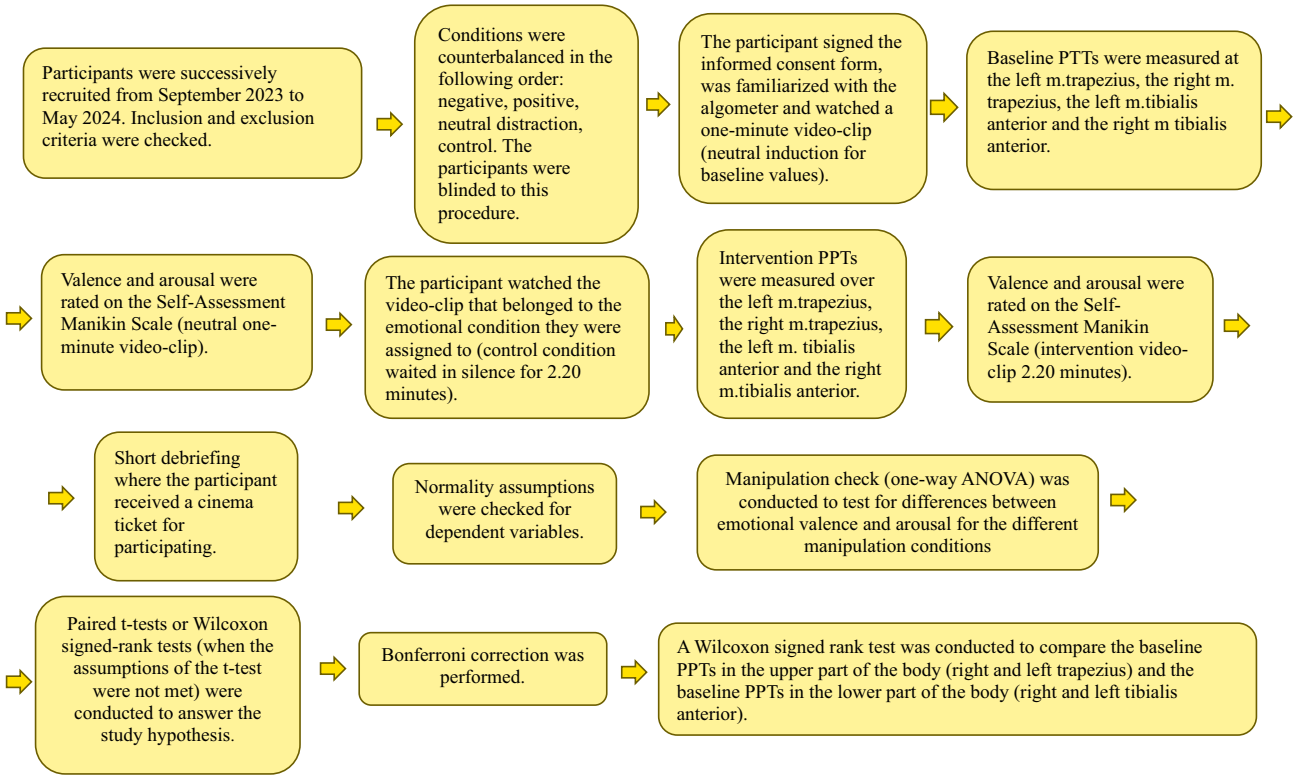

Figure 1 Flowchart of study design, procedure and data analysis.

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was not placed on exactly the same spot twice, but as close as possible. The experimenter had earlier experience in performing pressure pain threshold measurements with a handheld algometer in research experiments with standardized written and oral instructions,[18] and hand-held algometer testing has shown good validity and reliability measures (r = 0.83 −0.86) for different muscle sites.[19]

If the pressure exerted by the algometer exceeded 1500 kPa, it was interrupted by the principal investigator to avoid tissue damage. All participants interrupted the pressure before this limit value. From clinical practice it is known that a common pain location is the upper part of the m. trapezius, and a location that is seldom connected with pain is the middle part of the m. tibialis anterior. Therefore, it was considered important to examine PPTs over these regions. Both locations have been used to examine PPTs in several earlier studies.[18,20–22]

Induction of Emotional States

The participants emotional states were manipulated through videos (2.20 minutes). Negative emotions (condition 1) were induced through a video containing violence. Positive emotions (condition 2) were induced through a humorous video. Neutral emotion induction (condition 3, distraction) was attained through an instructional video about how to paint a house. The mind-wandering control group did not watch any video but was instructed to wait in silence (mind-wandering).

To ensure a neutral mood before all baseline PPT-measurements, an instructional video was shown for 1 minute. The videos were chosen since they matched films used in an earlier study.[15] All videos were tested and adjusted at the beginning of the study (pilot part) with a handful of participants. In this adjustment procedure the neutral video was changed from a video containing Swedish nature to an instructional video about how to paint a house. The videos had not been used in any earlier study. The videos could be available upon request from the corresponding author.

Manipulation Check

A manipulation check was conducted. Emotional experience has been described as an interaction between valence (pleasant–unpleasant) and arousal (calm–excited).[22] The Self-Assessment Manikin Scale has been extensively used in earlier research, and enables a fast and easy measurement.[8,9,23] It has been considered a valid scale to measure picture valence (r = 0.97) in comparison with the semantic differential pleasure score, and (r = 0.94) in comparison with the semantic differential arousal factor.[22] It is a 9-value scale consisting of 5 pictures, with each picture and the spaces between the pictures resembling a number from 1–9.[22,24]

Statistics

An a priori power calculation using G*Power with a power level of 85%, a moderate effect size (dz = 0.5), $p < 0.05$, in a repeated-measures paired *t*-test required a sample size of 38 participants in each group (in total, 152 participants). The repeated *t*-test was selected since we had two repeated measures and no comparisons between groups.

Descriptive statistics were (mean and standard deviation) performed to report the central tendency and distribution of the data. A one-way ANOVA was used to test for differences between emotional valence and arousal for the different manipulation conditions (manipulation check) with significance level $p < 0.05$. The Wilcoxon signed-rank test was conducted to check for differences in valence and arousal between the baseline condition and the intervention conditions 1, 2 and 3. The Kruskal–Wallis test was used to explore the descriptive variables age and gender between the four different groups (condition 1, condition 2, condition 3, condition 4).

Prior to the data analysis, tests of normality were performed using Kolmogorov–Smirnov and Shapiro–Wilk tests ($p > 0.05$).

To test the study hypothesis, paired t-tests or Wilcoxon signed-rank tests were conducted. The Wilcoxon signed-rank tests were conducted when the assumptions of the *t*-test were not met. These tests compared the baseline measurements with the post-induction measurements for each muscle (right m. trapezius, left m. trapezius, right m. tibialis anterior, left m. tibialis anterior) across different conditions (condition 1 negative emotion; condition 2 positive emotion; condition 3 distraction control; condition 4 control). To adjust probability (p) values for minimizing type I error due to multiple comparisons, Bonferroni correction was performed with significance level 0.0125 to control for the family-wise error rate and to ensure the robustness of the study finding. The result is marked with ** if the values are still significant after Bonferroni correction.

Additionally, since it is known from clinical experience that pain is more prevalent over m. trapezius compared to m. tibialis anterior, a Wilcoxon signed-rank test was conducted to compare the baseline PPTs in the upper part of the body (right and left m. trapezius) and the baseline PPTs in the lower part of the body (right and left m. trapezius). Stastical analyses were conducted using SPSS statistics version 30.

Results

Sociodemographic Characteristics

Sociodemographic characteristics (gender and age) for each condition are displayed in Table 1. No significant difference in age H (3) = 4.495, $p < 0.213$ or gender H (3) = 2.295, $p < 0.514$ was detected between the four different conditions.

Manipulation Check

Analysis revealed no significant difference between the different groups (baseline) (condition 1 negative emotion; condition 2 positive emotion; condition 3 distraction control; condition 4 mind-wandering control) in the estimated valence F (3) = 0.132, $p < 0.941$ and the estimated arousal F (3) = 0.602, $p < 0.615$.

Analysis revealed significant differences between the different groups (intervention) (condition 1, condition 2, and condition 3) in estimated valence F (2) = 73.73, $p < 0.001$ and arousal F (2) = 53.76, $p < 0.001$. Pairwise comparisons showed a significant difference between the baseline condition and the intervention condition regarding valence and arousal in condition 1 (negative emotion), $z=-4.949$, $p < .001$; $z = -5.040$ $p < 0.001$, and between the baseline condition and the intervention condition regarding valence in condition 2 (positive emotion), $z=-4.880$, $p < .001$; $z=-5.253$, $p < 0.001$. No significant difference was found between the baseline condition and the intervention condition regarding valence in condition 3 (distraction control), $z = -.108$ $p < 0.914$; $z = -.240$ $p < 0.810$ (see Tables 2 and 3 for mean and SD).

Table 1 Gender and Age for Each Condition

	Gender % Females	Mean Age (SD)	Min-Max Age
Condition 1 n = 38	66	27.81 (10.51)	19–58
Condition 2 n = 38	79	24.46 (7.91)	19–64
Condition 3 n = 38	66	30.00 (13.83)	18–71
Condition 4 n = 38	66	28.31 (11.66)	18–62

Table 2 Mean and SD Manikin Scale Valence and Arousal Baseline for All Four Groups (Condition 1, Condition 2, Condition 3 and Condition 4)

	N	Mean	SD
Valence condition 1	38	5.55	1.29
Valence condition 2	38	5.42	1.00
Valence condition 3	38	5.55	1.16
Valence condition 4	38	5.46	1.04
Arousal condition 1	38	2.50	1.86
Arousal condition 2	38	2.16	1.41
Arousal condition 3	38	2.05	1.39
Arousal condition 4	38	2.37	1.72

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Table 3 Mean and SD Manikin Scale Valence and Arousal Induction for All Three Video Induction Groups (Condition 1, Condition 2 and Condition 3)

	N	Mean	SD
Valence condition 1	38	2.92	1.74
Valence condition 2	38	7.68	1.23
Valence condition 3	38	5.50	1.20
Arousal condition 1	38	6.14	1.70
Arousal condition 2	38	6.03	1.28
Arousal condition 3	38	2.15	1.72

Inferential Statistics

In condition 1, Wilcoxon signed-rank test showed significantly lower PPTs after negative emotion induction in the right m. trapezius, $z = -342$, $p = 0.019$, $r_{rb} = -0.436$, the left m. trapezius, $z = -2.952$, $p < 0.003^{**}$ $r_{rb} = -0.549$, and the left m. tibialis anterior, $z = -4.257$, $p < 0.001^{**}$ $r_{rb} = -0.549$ compared to before the negative emotion induction, but after Bonferroni correction only the PPT values in the left m. trapezius and the left m. tibialis anterior remained significant. A paired *t*-test showed significant lower PPTs after negative emotion induction in the right m. tibialis anterior, t (37) = 2.55, $p < 0.015$, *Cohen's d* = 0.414, compared to before the negative emotion induction, but after Bonferroni correction the result was no longer significant (Table 4 and Figure 2). Thus, the PPTs after the negative emotion induction were significantly reduced compared to the PPTs before the negative emotion induction in the left m. trapezius and the left m. tibialis anterior. According to the mentioned effect sizes, 54.9% and 54.9% of the ranked data support that the PPTs were lower over the two body locations (left m. trapezius and left m. tibialis anterior) after negative emotion induction. In total, the negative emotion induction lowered the PPTs with large effect sizes in the left m. trapezius and the left m. tibialis anterior.

In condition 2, Wilcoxon signed rank test showed no significant difference between the PPTs over the right m. trapezius, $z = -1237$, $p = 0.216$, $r_{rb} = 0.233$, left m. trapezius, $z = -1748$, $p = 0.079$, $r_{rb} = -0.331$, right m. tibialis anterior, $z = -0.994$, $p = 0.320$, $r_{rb} = -0.185$ and left m. tibialis anterior, $z = -1.603$, $p = 0.109$, $r_{rb} = -0.298$ was found when comparing before and after the positive emotion induction (Table 4). Thus, no difference in PPT values was detected after inducing positive emotions (mean difference range from 8 to 15).

The Wilcoxon signed-rank test showed no significant difference between the PPTs in the right m. trapezius, $z = -0.950$, $p = 0.342$, $r_{rb} = -0.177$, left m. trapezius, $z = -1.305$, $p = 0.192$, $r_{rb} = -0.243$, the right m. tibialis anterior, $z = -1.539$, $p = 0.124$, $r_{rb} = -0.290$) in condition 3 (mean differences range from 1 to 11). A significant difference was detected between before distraction control and after the distraction control over the left m. tibialis anterior, $z = -3.041$, $p = 0.002^{**}$ $r_{rb} = -0.581$) (Table 4 and Figure 3). Thus, the PPTs over the left m. tibialis anterior were significantly reduced after the distraction control induction (mean difference = 37), with 58,1% of ranking data supporting the lower PPTs after distraction induction, but no other body locations showed any difference in PPTs after distraction control induction.

In condition 4, Wilcoxon signed-rank test showed no significant difference between the PPTs in the right m. trapezius, $z = -0.015$, $p = 0.998$, $r_{rb} = 0.003$, the left m. trapezius, $z = -1.064$, $p = 0.287$, $r_{rb} = -0.201$, right m. tibialis anterior, $z = -0.790$, $p = 0.429$, $r_{rb} = -0.147$, and left m. tibialis anterior, $z = -1.842$, $p = 0.065$, $r_{rb} = -0.343$ when comparing before and after the mind-wandering time (Table 4). Thus, no difference in PPTs was detected after waiting for 2 minutes and 20 seconds in silence (mean differences ranged from 1 to 15).

In the baseline measurement, the PPTs in the upper part of the body (right and left m.trapezius) were significantly lower (mean = 395.48, SD = 170.97) compared to the lower part of the body (right and left m.tibialis anterior) (mean = 684,01 SD = 298.37) within participants (n = 152), z = −10.586, $p < 0.001$.

Table 4 Means, SD, p-values and Effect Sizes for the Four Different Body Locations (Left Trapezius, Right Trapezius, Left Tibialis Anterior, Right Tibialis Anterior) and Different Conditions (Negative Emotion Induction; Positive Emotion Induction; Distraction Control and Control)

	Mean (SD) PPT Right m. trapezius	**P-value Effect Size**	**Mean (SD) PPT left m. trapezius**	**P-value Effect Size**	**Mean (SD) PPT right tib. ant**	**P-value Effect Size**	**Mean (SD) PPT left tib. ant**	**P-value Effect Size**
Before negative emotion	193.34 (81.80)	p =0.019	205.21 (71.81)**	p <0.003**	341.89 (137.12)	p <0.015	319.42 (122.92)**	p <0.001**
After negative emotion	178.89 (76.18)	r_{rb} = −0.436	183.50 (86.40)**	r_{rb} = −0.549	306.68 (149.50)	d =0.414	270.87 (131.65)**	r_{rb} = −0.549
Before positive emotion	190.18 (80.32)	p =0.216	199.53 (87.85)	p =0.079	347.63 (139.83)	p =0.320	321.71 (119.87)	p =0.109
After positive emotion	198.89 (92.32)	r_{rb} =0.233	190.32 (79.28)	r_{rb} = −0.331	339.18 (134.95)	r_{rb} = −0.185	306.92 (122.12)	r_{rb} = −0.298
Before distraction control	209.89 (115.15)	p =0.342	218.82 (100.86)	p =0.192	390.38 (194.43)	p =0.124,	379.59 (213.50)**	p =0.002**,
After distraction control	210.08 (149.21)	r_{rb} = −0.177	217.74 (138.00)	r_{rb} = −0.243	390.51 (231.89)	r_{rb} = −0.290	342.41 (195.54)**	r_{rb} = −0.581
Before control	172.08 (71.81)	p =0.998	192.89 (82.31)	p =0.287	323.63 (127.64)	p =0.429	314.02 (146.77)	p =0.065
After control	173.11 (80.62)	r_{rb} =0.003	188.00 (86.88)	r_{rb} = −0.201	322.18 (153.76)	r_{rb} = −0.147	299.79 (143.82)	r_{rb} = −0.343

Note: **shows significant results after Bonferroni correction.

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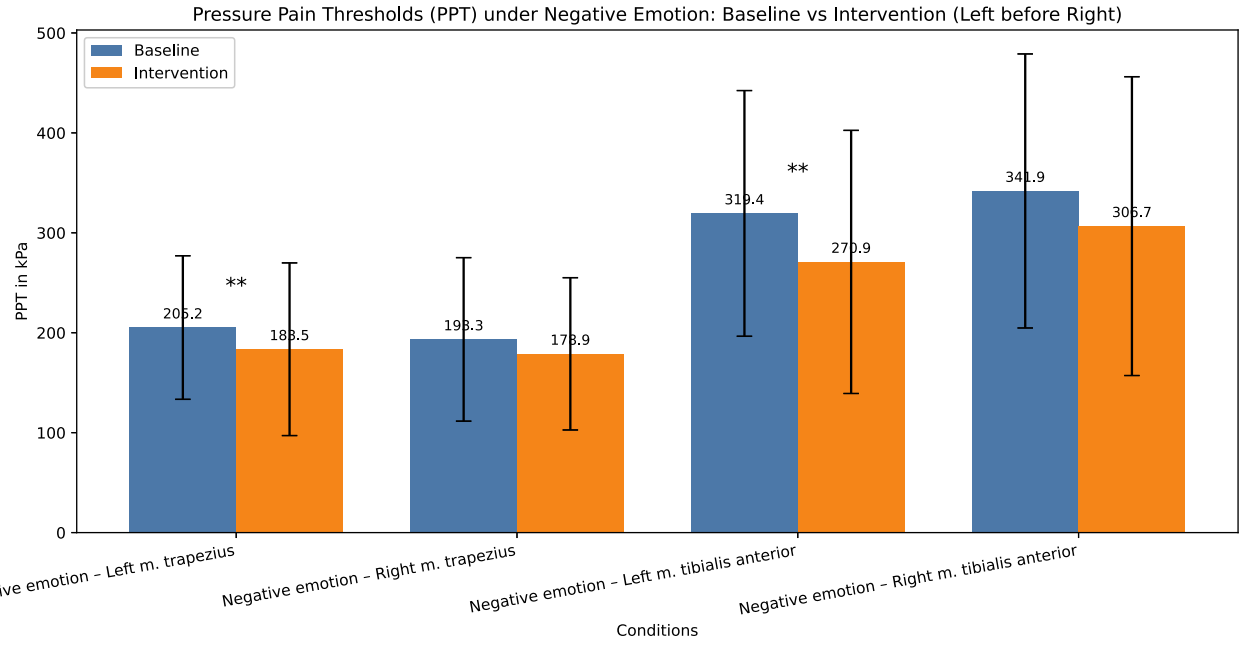

Figure 2 Mean PPT values with standard deviations (error bars) from condition 1 (negative emotion). Baseline PPT values left m.trapezius and intervention left m. trapezius, baseline PPT values right m.trapezius and intervention right m. trapezius, baseline PPT values left m. tibialis anterior and intervention left m. tibialis anterior, baseline PPT values right m. tibialis anterior. ** marks the significant differences (p <0.003 left m. trapezius and p <0.001 left m. tibialis anterior).

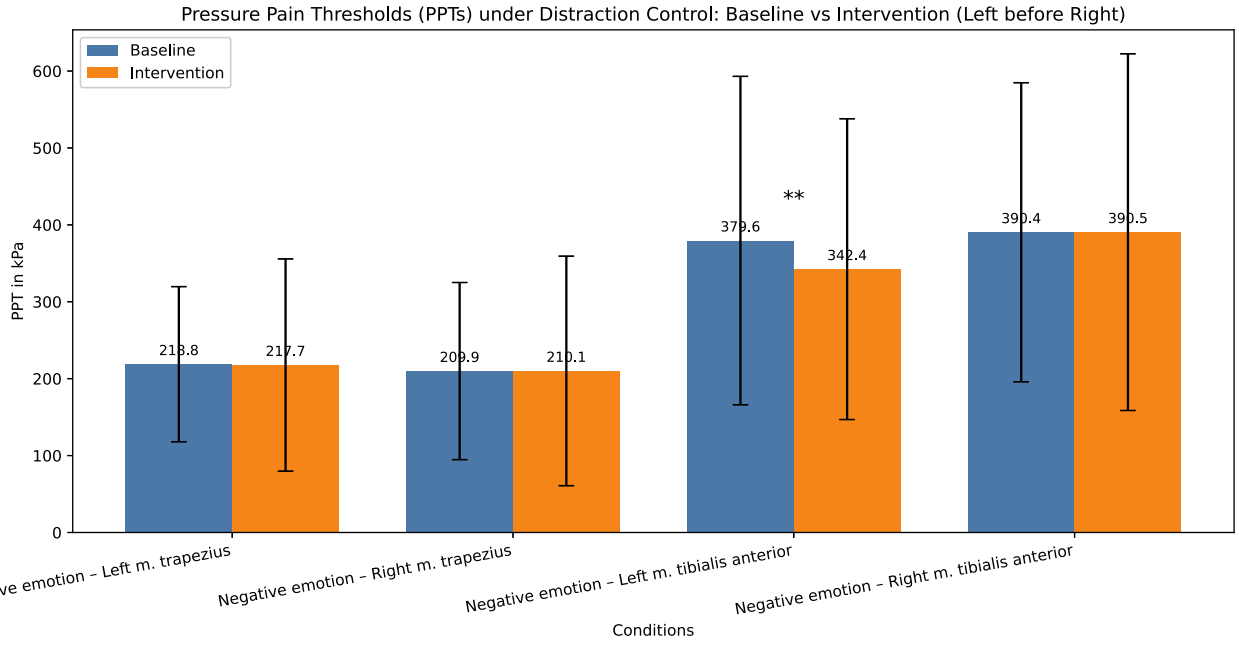

Figure 3 Mean PPT values with standard deviations (error bars) from condition 3 (distraction control). Baseline PPT values left m.trapezius and intervention left m. trapezius, baseline PPT values right m.trapezius and intervention right m. trapezius, baseline PPT values left m. tibialis anterior and intervention left m. tibialis anterior, baseline PPT values right m. tibialis anterior. ** marks the significant difference (p =0.002 left m. tibialis anterior).

Discussion

In this experimental study, the effect of negative and positive emotions on PPTs was examined in pain-free individuals. Based on the findings of pain perception from previous studies, we hypothesized that positive emotions would elevate PPTs, and negative emotions would lower PPTs. We found that negative emotions significantly lowered PPTs on the left side of the body (body locations m. trapezius and m. tibialis anterior) with large effect sizes. Positive emotions did not

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significantly affect PPTs. We found one significant lowered PPT body location (left m. tibialis anterior) in the distraction control condition. It could be speculated that lateralization of pain towards the left side of the body depended on right hemispheric amygdala processing negative emotionally laden content, while the left hemispheric amygdala was less prominent in nociceptive processing and negative emotionally laden content or even active in processing positive emotions.[25–27] Perhaps, this could explain the lateralization of negative emotions sensitizing the PPTs in this study, even though it must be mentioned that the literature is inconclusive, with studies also supporting a left side hemispheric processing of pain-related content.[28] Negative emotions, such as pain-related fear, have been associated with increased pain intensity in clinical pain states in previous studies.[2,29,30] Descending pain modulation from the endogenous opioid system regulates the neurotransmission in the spinal cord, thereby facilitating sensitization of PPTs.[31] If fluctuating emotional states affected by everyday living continuously alters pain thresholds, it could be speculated that the transition from acute to chronic pain could be facilitated in cases where negative emotional states persist over time in individuals experiencing acute pain. As a practical implication, some exposure to negative emotional engaging events might be possible to avoid when experiencing acute pain. It could be important knowledge for caregivers within the health care system to provide an emotionally positive experience during examinations and treatments of patients with pain. Another practical implication could be to encourage patients to watch pleasant emotional content when a short-lasting painful treatment must be endured.

According to the manipulation check, participants in the distraction control condition seem to have experienced the distraction control video as neutral in valence and low in arousal. That means it was regarded as a quite weak emotional arousing external stimulus. Even though this was an experimental setting with a controlled environment with induction and measurements, we could never control internal brain processes that could vary, both in response to external stimuli and internal stimuli (for example, memory processes and unconscious processes). Perhaps, such internal processes could influence descending pain modulatory systems when the external stimuli were too boring in character to give an emotionally aroused state, since unconscious processes have been shown to impact our thoughts and emotions.[32,33] Since we found no PPT sensitization in the mind-wandering control condition, it seemed better to engage in free mind-wandering than enduring a somewhat boring, low arousal external stimulus.

The sensitivity to pressure was significantly lower over the m. trapezius region compared to the m. anterior tibialis region, which is consistent with the clinical picture pain is more commonly experienced over the m. trapezius region in the population compared to the m. tibialis anterior region. Despite this, we observed the largest effect size over the left m. tibialis anterior. It was unexpected that the largest effect size would be found in a clinically less sensitive body part.

The results that negative emotions sensitized PPTs are in line with some earlier studies, where negative emotions significantly decreased pain tolerance and increased pain intensity in pain-free individuals,[7,13,15] the nociceptive flexion reflex was significantly increased,[9,23] and significant negative associations were found between psychological distress and lower mechanical pain thresholds.[16] The results of our study were somewhat inconclusive compared to another study,[26] where they found that participants with induced depressed moods showed significantly lower pain tolerance and higher pain catastrophizing scores compared to participants in neutral moods, but pain thresholds measured in a cold pressor apparatus were not affected. The inconclusiveness between this study and the other study[26] could perhaps be explained by the different measurement procedures. The cold pressor apparatus has been used to test both pain threshold and pain tolerance and has shown good reliability[34] but to the best of our knowledge, the cold pressor apparatus has not been validated to measure pain thresholds, while pressure algometry has been validated to test pain thresholds.[35]

We found no effect of induced positive mood on PPTs. This is to some extent in line with earlier studies, where one study reported that a positive mood decreased the perceived unpleasantness of induced heat pain, but the pain intensity rating was not affected.[14] It could be argued that perceived pain intensity when experiencing positive emotions could be represented more in cortical networks (for example the ACC) while pain thresholds more reflect descending modulatory processes affecting the spinal dorsal horn.[5,36] In the former study, the mood states were induced by different odors, compared to videos in our study and this could affect the brain differently. Rhudy et al,[8,9] reported that a positive emotional state induced from picture viewing significantly decreased pain ratings and inhibited the nociceptive flexion reflex in healthy participants. Roy et al,[13] also reported lower pain ratings in positive mood induction compared to neutral mood induced with different picture content. Perhaps, the participants in our study did not find the video with positive

content humorous enough to affect the descending pain modulatory system and thereby the PPTs. Although the manipulation check showed that the videos were rated significantly different regarding negative, positive and neutral valence and they were chosen from the description of film fragments used in an earlier study,[15] the positive valence was rated as differing slightly less from the neutral baseline state compared to the negative valence rating (2.18 and 2.58 steps, respectively). The Self-Assessment Manikin Scale was used as the manipulation check to rate the valence and arousal in the presented videos. Although, this scale is well validated it could be new to a participant to understand the difference between emotional valence and arousal. The difference was clearly described to each participant, but perhaps these new terms could have influenced some participant's estimations. A strength of our study was the power level of 85%, and the experimental design with two control groups, to control for the distraction elicited from the videos and the spontaneous shifts in the brain's continuous dynamic processing of internal and external events. Due to the nature of the quasi-randomized trial conducted among specific populations, the study results cannot be generalized to a larger population. This limitation arises also from the lack of control over all confounding variables that may influence the pressure pain threshold. For example, a clear limitation in our study was the uneven gender distribution with more women than men. We also had an uneven gender distribution between the groups, with more women than men in condition 2 (positive emotion condition). This is important to consider since emotional processes (activation patterns in the brain, expression of emotions) differ between women and men,[37] and females show more sensitivity to pain than males.[38,39] In this study, data was not analyzed separately for males and females, since the power would be too low to allow any meaningful conclusion from the results.[40] In future studies it is advisable to stratify samples based on socio-demographic characteristics, which can impact both negative and positive emotional induction as well as pressure pain thresholds. Another limitation in our study is that we did not control factors such as exercise before the test session, current sleep quality, caffeine/nicotine use before the test or previous experienced anxiety or depression[41–44] These factors could influence mood, but in a within-subjects design these factors matter less than in a between-subjects design. To ensure a baseline mood state at the test session, all participants watched a baseline video before the baseline PPT measurement. Another limitation is that the PPT measurement order was not balanced between participants, but instead the fixed order (left m. trapezius, right m. trapezius, left m. tibialis anterior, right m. tibialis anterior) was conducted in all participants. This could produce systematic effects that would affect the PPT measurements due to the time factor from watching the video. Strengthening the fact that this did not happen in this study is the result that only the PPTs on the left side of the body were affected by negative emotions. Another future advice is to double blind studies investigating PPTs to reduce any risk of impact from the experimenter or the participants. Our study was only single blinded, and this must be considered as a strong limitation. Another future improvement could be to have both male and female experimenters to minimize experimenter bias connected to gender. Earlier studies have reported a significant effect on pain intensity and pain tolerance measures in relation to experimenter gender.[45,46] Most participants were students at the university, but since the laboratory was situated in the middle of the campus, the students came from different departments of the university and did not know the test leader as a teacher.

The self-assessment manikin scale was used to measure the accuracy of the induced emotions in our study. A self-assessment tool offers limited psychometric information, and therefore an improvement in future studies could be to use a physiological measure, such as skin conductance or variations in heart rate, as well. Due to non-normal data distribution, non-parametric tests were used in this study. Future studies should consider Linear Mixed-Effects Models or Repeated Measures ANOVA, if assumptions are met, for more robust analysis accounting for within-subject variability and covariates. We also recommend considering less conservative correction methods than the Bonferroni correction in future studies, such as the Holm-Bonferroni and Benjamini–Hochberg procedures, to better balance type I and type II errors.

Conclusion

The result of this study could verify our hypothesis that negative emotional states would lower PPTs in pain-free individuals in the specific body locations, left m. trapezius and left m. tibialis anterior, with large effect sizes. The large effect sizes found in relation to the perceived negative emotions could be interpreted as meaningful differences for everyday living.

Data Sharing Statement

The deidentified data material is shared in Open Science Foundation repository https://doi.org/10.17605/OSF.IO/2ZY7H. The data will be public with no end date. The videos used in the study will be available upon request to the corresponding author.

Ethical Committee Approval

All participants signed an informed consent form, and the study was approved by the Swedish Ethical Review Authority (code: 2023-03968-01). This study was conducted in compliance with the Declaration of Helsinki.

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Disclosure

The authors declare that they have no conflict of interest in this work.

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