



Physiological arousal effects on pain perception in elite male and female endurance and strength athletes

El efecto de la excitación fisiológica en los índices de percepción del dolor en atletas de élite masculinos y femeninos de resistencia y fuerza

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Abstract

Introduction: Sports performance depends on pain, arising from three elements: physiology, cognition, and emotion. Arousal significantly affects pain perception in competition, as athletes must regulate physical exertion and emotional stress.

Objective: The present study aims to determine the effect of physiological arousal on pain perception in elite male and female endurance and strength athletes.

Methodology: A quasi-experimental pre-post design was used to evaluate 63 participants categorized as endurance athletes, strength athletes, or non-athletes. The measurement of pain included the Cold Pressor Task, which had participants experience durability testing through virtual reality boxing simulations that replicated competitive conditions. The researchers examined heart rate to measure physiological arousal.

Results: Pain threshold and tolerance measured through Analysis of Covariance showed important distinctions between groups ($p = 0.001$ for both variables), ($F = 78.67; 117.51$), respectively. Non-athletes' scores grew after arousal, but endurance and strength athletes showed declines in these measurements after the intervention. Gender did not influence the results measured for pain perception during the study.

Discussion: Present study indicates that arousal produces unique effects on pain sensitivity based on whether participants belong to athletic or non-athletic groups because their bodies have different ways of responding to stress and the physiology of endogenous opioids together with mental conditioning mechanics.

Conclusions: No significant differences in pain perception were observed between the two athlete groups. Non-athletes exhibited significant improvements in pain threshold and tolerance, aligning with previous research findings.

Keywords

arousal; cold pressor task; endurance athletes; pain perception; strength athletes

Resumen

Introducción: El rendimiento deportivo depende de la percepción del dolor, la cual surge de la interacción entre tres elementos: la fisiología, la cognición y la emoción. La activación fisiológica influye significativamente en la percepción del dolor durante la competición, ya que los atletas deben regular tanto el esfuerzo físico como el estrés emocional.

Objetivo: El presente estudio tiene como objetivo determinar el efecto de la activación fisiológica sobre la percepción del dolor en atletas élite masculinos y femeninos de resistencia y fuerza.

Metodología: Se utilizó un diseño cuasi experimental pretest-postest para evaluar a 63 participantes categorizados como atletas de resistencia, atletas de fuerza y no atletas. La medición del dolor incluyó la prueba Cold Pressor Task, en la que los participantes fueron sometidos a una simulación de boxeo en realidad virtual que recreaba condiciones competitivas. La frecuencia cardíaca fue evaluada como indicador de activación fisiológica.

Resultados: El análisis de covarianza mostró diferencias significativas entre los grupos en el umbral y la tolerancia al dolor ($p = 0.001$ para ambas variables; $F = 78.67$ y 117.51 , respectivamente). Las puntuaciones de los no atletas aumentaron después de la activación, mientras que los atletas de resistencia y fuerza mostraron disminuciones en estas medidas tras la intervención. El género no influyó significativamente en los resultados relacionados con la percepción del dolor.

Discusión: El presente estudio indica que la activación produce efectos diferenciados sobre la sensibilidad al dolor dependiendo de si los participantes pertenecen a grupos atléticos o no atléticos, debido a diferencias en la respuesta al estrés, la fisiología de los opioides endógenos y los mecanismos de acondicionamiento psicológico.

Conclusiones: No se observaron diferencias significativas en la percepción del dolor entre los dos grupos de atletas. Los no atletas mostraron mejoras significativas en el umbral y la tolerancia al dolor, en consonancia con investigaciones previas.

Palabras clave

atletas de fuerza; atletas de resistencia; excitación; percepción del dolor; tarea de presión en frío



Introduction

The human body uses pain signals as its vital warning system to demonstrate potential threats. The whole pain experience results from four dimensions: sensory, physiological, cognitive, and emotional elements. Through physiological mechanisms, pain causes the body to increase heart rate and breathing speed and boost blood circulation to muscles and brain tissues. The interpretation of pain signals and personal focus on attention factors define how someone perceives pain, and the emotional distress from pain affects their pain tolerance (Salwin & Zajac, 2016). Pain evaluation is highly personal and dependent upon specific situations because different factors shape it (Banozic et al., 2018). Two fundamental aspects of assessing pain exist: pain threshold and pain tolerance. Individuals mark the pain threshold when they first recognize pain.

In contrast, pain tolerance defines the most severe pain level before reaching intolerance (Tse et al., 2002). The widespread occurrence of pain in athletics and physical exercise demands efficient perceptual control and management strategies for improving athletic outcomes (Addison et al., 1998). Pain tolerance in athletes varies considerably, with growing evidence indicating that psychological factors—such as coping strategies, personality traits, and pain-related cognitions—play a crucial role in shaping how individuals experience and manage pain (Pettersen et al., 2020). Pain is a functional signal to prevent injuries and a warning indicator of physical boundaries (Pawlak, 2013). Exercise-activated pain develops from muscle tissue compression, tissue deformation, and substance buildup from metabolic processes (Pettersen et al., 2020). Numerous research studies demonstrate that athletes experience pain differently than non-athletes since athletes show a higher tolerance to pain (Tesarz et al., 2012).

The ability of top athletes to endure cold or ischemic pain owes itself to their well-developed methods for coping with pain, along with attention-splitting techniques. Studies reveal that pain threshold and sensitivity levels differ between different sports regardless of the stimulus type. Pain tolerance generally improves among athletes who participate in endurance events with extended training duration, and the amount of training directly affects how they perceive pain (Pettersen et al., 2020). Extended swimming practices cause participants to have more significant pain thresholds and reduced pain sensitivity levels (Kuppens et al., 2019). Endurance athletes can better endure cold and heat pain according to studies linking both characteristics to their prolonged training and game (Pettersen et al., 2020). Proof indicates that strength athletes possess better heat pain tolerance than endurance athletes, who show superior CPM responses and decreased pain anxiety (Assa et al., 2019). Diverse pain processing capabilities exist between endurance and strength training athletes due to their distinct workout loads. People demonstrate unique ways to process pain because psychological factors and social influences affect how they handle such sensations beyond their specialization in athletics. Research reveals that gender constitutes a major variable, which shows women experience decreased pain thresholds and increased sensitivity toward pain stimuli than men (Mogil, 2012; Goodin et al., 2015). The research shows men typically demonstrate higher levels of pain tolerance, so scientists have questions about whether gender-based differences exist in pain threshold levels (Robinson et al., 2003). Current research indicates that the comparison of opioid receptors and hormonal activities between sexes determines the observed differences in vulnerability to pain (Melchior et al., 2016).

Beyond biological determinants, gender-related psychological factors significantly influence athletes' motivational orientations and their responses to physical exertion. Evidence indicates that female athletes tend to report higher satisfaction of relatedness needs and more integrated forms of motivation, whereas male athletes more frequently prioritize extrinsic incentives such as recognition or financial rewards (López-Roel et al., 2025). These differences in motivational regulation are likely to affect pain perception, as psychological readiness and attentional focus are well-established modulators of pain. Within this framework, emotional support represents a key element of psychological safety, serving both immediate coping and long-term resilience functions. By facilitating the regulation of heightened arousal—particularly in situations such as pre-competition anxiety, post-performance frustration, or gender-related marginalization—emotional support may indirectly modulate pain perception and tolerance. This interaction between arousal, motivation, and psychological support is especially relevant in elite endurance and strength athletes, where subtle differences in pain processing can have meaningful implications for performance across both female and male groups (Apriady et al., 2025).



Recent research on competitive anxiety has further demonstrated that female athletes report higher levels of cognitive anxiety and greater fluctuations in self-confidence compared to males, suggesting that gender-related psychological factors influence how athletes interpret physiological stress during competition (Kaur Chawla et al., 2025). These findings complement the evidence that psychological readiness and attentional focus serve as important modulators of pain perception (López-Roel et al., 2025).

Awareness and environmental sensitivity are marked as arousal functions, which alter how the body interprets pain sensations. The regulation of arousal happens through physiological, cognitive, and behavioral pathways that the sympathetic and parasympathetic nervous systems control (Lee et al., 2020). The way arousal affects pain perception remains uncertain because research points to CEO enhancement in certain situations yet increased intensification in different ones (Piovesan et al., 2019). Routinely implemented descending pain modulation pathways act as vital connections between central nervous system operations and peripheral nociceptive processing to control neural pathways. Multiple pain management approaches use techniques to monitor arousal levels because they affect how someone perceives pain (Kyle & Mcneil, 2014). Cold water immersion, a common recovery strategy in soccer, has been shown to influence the nervous system by reducing nerve conduction velocity and increasing the release of analgesic neurotransmitters such as norepinephrine, thereby contributing to reduced pain perception (Dewangga et al., 2025). This suggests that physiological interventions targeting inflammation and muscle damage may also modulate pain responses, highlighting the interconnected nature of physiological arousal and pain perception in athletes.

Detection of pain as an inevitable aspect of athletics requires a proper understanding of how arousal influences pain perception to optimize performance outcomes. Pain challenges endurance and strength athletes throughout their training routine, although their mechanisms to regulate pain might depend on the athletic discipline they practice (Pettersen et al., 2020). Understanding pain reactions under different arousal levels among various athletic populations helps develop psychological and physiological pain management techniques for athletic sports. This study examines arousal's effects on pain threshold and tolerance in male and female endurance athletes, strength athletes, and non-athletes, focusing on differences in their pain modulation systems.

Method

Participants

This study employed a quasi-experimental, pre-test-post-test design with a control group in a laboratory setting. Participants included 63 healthy individuals (aged 16–30), the sample comprised endurance athletes (11 male, 10 female; sports included ice hockey, water polo, and rowing), strength athletes (10 male, 10 female; from weight throwing and powerlifting), and non-athletes (11 male, 11 female). To be eligible for the study, participants had to meet the following criteria: 1) membership in a national team within the past two years (elite level), and 2) participation in regular training sessions, three times per week over the past six months. Participants with chronic pain, recent injuries, or a baseline heart rate >80 bpm were excluded from the study. All participants were informed about the procedures and could withdraw freely.

Procedure

The research was conducted at the virtual reality laboratory of the Psychology Department at Shahid Beheshti University. Soundproofed conditions and a standard temperature of 21°C kept the environment free of outside interference throughout the experiment. Initially the participants received information about the purpose and the procedure of the study and signed the consent form. Participants were tested individually. Baseline blood pressure and heart rate were recorded in a seated position prior to the experimental trials.

Instrument

The pain perception indicators were investigated after participants washed their hands before spending twenty minutes on hand rest. Heart rate and blood pressure were measured using the Polar Belt heart rate monitor and the Hingmed ambulatory blood pressure monitor. After collecting initial measurement points, the participants began the Cold Pressor Task (CPT) when their hands soaked up to their wrists



in cold water. For each participant, the ice bucket contained water that reached 0 to 1°C temperatures using a steel vessel with ice cubes, along with fresh cleaning and refilling of the water. The participants had to maintain their hands stationary before verbally reporting their first pain perception to the researcher for the pain threshold measurement. They were then instructed to keep their hand submerged in the ice bath until the pain became unbearable, with the duration recorded as their pain tolerance level. The performance task phase was followed by a thirty-minute session of rest, which prevented the maintenance of immediate stress responses from the task and subsequent evaluations.

Physical Activity Quiz

Baseline heart rate and blood pressure measurements were obtained using a Polar Belt monitor. Participants with resting heart rates exceeding 80 bpm were excluded to ensure standardized baseline measurements. To induce physiological arousal, participants engaged in a three-minute high-intensity VR boxing game using the HTC Vive system. This competitive gameplay format has been previously demonstrated to effectively elevate arousal levels. Following VR exposure, we reassessed heart rate to quantify physiological responses. Participants then underwent a one-hour rest period to eliminate residual effects before repeating the Cold Pressor Test (CPT). This washout period ensured that subsequent pain tolerance measurements reflected only the intervention effects. Subsequently participants completed a three-minute physical punching exercise mimicking VR movements outside the virtual environment. By comparing cardiovascular data between VR and physical exercise conditions, we could distinguish arousal effects specific to virtual reality.

Ethics statement

This study was approved by the Ethics Committee of Shahid Beheshti University (Code: IR.SBU.REC.1400.146). All participants provided informed consent prior to participation, and the study was conducted in accordance with the ethical standards of the Declaration of Helsinki.

Data analysis

The results of Shapiro-Wilk test indicated normal distribution of data ($p < 0.05$). Additionally, Levene's test demonstrated that the variances of dependent variables were homogenous across groups ($p < 0.05$). One-way ANOVA was applied to assess pre-test measurements. For assessing the research hypotheses, we employed paired sampled t-tests and analysis of covariance (ANCOVA). All statistical analyses were performed using SPSS version 26.

Results

Table 1 presents the descriptive data (mean and standard deviation) of the pre-test and post-test scores for the groups, categorized by gender (male and female).

Table 1. Pre-Test and Post-Test Data in Study Groups

Variable	Groups	Gender	Mean \pm SD (Pre-Test)	Mean \pm SD (Post-Test)
Pain Threshold	Endurance	Male	14.79 \pm 4.72	9.38 \pm 3.62
		Female	18.17 \pm 4.28	10.11 \pm 3.62
	Strength	Male	13.33 \pm 4.02	7.75 \pm 2.42
		Female	12.10 \pm 2.75	6.90 \pm 1.92
Pain Tolerance	Non-Athletes	Male	8.42 \pm 2.46	14.98 \pm 4.94
	Endurance	Male	68.60 \pm 30.85	43.82 \pm 15.29
		Female	70.85 \pm 24.40	42.74 \pm 16.79
	Strength	Male	40.65 \pm 7.20	26.75 \pm 6.87
		Female	35.80 \pm 6.20	22.83 \pm 4.86
	Non-Athletes	Male	31.80 \pm 13.91	60.64 \pm 10.95
		Female	34.87 \pm 7.44	59.49 \pm 12.36

*Significant differences, $p < .05$.

The data analysis using Analysis of covariance (ANCOVA) confirmed significant statistical differences between groups based on the results for pain threshold ($P = 0.001$, $F = 78.67$) and pain tolerance ($P =$

0.001, $F = 117.51$). The results indicated no statistically significant differences between males and females in the study groups for both variables after controlling for the independent variable since their main effect and interaction effect were not significant ($F < 1$; $P < 0.05$).

The results from post-hoc Bonferroni test showed that the strength and endurance groups displayed no considerable differences in pain threshold ($P = 1.00$) and pain tolerance ($P = 1.00$) following the arousal intervention. Non-athletes' pain threshold and pain tolerance scores surpassed those of both endurance-trained and strength-trained athletes, as shown by statistical analysis with $P = 0.001$. The results showed that non-athlete participants demonstrated different levels of arousal response concerning pain perception than trained athletes. The non-athletes experienced heightened arousal, which created a 5.74% higher pain threshold value ($P = 0.001$, $t = -6.55$) among female participants (Figure 1). Endurance-trained males displayed an enhanced pain threshold enhancement of 14.87% compared to females, whereas strength-trained males demonstrated a 1.75% increase. The results showed that non-athletes experienced a significant rise in pain tolerance levels ($P = 0.001$, $t = -9.01$), and their females counterpart exhibited higher values (1.24%) than males (Figure 2). The endurance group of males showed 6.83% higher pain tolerance, while strength-trained males reported 5.17% higher tolerance rates than females during testing.

Figure 1. Changes in pain threshold among groups

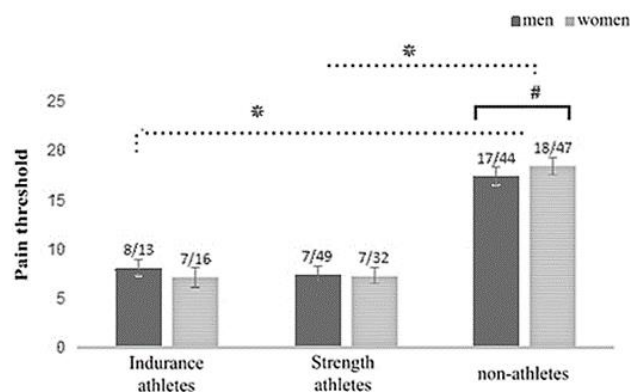
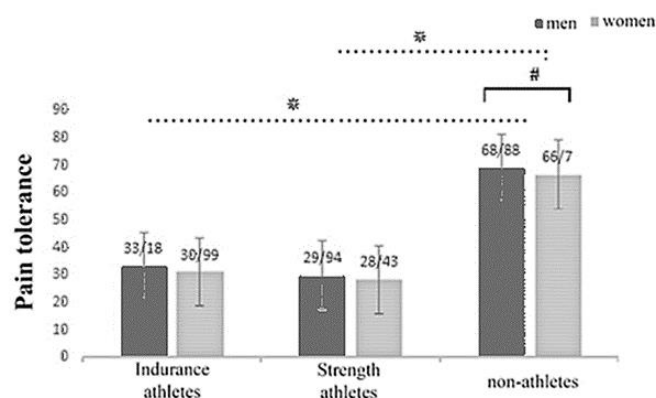


Figure 2. Changes in pain tolerance among groups



Discussion

According to study results, people from different athletic backgrounds demonstrate a non-uniform effect of arousal on their pain perception. After the arousal intervention, both strength and endurance athletes and non-athletes show significant improvements in pain response measurements, yet these groups don't have noticeable changes within their respective groups. Athletes seem to possess defensive

adaptation, which controls their physiological and psychological response mechanisms toward stimulation, leading to the stable perception of pain signals. Long-term intensive physical training induces stabilized pain perception in both endurance and strength athletes, as measured during rest intervals. While gender-based variations were observed among participants, these differences did not achieve statistical significance in the correlation between arousal levels and pain thresholds.

The study results demonstrate how arousal decreases endurance and strength athletes' ability to handle pain effectively. The present findings partially contradict previous studies reporting increased pain tolerance under heightened arousal (e.g., Perkins et al., 2001; Tesarz et al., 2012). One possible explanation for this discrepancy is differences in participant characteristics, particularly training status. Unlike non-athletic populations in previous research, athletes in the present study may exhibit more stable pain regulatory systems due to long-term exposure to physical stress and training adaptations. In addition, the nature of the arousal manipulation may account for the inconsistent results. The virtual reality boxing task likely induced primarily psychological arousal rather than physical stress, which may differentially affect pain modulation across populations. Furthermore, cognitive factors such as self-efficacy may play a moderating role in pain perception. Consistent with Bandura's theory, individuals with higher self-efficacy may exhibit altered pain processing through endogenous regulatory mechanisms. Finally, individual differences in stress responsiveness and coping strategies may have contributed to variability in pain outcomes, highlighting the importance of considering both psychological and neurophysiological factors in pain modulation research. The inconsistent study results indicate that arousal affects different groups differently because their training practices impact their physiological responses and neural adaptations. The research findings from Ferdowsi indicate that stress can produce opponents' stress-related effects where pain becomes more intense while simultaneously triggering stress-induced hyperalgesia. Constant stress exposure can reduce opioid receptor functions in the prefrontal cortex, leading to greater pain sensitivity. Future research should study how competitive situations with mental stress affect athlete pain perception after arousal treatments, even though reduced pain seems to occur.

According to Bandura (1988), elevated self-efficacy among individuals produces different pain responses under stressful circumstances because it alters their opioid system activity. The superior self-confidence and enhanced motor skills that athletes possess enable them to experience elevated self-efficacy and decreased opioid system activation, thus making them more sensitive to pain. Research showed that participants who played virtual reality boxing displayed reduced opioid system activity because they had low confidence levels, which produced both more extended ice water tolerance and reduced pain sensitivity. Studies show that self-efficacy protects individuals from adverse pain perception effects, which is consistent with past research about how cognitive factors actively affect pain regulation.

Research findings support the notion that arousal changes do not influence pain responses in individuals who do not participate in athletics. Studies show pain perception depends on sensory inputs and psychological elements, according to current pain research involving the gate control mechanism. Through spinal cord neuron processing, nociceptive signals travel until the brain receives them, while spinal gate channels decide whether pain signals transmit through or block them. Hurts or feelings of increased attention, together with stress levels, influence the sensitivity of these gates, boosting the intensity of experienced pain. The activation of the sympathetic nervous system from arousal results in elevated heart rate while playing the VR boxing game, which leads to reduced pain tolerance. Body stress reactions induce higher sensitivity to felt pain. Research indicates proper pain perception assessments need a comprehensive analysis of biological elements and mental factors within distinct population groups.

According to research data, strength and endurance athletes do not show measurable variations in pain responses after the arousal process, which contradicts previous findings presented by (Pettersen et al., 2020). The intervention failed to produce any significant variations in pain measurements during assessment. Multiple elements exist to account for this disagreement.

The intensity, along with the type of arousal generated by the virtual reality boxing game, possibly failed to produce the forecasted distinctions between strength and endurance athletes. The participants from each group displayed comparable physiological reactions to the stressful event because the generated arousal mainly stemmed from psychological stimulation instead of physical strain. The observed group differences likely failed to materialize because individual participants exhibited variations in coping



profiles, psychological resilience, and baseline stress levels. The research would benefit from exploring additional arousal environments that advance beyond present levels of physical stress and create realistic athletic scenarios.

Study conditions that used VR technology, together with sample makeup and experimental protocols, differently affected pain perception and tolerance compared to previous research conducted by (Saquib et al., 2021). The particular research conditions utilizing virtual reality technology for arousal simulation potentially produced unique factors affecting how participants experienced pain between different groups during the study. Research must confirm these results by studying actual sporting environments that enable dynamic evaluation between athletes and their natural playing environments.

The exam should expand its evaluation of how psychological and neurophysiological processes influence pain modulation. The effect of time-dependent changes on endogenous pain regulation mechanisms following persistent competitive stress exposure deserves further research investigation because training status and psychological preparation play a role in pain perception. Studying how various training intensities, recovery strategies, and mental skills programs affect pain perception patterns would create knowledge about high-performance athlete discomfort management.

The research discoveries demonstrate that non-athletes develop enhanced tolerance and threshold to pain after arousal, yet endurance and strength athletes display no substantial change between group measurements. Elaborate training methods linked to athletics develop stable pain response mechanisms that resist alterations arising from external sources of arousal. Future studies should expand research on these processes to identify specific factors that help control pain between athletic and non-athletic groups.

Conclusions

The findings of this study demonstrate that endurance and strength athletes develop more stabilized pain perception following long-term intensive training, while non-athletes exhibited higher pain tolerance after arousal. Although gender differences were observed, these variations were not statistically significant. These results highlight the importance of training-induced adaptations and psychological mechanisms in pain regulation.

To advance understanding of pain modulation in athletic and non-athletic populations, future studies should: (1) investigate how individual psychological traits (competitiveness, emotional resilience, anxiety sensitivity) interact with arousal to shape pain perception; (2) examine gender-specific effects of training on pain responses, combining biological and psychological assessments; (3) compare the efficacy of different arousal stimuli (competitive scenarios, cognitive stressors) against VR interventions; and (4) integrate neuroimaging (fMRI/EEG) with hormonal and behavioral analyses to elucidate sport-specific adaptation mechanisms. Such multidisciplinary approaches will optimize pain management protocols for both performance enhancement and clinical rehabilitation.

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