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DIFFERENCES IN PAIN PERCEPTION BETWEEN AMATEUR AND PROFESSIONAL MUAY THAI FIGHTERS

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Różnice w percepcji bólu między amatorskimi i profesjonalnymi zawodnikami muay thai

Streszczenie

Muay thai to sztuka walki, która obejmuje walkę wręcz, z wykorzystaniem ciosów pięściami, łokciami, kolanami oraz kopnięć. Formułą walki jest wyłącznie *full contact*. Celem poznawczym pracy jest pokazanie, jak trenowanie tajskiego boksu wpływa na kształtowanie się odczuwania bólu u ćwiczących. Grupę badawczą stanowiło 20 zawodników płci męskiej w wieku minimum 15 lat, ze stażem treningowym minimum 6 miesięcy. Narzędzia pomiarowe to: termometr, ciśnieniomierz, stoper oraz naczynie z wodą o niskiej temperaturze. Jako metody badawcze zastosowane zostały następujące testy: Zmodyfikowany Cuff Pressure Test oraz Cold Pressor Test. Badanie wykazało, że po sesji treningowej średnia tolerancja na ból związany z uciskiem w Zmodyfikowanym Cuff Pressure Test wzrosła, co wskazuje na zwiększoną tolerancję bólu. Średnia tolerancja w teście na ramieniu wzrosła z 255,0 mmHg przed treningiem do 270,3 mmHg po treningu, na nodze natomiast wzrosła z 228,3 mmHg do 250,8 mmHg po treningu. W Cold Pressor Test percepcja bólu pozostała niezmieniona, nie zaobserwowano istotnych różnic w tolerancji przed i po jednostkach treningowych. Trenowanie boksu tajskiego może prowadzić do częściowego zwiększenia tolerancji na fizyczny ból, szczególnie bezpośrednio po sesji treningowej.

Słowa kluczowe: muay thai, ból, percepcja bólu, Zmodyfikowany Cuff Pressure Test, Cold Pressor Test.

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Abstract

Muay Thai is a martial art that involves close combat, utilizing punches, elbows, knees, and kicks. The combat format is strictly full contact. The objective of this study is to show how training in Thai boxing influences the development of pain perception among practitioners. The study group consists of 20 male athletes, aged at least 15, with a minimum of 6 months of training experience. Measurement tools include a thermometer, blood pressure monitor, stopwatch, and a vessel with cold water. The research methods employed were the Modified Cuff Pressure Test and the Cold Pressor Test. The study found out that after a training session, the average pressure tolerance in the Modified Cuff Pressure Test increased, indicating a heightened pain perception. Specifically, the mean tolerance for arm pressure went from 255.0 mmHg before training to 270.3 mmHg after, and for leg pressure, it increased from 228.3 mmHg to 250.8 mmHg post-training. In the Cold Pressor Test, pain perception remained unchanged, with no significant variation in tolerance observed before and after training units. Training in Thai boxing may lead to a partial increase in tolerance to physical pain, especially immediately after a training session.

Keywords: Muay Thai, pain, pain perception, Modified Cuff Pressure Test, Cold Pressor Test.

Introduction

Muay Thai, also known as Thai boxing, is a martial art that focuses on close combat, utilizing punches, elbows, knees, and kicks (Turner, 2009). Due to its extensive range of strikes, it is also referred to as the “art of eight limbs” (Vail, 2014). Matches take place in a ring exclusively in a standing position; a competitor on the ground does not participate in the fight. The combat format is strictly full-contact, with strikes delivered with full force (Gartland et al., 2005). Muay Thai is a combat sport that carries a significant risk of injury (Gartland et al., 2001; Strotmeyer & Lystad, 2017), even when compared to other martial arts such as Olympic Taekwondo, where the focus is on the accuracy of leg strikes and scoring points against the opponent. In Taekwondo, strikes are aimed at speed rather than strength, and punching the opponent’s head is prohibited. During matches, competitors wear helmets and body protectors (McIntosh & Patton, 2015). Brazilian Jiu-Jitsu is also characterized by lower injury rates, where the fight takes place on the ground without strikes and kicks, and competitors often surrender due to “locks” or chokeholds (Moriarty et al., 2019; Scoggin et al., 2014). Moreover, the “range” of possible strikes in Muay Thai, not only with fists or legs but also with elbows and knees, contributes to its distinctiveness. In Thai boxing, competitors aim to deliver strikes with the greatest force, intending to knock out the opponent as quickly as possible.

Training sessions that rely on the core training methods from the birthplace of the sport, i.e. Thailand, are intense and highly demanding on the practitioner’s body. In summary, according to Thai trainers, training must be more rigorous than the fight itself. Thousands of kicks against punching bags and pads,

as well as punches, are executed with great force (Lee & McGill, 2017). An important element of Muay Thai combat is the "clinch", which involves close quarters fighting with knee and elbow strikes, pulling the opponent's head, and taking them down. A fight can end in the following ways: on points, by knockout, by triple count in one round or four counts in the whole fight (seniors), by medical interruption, by corner submission, by unwillingness to fight of one of the fighters and by disqualification. In traditional setup and sparring methods, athletes do not wear any protective gear besides stripes on the hands and wrists. All blows are taken straight to the body. In Western circumstances, sometimes protective gear as shin protectors or headgear are incorporated in official matches or training sparring sessions, depending on coaches and competition rules. Also, practice involves training particular techniques in pairs, especially blocking techniques. Therefore, Muay Thai fighters are constantly exposed to direct external force of their opponent.

Repetitive stimuli in Muay Thai training or fighting include both delivering and receiving strikes and kicks (Cimadoro et al., 2019). For example, all kicks to the punching bag, training pads, or during sparring and actual fights are executed with the shin, specifically the tibia bone. In Thai boxing, the same leg is also used for defence against kicks by blocking them. Thus, both the skin surface on the shin and the bone itself are heavily utilized (Vaseenon et al., 2015). Similarly, the entire body of the fighters is exposed to receiving blows. The organism then adapts to these repetitive pain stimuli.

Short, acute pain stimuli quickly subside and do not induce any changes in the central nervous system. However, repetitive stimuli lead to adaptive changes in the central nervous system, resulting in the activation of pain inhibitory systems (Staud, 2013). Muay Thai is a striking type of martial arts. It means that confrontation is direct, with blows exchange and blocking, rather than avoiding hits and disarming techniques. Higher pain tolerance could be understood then not only as direct changes in the central nervous system involving pain gates, but also as an altered attitude towards receiving pain in general. Thanks to this adaptation, it is possible to hypothesize that among Muay Thai fighters, the sensation of pain decreases as the painful stimuli recurring during direct contact with an opponent are repeated.

Another aspect of training a martial art, which is highly demanding in terms of physical effort and competitiveness, is one's mental state and its improvement over time. Mental toughness is defined as an ability to maintain and improve performance and ability in demanding situations (Bird et al., 2021; Yankov et al., 2019).This phenomenon is not inherited-only but could be developed over time with practice. Understanding that pain is a temporary sensation if a blow does not inflict permanent damage, an ability to maintain rational thinking and high morale upon heavy blows is an acquired skill that needs to be experienced

by every trained individual. Mental toughness is probably a mix of an increased pain threshold and increased competences in various components of this mental ability, such as attitude and goal (Przybylski, 2018). As there is a difference in mental toughness between non-practitioners and martial arts contestants (Beheshti et al., 2021), there needs to be gradual improvement in this competence from those starting practice to seasoned fighters.

Based on both psychological and physiological mechanisms of pain tolerance in Muay Thai fighters, we could hypothesise that there can be different pain tolerance and perception between novice and expert fighters, as both mechanisms require practice time to be elevated to a certain level. Due to ethical concerns and lack of proper instruments for analysis, pain is not tested on stimuli that reflect a fight. It is not a direct bone-to-bone hit or a body towards a hardened object. The most commonly used test is based on temperature sensation and pressure. Even more sophisticated devices such as algometers are based on constant pressure to a point. Those methods are considered to be current state of art, measuring the pain threshold itself, without considering other aspects of mental toughness. Cold and pressure-based tests measure pain endurance, with isolation from adrenaline, competing and fight-related psychological responses in real time. But all humans have their initial psychological and physiological state before testing, thus measuring circumstances such as exposure to previous training sessions needs to be considered upon results (O'farrell et al., 2022).

The main objective of the study is to demonstrate the relationship between training Muay Thai at both professional and amateur levels and the perception of pain among practitioners. The secondary aim is to verify if exposure to a training session changes the perception of pain among practitioners.

The main research question is how Thai boxing training affects the athletes' pain perception. The second research question is if their differences in pain perception depend on the stimuli, i.e. compression and low temperature. Based on research questions and premises from the introduction, we formulated two corresponding hypotheses: Athletes with longer training tenure exhibit greater pain tolerance. The second hypothesis is that exposure to training sessions will increase a pain threshold in both novice and expert athletes.

Material and methods

Participants

The research group consists of 20 male individuals, aged at least 17 years old. Nine of them had more than 5 years of training experience, two: 2–4 years of training experience, four: 1–2 years of training experience, and five: between

six months and one year of training experience. The age range was from 17 to 37 years. Sequentially, the average age in the groups was: more than 5 years of training experience ~25 years, 2– 4 years of experience ~19 years, 1–2 years of experience ~25 years, six months – 1 year of training experience ~20 years. These are Muay Thai fighters with a minimum training experience of 6 months and without any contraindications to participate in the study. The research location is the training room of the "Akademia Walki Częstochowa" sports club, with the study conducted in February 2023.

Methods

The measurement tools include a pin thermometer with a LCD and a 145 mm needle, a manual pressure gauge, a smartphone's stop watch, and a vessel with cold water (about 3.3–3.5 degrees Celsius) and ice cubes. Inclusion criteria for the group were: minimum training tenure of 6 months, age of at least 15 years, written consent to participate in the study, and parental consent in the case of minors.

Modified Cuff Pressure Test

The test involves the use of a cuff and a blood pressure monitor, where the cuff is first applied to the arm and then to the lower leg. The blood pressure monitor is inflated to a value when the participant reports feeling pain (Cummins et al., 2020; Lemming et al., 2017). When pain is reported, the value indicated by the blood pressure monitor is recorded. Figure 1 presents the visualization of the test.

Cold Pressor Test

The test utilizes a container filled with ice water of a constant low temperature. Blood pressure and heart rate measurements are taken before the participant immerses their forearm into the container. A stopwatch is started and left running until the participant feels pain, at which point the stopwatch is stopped, and the participant removes their hand from the container (Årnes et al., 2021; McIntyre et al., 2020; Schwabe & Schächinger, 2018). Figure 1 presents the visualization of the test.

Before the training session, heart rate and blood pressure measurements were taken from the individuals designated for the study. Subsequently, the participants underwent two tests in the following order: the Modified Cuff Pressure Test and the Cold Pressor test. During the training, their heart rate was monitored. After the training, the participants' heart rate and blood pressure were

measured again, and all tests were repeated in the same order. Each of the training sessions preceding the tests conducted on the athletes had a similar specificity. The research group was divided into novice and advanced participants based on their training tenure. At the time of the study, the charges were not ill or injured.

Figure 1
Modified Cuff Pressure Test for arm and shank & Cold Pressor Test on hand

Statistical analysis

In this study on the impact of Muay Thai training on pain perception, statistical analysis encompassed descriptive statistics to outline data trends, Wilcoxon Pair Test was used for assessing pre- and post-training changes in the individuals, and Mann Whitney U Test for examining pain perception across proficiency levels. Descriptive statistics provided an initial data overview, while Wilcoxon's evaluated the immediate training effects on pain tolerance, revealing whether changes were statistically significant. Mann Whitney U Test further analysed differences in pain tolerance among athletes of varying training experiences, offering insights into how proficiency influences pain perception. This unified statistical approach aimed to capture both the short-term training impacts and the potential long-term adaptations related to proficiency in Muay Thai.

Results

The results of the modified Cuff Pressure Test on upper limb in the studied group of athletes improved after training. A similar trend was observed for the results of this test conducted on the lower limb. In both cases, the difference in results between the before and after measurements was statistically significant

(p = 0.022 and p = 0.006, respectively). When separating the test results according to training seniority, they show that for both the upper and lower limb the differences were statistically significant in the advanced group. The results of the Cold Pressor Test showed an inverse relationship, the average time of keeping the upper limb in cold water decreased (Table 1).

Table 1
Results of Wilcoxon Pair Test, the Cuff Pressure Test before and after training session & results of the Cold Pressor Test before and after training sessions in each experience group

	N	Mean (sec.)	Minimum (sec.)	Maximum (sec.)	SD	p value
Cuff arm – before	20	255	200	320	31.53	0.022*
Cuff arm – after	20	270.3	190	320	37.95	
Cuff arm advanced – before	11	250	230	320	27.5	0.019*
Cuff arm advanced – after	11	274.10	215	320	31.37	
Cuff arm beginners – before	9	251.11	200	310	37.23	0.236
Cuff arm beginners – after	9	265.5	190	320	46.33	
Cuff leg – before	20	228.3	180	320	34.34	0.006*
Cuff leg – after	20	250.8	150	320	46.96	
Cuff leg advanced – before	11	231.36	200	320	32.17	0.028*
Cuff leg advanced – after	11	253.18	180	320	39.26	
Cuff leg beginners – before	9	224.44	180	280	38.44	0.093
Cuff leg beginners – after	9	247.77	150	310	57.39	
CPT before	20	55.75	17	182	37.24	0.042*
CPT after	20	46.85	10	142	31.81	
CPT advanced – before	11	66.27	22	182	44,08	0.182
CPT advanced – after	11	58.09	15	142	37.87	
CPT beginners – before	9	42.88	17	85	22.94	0.110
CPT beginners – after	9	31.11	17	60	15.02	

* significance level $p < 0.05$

The Cold Pressor Test results showed no significant statistical difference between the advanced and novice groups both before (p = 0.16) and after (p = 0.10) the training unit. Yet, the difference was statistically significant, as seen in Table 1, i.e. p = 0.042. It was the inverse relationship as the average time for the researched group decreased after training. In each group, before and

after training, the results showed no statistically significant differences (advanced p = 0.182; beginners p = 0.110). Figure 2 presents the visualization of the results.

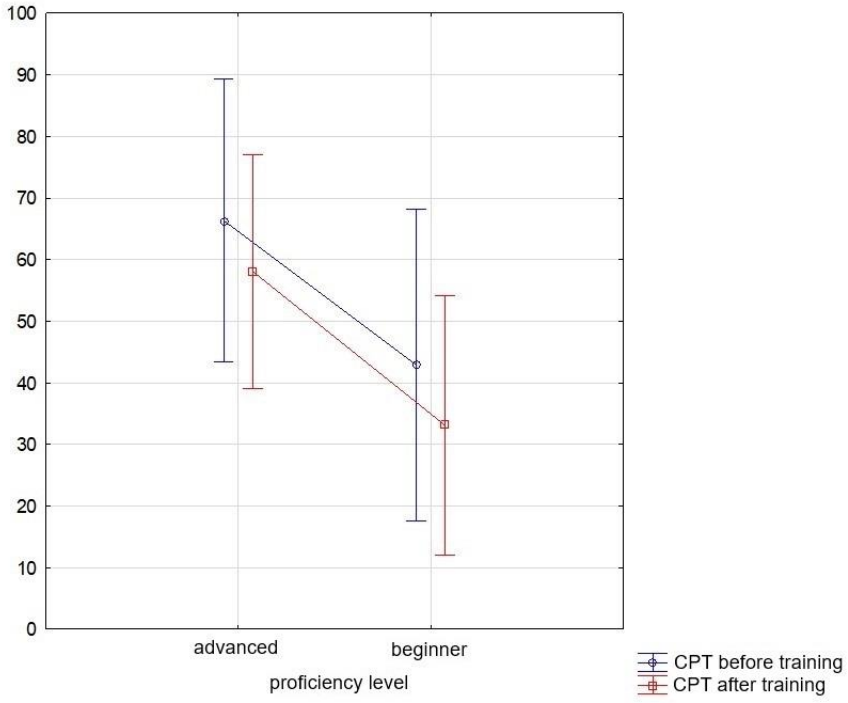

Figure 2
Results of the Cold Pressor Test showed separately for the beginner and advanced group

In the examination of pain tolerance and physiological response among Muay Thai athletes, the Modified Cuff Pressure Test was administered both before and after training sessions, organised by the level of expertise, i.e. for advanced and beginner groups. The comparison of the results of the advanced group with the beginner group's results before and after training for the upper limb and lower limb showed the absence of significant statistical differences. For the upper and lower limb before training it was p = 0.54 & p = 0.90 accordingly, and after training the differences were as follows: p = 0.93 in the arm and p=0.90 in the leg. This comprehensive analysis delineates nuanced physiological adaptations across different training intensities and durations within the domain of Muay Thai, underpinning the intricate correspondence between athletic training and pain tolerance thresholds. Visualization is presented in Figure 3.

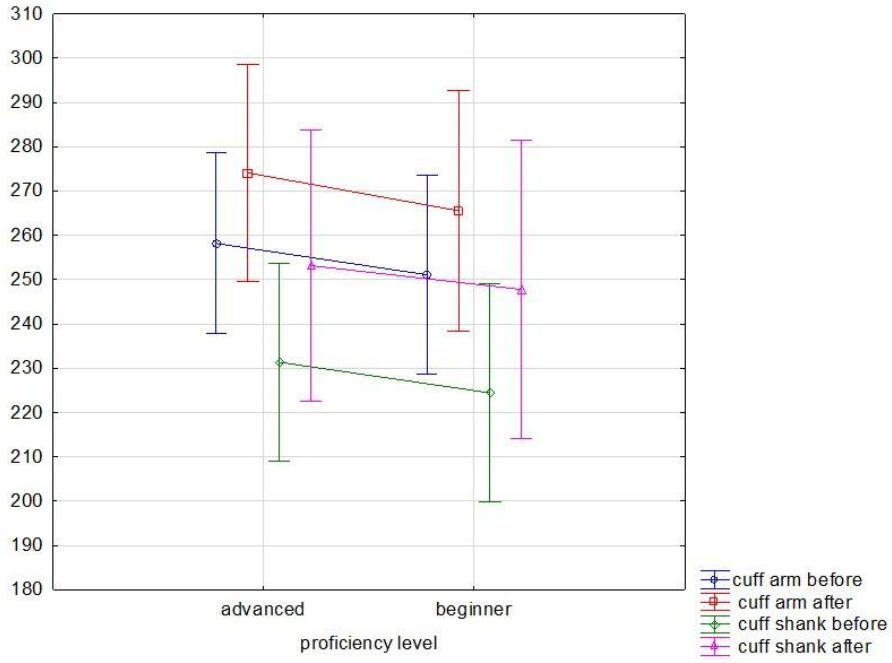

Figure 3
Results of the Modified Cuff Pressure Test (cuff types on the legend) divided by the proficiency levels

Discussion

The guiding thought in the construction of this study centres on the practice of limb and torso conditioning — a method utilized by fighters from Thailand, who subject their unguarded body parts, such as thighs or torso, to numerous leg or fist strikes, believing that their bodies will, over time, adapt to these blows and develop a specific resistance to them. They also perform many shin kicks against punching bags. Repetitive stimuli quickly lead to adaptive changes in the central nervous system (CNS) and the activation of a series of systems, both sustaining and inhibiting pain (Staud, 2013). Based on such adaptation, a hypothesis was formulated stating that athletes with longer training tenure exhibit greater pain tolerance and another one suggesting that sensitivity to pain decreases after a training unit. Regarding the first hypothesis, which posits that athletes with longer training tenure exhibit greater pain tolerance, no significant correlation was found between the duration of training experience and resistance to physical pain. Contrary to rationale and conjecture, this hypothesis was rejected. Despite the adaptations induced in the CNS by pain stimuli, they did not translate

into pain perception in the athletes. Multiple components of pain perception may be the issue here. Also, the nature of the stimuli (pressure and low temperature) may play a key role. Their type will never reflect the pain stimulus associated with being hit by an opponent. Perhaps studies of pain perception in Thai boxing fighters should be focused on such a stimulus. It is possible that only then would it be possible to look for a correlation between the training seniority of the fighters and the perception of pain associated with the blows that are inflicted in Thai boxing.

It is essential to recognize the complexity of pain perception and tolerance. While the study hypothesized that athletes with longer training tenure would exhibit greater pain tolerance, the results did not support this hypothesis. These findings challenge the notion that prolonged exposure to limb and torso conditioning necessarily leads to heightened pain tolerance. However, it is crucial to consider various factors that may contribute to pain perception beyond training duration alone.

One such factor is individual variability in pain sensitivity and response. Pain perception can be influenced by genetic predispositions, psychological factors, and previous experiences with pain (Mogil, 2021). Therefore, the lack of correlation between training tenure and pain tolerance may be attributed to individual differences among the participants. Future studies could explore these individual differences more comprehensively through psychometric assessments and genetic analyses to better understand the interplay between genetics, training, and pain perception.

The study utilized two pain tolerance tests – the Cold Pressor Test and the Modified Cuff Pressure Test — to assess participants' responses to pain. While the Modified Cuff Pressure Test showed an increase in pain tolerance following a training session, the Cold Pressor Test yielded inconclusive results, with some athletes exhibiting lower post-training pain tolerance. This discrepancy suggests that different pain stimuli may elicit varying responses and highlights the importance of considering the specificity of pain assessment methods.

Further research could investigate the underlying mechanisms contributing to the observed differences in pain tolerance between the two tests. For example, physiological changes induced by Muay Thai training, such as alterations in pain modulation pathways or endorphin release, may influence pain perception differently depending on the type of pain stimulus. Additionally, exploring the role of contextual factors such as environmental temperature or psychological state in pain perception could provide valuable insights into the multifaceted nature of pain tolerance (Loggia et al., 2008).

The two tests conducted on a group of 20 athletes (9 beginners and 11 advanced), namely the Cold Pressor Test and the Modified Cuff Pressure Test, did not demonstrate a significant difference in the outcomes between both groups,

both before and after a training unit (Belavy et al., 2021). However, the second hypothesis was partially confirmed in the Modified Cuff Pressure Test conducted on participants from both groups before and after a training unit. The results indicated that athletes showed an increased tolerance to physical pain after a training session, a finding consistent with the study by Vaegter et al. (2017), in which a group of 20 men exhibited increased pain tolerance following physical exercises. The average for the arm before the training session was 255.0 mmHg, which increased to 270.3 mmHg afterward. For the leg, it was 228.3 mmHg before and 250.8 mmHg after. Comparing these results with those of the study by Lemming et al. (2017), where a similar test was conducted on a group of 98 individuals (48 men and 50 women) in which 22 men were described as physically highly active, this group was compared to the 20 Muay Thai athlete participants. The average test score for the arm among physically active men was 228.76 mmHg, and for the leg, it was 255.77 mmHg. Compared to the group of active men, the Muay Thai fighters demonstrated greater pain tolerance in the arm (not considering the training unit) and lower in the lower limb. This may be related to the heavy use of the lower limbs by the fighters. In the Cold Pressor Test, the results did not indicate an increase in pain tolerance among the athletes. An inverse relationship was observed here, with athletes more frequently, in 14 out of 20 cases, achieving better results before the training session than after. This could be related to body temperature differences post-exercise, where the body, once "warmed up," is less tolerant of cold applied locally (Algafly & George, 2007).

A significant limitation of the study presented was the number of participants. A larger cohort of subjects would have allowed for a more detailed segmentation based on training tenure, which could have yielded more precise outcomes. Additionally, the athletes were not compared with non-training individuals. A benefit of the study for those practising Thai boxing could be demonstrating how training translates into a partial increase in physical pain tolerance.

Another notable limitation of the study is its exclusive focus on male participants. Given that many women also engage in Muay Thai training and competition, the generalizability of the findings to female athletes is uncertain. Future research should aim to include a more diverse population sample to better understand potential gender differences in pain tolerance and the effects of training on pain perception (Davies & Deckert, 2020; Hashmi & Davis, 2014).

The relationship between pain tolerance and performance outcomes in combat sports warrants attention. While the current study focused primarily on pain tolerance as an outcome measure, it is essential to consider how pain perception may affect athletes' training adherence, performance, and injury risk. For example, athletes with higher pain tolerance may be more likely to push through discomfort during training sessions, potentially leading to overuse inju-

ries or burnout (Aicale et al., 2018). Conversely, athletes with lower pain tolerance may be more cautious in their training approach, reducing their risk of injury but potentially limiting their performance gains. Exploring the interplay between pain tolerance, training intensity, and performance outcomes can provide valuable insights for optimizing training protocols and injury prevention strategies in combat sports.

One of the studies describing the epidemiology of injuries among Muay Thai fighters was conducted in 2016 by Strotmeyer Jr. and colleagues on a group of 195 Muay Thai fighters, including 165 men and 27 women (96 professionals and 99 amateurs). They were asked to complete a survey related to injuries incurred during fights (Strotmeyer et al., 2016). Out of the study participants, 110 fought only with boxing gloves, while 85 additionally used helmets and shin guards. Among all the participants, 108 reported having sustained injuries during fights, whereas the remaining 87 did not report any injuries. Among those reporting injuries, the majority did not wear additional protection besides gloves (70 people) and were professionals (64 people). They also did not enter the fight with a pre-existing injury (64 people). The main injuries were to the limbs (58.6%), followed by head injuries (30.6%), with torso injuries being the least common (10.8%). The primary cause or mechanism of injury in fights was being struck by an opponent (Strotmeyer et al., 2016). Most injuries reported by the fighters in the study were of minor severity and did not require them to stop the fight. The percentage occurrence of injuries among the fighters was as follows: bruises 38.7%, skin lacerations 14.4%, swelling 14.4%, fractures 12.6%, sprains 10.8%, concussions 5.4%. When injuries occurred, the fighters were asked to specify their treatment methods. The injured fighters dealt with the injury on their own, received help from their coach, went to hospital, while 9.4% of those surveyed sought help from a physiotherapist.

The potential long-term effects of Muay Thai training on pain perception and tolerance merit investigation. While the current study focused on acute changes in pain tolerance following a single training session, longitudinal research could assess how pain perception evolves over extended periods of training and competition. Longitudinal studies could track changes in pain tolerance throughout athletes' careers, examining how factors such as training volume, intensity, and injury history influence pain perception trajectories (Cooper et al., 2016). Understanding the long-term effects of training on pain perception can impact injury prevention strategies, rehabilitation protocols, and athlete management practices in combat sports.

Another important consideration is the potential influence of cultural and social factors on pain perception among Muay Thai fighters. Muay Thai is deeply rooted in Thai culture, with traditional rituals, beliefs, and customs shaping athletes' attitudes toward pain and injury. For example, the concept of "Mai Pen

Rai" (translated as "never mind" or "no worries") emphasizes resilience and stoicism in the face of adversity, including physical pain. Exploring how cultural beliefs and social support networks influence athletes' pain experiences and coping strategies can provide valuable insights into the psychosocial determinants of pain tolerance in combat sports.

The integration of complementary training modalities, such as strength and conditioning, flexibility training, and mental skills training, may enhance athletes' pain tolerance and resilience. Strength training, for example, has been shown to improve pain tolerance by increasing muscle mass, enhancing neuromuscular coordination, and promoting the release of endogenous opioids (Anshel & Russell, 1994; Gintzler & Liu, 2020). Similarly, mindfulness-based interventions, relaxation techniques, and cognitive-behavioural strategies can help athletes manage pain, reduce stress, and optimize performance. By incorporating multidisciplinary approaches to training and performance optimization, coaches and practitioners can support athletes in developing holistic strategies for pain management and injury prevention.

Research on pain tolerance can be of value to the scientific community by expanding our knowledge of the physiological and psychological mechanisms that influence pain perception. Scientific discoveries in this area may contribute to a better understanding of the role of the nervous, endocrine, and immune systems in pain regulation and to the identification of potential pharmacological and behavioural therapies for chronic pain sufferers.

In the context of sports training, they have the potential to change approaches to pain management in sports and contribute to improving athletic performance and quality of life for athletes. Through collaboration between science, practice and sports, innovative training and rehabilitation strategies can be developed that take into account the complex effects of training on the human body and individual differences in pain perception (Huxel Bliven & Anderson, 2013).

There are more research possibilities for studying pain perception in athletes in the future, such as: electrophysiological measurement methods such as electromyography (EMG) or evoked potential measurement (ERP) can be used to monitor neural responses to painful stimuli (Rubin, 2019). By examining the electrical activity of muscles or the brain in response to painful stimuli, objective indicators of pain tolerance in Muay Thai athletes can be obtained. Neuroimaging methods, such as magnetic resonance imaging (MRI) or computed tomography (CT), can be used to study brain activity in response to painful stimuli (Luo et al., 2022). Imaging the brain during painful tasks can provide information about the activation of brain areas associated with the perception and processing of pain in Muay Thai athletes. Hormonal studies, such as measuring cortisol or beta-endorphin levels, can be used to assess hormonal responses to

painful stimuli in athletes (Traub & Ji, 2013). Changes in the levels of these hormones can indicate physical and psychological stress associated with experiencing pain and may be an indicator of pain tolerance in Muay Thai athletes. In addition to physiological assessment, behavioural studies can also be used to measure responses to painful stimuli. Observing behaviours such as facial expressions, body posture, or movement reactions can provide information about the subjective experience of pain in Muay Thai athletes (Kunz et al., 2023). There exist various pain assessment scales: the visual analog scale or the Borg scale, there are also other scales specifically developed for assessing pain in athletes, such as the Sports Pain Rating Scale (SPORTS) or the Pain Assessment Scale in Sports Context (SPoRT) (Breivik et al., 2008). Utilizing these specialized scales can provide more precise and comprehensive information about the experience of pain among Muay Thai athletes.

Utilizing these diverse measurement methods can allow for a more comprehensive understanding of pain tolerance among Muay Thai athletes and a better comprehension of the mechanisms of adaptation of the body to intense training and competition in this sports discipline.

Conclusions

In the Modified Cuff Pressure Test, results indicated that athletes' sensitivity to pain decreases after a training session. An increase in pain endurance caused by the pressure of the blood pressure cuff was observed in individuals both with greater and lesser training tenure. In the Cold Pressor Test, results did not show a change in pain perception among the participants before and after a training unit. Conclusively, practicing Thai boxing may increase resistance to pain related to compression but does not affect the perception of pain in the case of low temperatures applied locally.

The answer to the first research questions could be that training Thai boxing may lead to a partial increase in tolerance to physical pain associated with compression, especially immediately after a training session, regardless of training tenure. The differences between the pain stimuli for this study may seem significant. For compression in each group, the mean (mmHg) increased in exercisers after the training unit. In contrast, for low temperature, the mean in each group (time in seconds) decreased. Therefore, we can conclude that there is a difference in the sensation of these two specific stimuli by Muay Thai exercisers after a training unit. Which answers our second research question posed in the introduction.

The recommendation arising from the study for practitioners is to expand knowledge on pain perception in this sport. Therapists and trainers, by better

understanding pain tolerance and the characteristics of the most common injuries occurring among athletes, will be able to guide their charges more effectively.

In conclusion, while the study offers valuable insights into the relationship between Muay Thai training and pain tolerance, several avenues for further research and refinement exist. By considering individual variability, exploring the specificity of pain assessment methods, and including a more diverse population sample, future studies can enhance our understanding of the complex interplay between training, pain perception, and adaptation.

STATEMENT OF ETHICS

This study was conducted in accordance with the World Medical Association Declaration of Helsinki. The study protocol was reviewed and approved by the Committee for the Ethics of Scientific Research at Jan Dlugosz University in Czestochowa, nr KE-U/28/2022, Częstochowa, Polska. All participants provided written informed consent to participate in this study.

DECLARATION OF CONFLICTING INTERESTS

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