Issue Rehabil. Orthop. Neurophysiol. Sport Promot. 2025; 53: 23–33. ISSN 2300-0767
DOI: 10.5114/IRONS/216737

ORIGINAL ARTICLE

A COMPARISON OF PRESSURE PAIN THRESHOLDS IN INDIVIDUALS WITH HIGH AND LOW PHYSICAL ACTIVITY LEVELS

PORÓWNANIE UCISKOWEGO PROGU BÓLOWEGO U OSÓB Z WYSOKIM ORAZ NISKIM POZIOMEM AKTYWNOŚCI FIZYCZNEJ

Marta Wiśniewska[1,A–F], Sławomir Marszałek[1,A–C,E,F]
[1]Department of Physiotherapy, Poznan University of Medical Sciences, Poznan, Poland

ABSTRACT

Introduction
The effect of physical activity on the pain threshold has been widely studied, yet variation in study populations and methods has hindered a clear conclusion.

Aim
The aim of this study was to examine the influence of physical activity on the pressure pain threshold (PPT) values, taking sex, training intensity, and time of participants into account.

Materials and methods
Fifty-three participants were assigned to high or low physical activity groups on the basis of questionnaire data. The PPT was measured at four sites on the right side of the body: the supraspinatus muscle, the lateral epicondyle of the humerus, the gluteal, and the medial knee area. These measures were used to determine upper- and lower-limb pain threshold values.

Results
Participants with high physical activity demonstrated significantly higher upper-limb PPT values than those with low activity. Lower-limb PPT values were significantly higher in men than in women. Weak but significant positive correlations were found between training intensity and upper-limb PPT values, between average physical activity time and upper-limb PPT values, and between average physical activity time and lower-limb PPT values. A longer history of regular activity significantly predicted lower lower-limb PPT values.

Conclusions
These findings indicate that higher physical activity levels may be associated with higher PPT values. Training intensity, duration of activity, long-term activity, and sex may also influence pain sensitivity, highlighting the need for further research.

Keywords: pain, physical activity, pain pressure threshold

STRESZCZENIE

Wstęp
Wpływ aktywności fizycznej na odczuwanie bólu był wielokrotnie analizowany w piśmiennictwie naukowym, jednak zróżnicowanie populacji badanych oraz stosowanych metod pomiaru utrudnia osiągnięcie jednoznacznych wniosków.

Author responsible for correspondence:
Marta Wiśniewska, Department of Physiotherapy,
Poznan University of Medical Sciences,
32/2 Saperska St., 61-493 Poznan, Poland
marta1.wisniewska@onet.pl
https://orcid.org/0009-0009-2017-1564

Authors reported no source of funding
Authors declared no conflict of interest

Date received: 25th November 2025
Date accepted: 12th January 2026

A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article

Cel
Celem niniejszego badania była ocena wpływu poziomu aktywności fizycznej na wartości uciskowego progu bólowego (PPT), z uwzględnieniem intensywności i czasu trwania treningu oraz płci.

Materiały i metody
Do badania włączono 53 osoby, które na podstawie wyników ankiety przypisano do grup o wysokim lub niskim poziomie aktywności fizycznej. Uczestnikom zbadano PPT w czterech punktach po prawej stronie ciała: w obrębie mięśnia nadgrzebieniowego, nadkłykcia bocznego kości ramiennej, okolicy pośladkowej oraz przyśrodkowej kolana. Na tej podstawie wyznaczono wartości PPT dla kończyny górnej i dolnej.

Wyniki
Wyniki wykazały istotnie wyższe wartości PPT kończyny górnej w grupie o wysokim poziomie aktywności fizycznej w porównaniu z grupą o niskim poziomie aktywności. Zaobserwowano również istotnie wyższy PPT kończyny dolnej u mężczyzn niż u kobiet. Ponadto stwierdzono słabą dodatnią korelację pomiędzy średnim czasem aktywności fizycznej a wartościami PPT kończyny górnej, średnią intensywnością treningu a wartościami PPT kończyny górnej oraz średnim czasem aktywności fizycznej a wartościami PPT kończyny dolnej. Dłuższy okres regularnej aktywności fizycznej okazał się istotnym czynnikiem predykcyjnym niższego PPT w kończynie dolnej.

Wnioski
Uzyskane wyniki sugerują, że wyższy poziom aktywności fizycznej może wiązać się z podwyższonym PPT, a na odczuwanie bólu mogą wpływać również intensywność i czas trwania treningów, długość utrzymywania aktywności fizycznej oraz płeć. Z uwagi na złożoność zjawiska konieczne są dalsze badania w celu pełniejszego zrozumienia tych zależności.

Słowa kluczowe: ból, aktywność fizyczna, uciskowy próg bólowy

Introduction

Pain is an unpleasant sensory and emotional experience, nevertheless, it serves an essential function in the body – it signals actual or potential tissue damage [1]. Despite significant advances in pain medicine achieved in recent years, the assessment and monitoring of pain stimuli remain a major challenge. One of the primary limitations is the lack of a reliable, objective biomarker of pain. Most available tools rely on the patients' subjective sensations, which increases the risk of error and limits diagnostic precision [2,3]. One of the most extensively validated methods of pain assessment described in the research is the measurement of the pressure pain threshold (PPT) using an algometer [4–7]. The PPT is defined as the point at which the applied pressure first evokes a sensation of pain [8]. This concept should not be confused with pain tolerance, defined as the maximum intensity of a painful stimulus an individual is able to tolerate under specific conditions [1].

Pain perception is a highly complex process influenced by numerous factors. Scientific research increasingly highlights the impact of regular physical activity on the modulation of pain processes. Some mechanisms describing the effects of physical activity on pain perception have been explained in contemporary research, while other relationships remain unclear. Studies confirm that physical exercise activates endogenous analgesia. This phenomenon occurs as a result of the release of endogenous opioids and the activation of supraspinal nociceptive inhibitory mechanisms coordinated by the brain [9,10]. However, several studies have demonstrated dysfunction of this mechanism in patients suffering from chronic pain [11].

Numerous scientific studies have been conducted on the influence of physical activity on increasing PPT. Although meta-analyses addressing this topic exist, the results of individual studies remain inconclusive. Some of them have confirmed a statistically significant increase in the pain threshold, whereas others have not observed meaningful differences between physically active individuals and control groups. Moreover, the universality of findings is limited by the fact that most studies involve participants with specific medical conditions, assessing PPT changes before and after a series of exercises [12–15]. Nevertheless, there remains a lack of sufficient research involving healthy populations and direct comparisons of PPT between trained and untrained individuals. Because pharmacological pain management is often associated with side effects, non-pharmacological approaches to pain reduction may represent an important alternative for many patient groups. Understanding the mechanisms underlying pain perception and identifying factors that modulate pain experiences – including the role of physical activity – constitute a significant area of scientific inquiry, particularly considering that an estimated one-third of the global population experiences pain-related conditions [16].

Aim of the study

The aim of the present study was to evaluate the influence of physical activity on the value of the PPT. To achieve this, PPT values were compared between individuals characterized by high and low levels of physical activity. The correlations between PPT values and physical activity level, sex, training intensity, and time were also examined. In addition, mechanisms that may be responsible for differences in PPT results between the studied groups were discussed, as well as factors that could potentially interfere with the obtained research results.

Materials and methods

A total of 53 participants (32 women and 21 men), aged 20 to 30 years, took part in the study. The inclusion criteria were as follows:

- age between 20 and 30 years;
- no injuries within the 6 months preceding the study;
- no chronic pain (defined as persisting or recurring pain for more than 3 months [17]);
- no pain prior to the start of the examination procedure;
- absence of delayed onset muscle soreness (DOMS) at the time of testing;
- voluntary consent to participate in the study.

Participants were from the general population of the city of Poznan. The study involved a retrospective analysis of anonymized data obtained from assessments using a handheld pressure algometer during routine physiotherapy visits. Prior to data analysis, participants completed a short questionnaire regarding their habitual physical activity. The questionnaire was distributed electronically via social media. The ethics committee confirmed that the study did not constitute a medical experiment and that ethical approval was not required. All data were anonymised prior to analysis.

Participants were divided into two groups based on their level of physical activity, in accordance with the guidelines of the World Health Organization. Individuals who performed at least 150–300 minutes of moderate-intensity aerobic activity per week or 75–150 minutes of vigorous-intensity aerobic activity, or an equivalent combination of moderate- and vigorous-intensity activity, were classified into the high physical activity group. Those who did not engage in physical activity or those showing a level of activity lower than the minimum recommendations for the high activity group were assigned to the low physical activity group [18].

Vigorous-intensity physical activity was defined as effort corresponding to level 7 or 8 on a 0–10 scale relative to individual capacity, whereas moderate-intensity activity corresponded to levels 5 or 6 on the same scale [18].

PPT was assessed at four anatomical points – two located in the upper body and two in the lower body. Measurements were performed using a handheld pressure algometer. The testing points were selected from the 18 tender points defined by the American College of Rheumatology (ACR) [19] and included:

- the supraspinatus muscle – located centrally above the spine of the scapula;
- the region 2 cm distal to the lateral epicondyle of the humerus;
- the gluteal region – at the muscle fold within the upper outer quadrant of the buttock;
- the medial knee region – located proximal to the joint line.

All measurements were performed on the right side of the body, following the sequence: supraspinatus muscle, lateral epicondyle region, gluteal region, and medial knee region. Prior to the main procedure, a trial measurement was carried out on the left forearm to familiarise participants with the testing protocol.

PPT was measured by applying the algometer tip perpendicularly to the skin at the designated points. Pressure was gradually increased at a rate of approximately 1 kg/s. Participants were instructed to signal the moment when the sensation of pressure first turned into pain by saying "stop". Two measurements were taken at each point, and the mean value of the two trials was used for further analysis. Subsequently, based on the averaged PPT values from the upper-body points (supraspinatus muscle and lateral epicondyle region) and lower-body points (gluteal region and medial knee region), regional PPT values were calculated for these two anatomical areas.

Additionally, participants completed a questionnaire in which they provided informed consent for participation and demographic information, including sex, age, average weekly duration of physical activity (in hours), duration of regular physical activity, and the subjectively assessed mean training intensity on a scale from 0 to 10.

Statistical analysis was performed using Statistica version 13.3. The Shapiro-Wilk test was used to assess data normality. For comparisons between the two groups, the Student's *t*-test was used for variables with normal distribution, whereas the Mann-Whitney *U* test was applied for non-normally distributed variables. The Pearson linear correlation coefficient was used to determine the strength of linear relationships between normally distributed variables. When normality assumptions were not met, the nonparametric Spearman rank correlation coefficient was used to assess relationships between variables. The χ^2 test was employed to examine associations between categorical variables. The significance threshold was set at $\alpha = 0.05$.

Results

Participant characteristics

The study included 53 participants, consisting of 32 women and 21 men, with a mean age of 24.2 years (Table 1). 25 participants reported a high level of physical activity, while 28 reported a low level of physical activity. The two physical activity groups did not differ significantly in terms of sex distribution ($p = 0.61$) or age ($p = 0.93$).

Differences in upper- and lower-limb PPT values depending on the level of physical activity

Statistical analysis did not demonstrate significant differences in lower-limb PPT values between participants with high and low levels of physical activity ($p = 0.068$) (Table 2).

Simultaneously, a statistically significant difference was observed in upper-limb PPT values between individuals with high and low levels of physical activity ($p = 0.04$). Participants with a high level of physical activity demonstrated higher upper-limb PPT values than those with a low level of physical

Table1. Characteristics of the study groups

Group Parameter	**Individuals with a high level of physical activity (*n* = 25)**	**Individuals with a low level of physical activity (*n* = 28)**
Women	16	16
Men	9	12
Average duration of physical activity (hours per week)	7.1	0.2
Average intensity of physical activity (0–10 scale)	5.1	0.4
Average period of training (years)	4.9	0.5

Table 2. Mean pressure pain threshold (PPT) values and standard deviation (SD) values of the upper and lower limbs in relation to the physical activity level of participants (*N* = 53)

Group Parameter	**Individuals with a high level of physical activity (*n* = 25)**	**Individuals with a low level of physical activity (*n* = 28)**
Mean upper limb PPT ±SD	3.7 ±1.2	3.1 ±1.1
Mean lower limb PPT ±SD	4.6 ±1.5	3.8 ±1.3

The p-value was determined using the Mann-Whitney U test.

activity. Table 2 presents the mean PPT values and standard deviation (SD) values for the upper and lower limbs according to physical activity level.

Differences in upper- and lower-limb PPT values depending on sex

Analysis indicated statistically significant differences in lower-limb PPT values between women and men (*p* = 0.04) (Table 3). Men exhibited higher lower-limb PPT values compared with women.

No statistically significant differences were found in upper-limb PPT values between women and men (*p* = 0.16). Table 3 presents the mean PPT values and SD values for the upper and lower limbs according to sex.

Relationships between upper- and lower-limb PPT and duration and intensity of physical activity

Weak but statistically significant positive correlations were observed between average weekly physical activity time and upper-limb PPT, between average training intensity and upper-limb PPT, and between average physical activity time and lower-limb PPT (Table 4).

A weak positive correlation was also noted between training intensity and lower-limb PPT, however, this relationship was not statistically significant.

The table presents correlation coefficients (*r*) and significance levels (*p*) for the analysed relationships.

Table 3. Mean pressure pain threshold (PPT) values and standard deviation (SD) values of upper and lower limbs in relation to sex (*N* = 53)

Sex Parameter	**Women (*n* = 32)**	**Men (*n* = 21)**
Mean upper limb PPT (kg/cm^2) ±SD	3.1 ±1.1	3.7 ±1.2
Mean lower limb PPT (kg/cm^2) ±SD	3.9 ±1.4	4.6 ±1.4

The p-value was determined using the Mann-Whitney U test.

Multiple linear regression analysis

Data concerning physical activity intensity, weekly duration of physical activity, and years of physical activity participation were used to construct a multiple linear regression model to predict PPT (Table 5). The variables included in the model significantly predicted PPT ($p = 0.0248$); however, the R^2 value indicated a small effect size ($R^2 = 0.1725$). Analysis of individual predictors showed that years of physical activity constituted a significant negative predictor of lower-limb PPT ($\beta = -0.1829$, $p = 0.0227$).

Discussion

The aim of the present study was to compare PPT in healthy individuals differing in their level of physical activity. The obtained results are partially consistent with data reported in the research. However, it should be noted that based on existing studies, no consensus has been reached regarding the effect of physical activity on PPT. Available research investigating the relationship between physical activity and PPT shows considerable variability in terms of study populations and applied methodologies. These factors and individual differences in pain perception may contribute to inconsistencies in the results and complicate a clear interpretation of the impact of physical activity on pain perception [15].

In this study, the participant group was selected to minimize measurement variability – the age range was limited to 20–30 years to maintain relative homogeneity in natural skin tension [20]. Additionally, participants could not have sustained any injuries within the six months preceding the study, in order to exclude those in whom local or generalized post-traumatic sensitization could reduce PPT [21]. Participants without chronic pain and without pain symptoms at the start of the study were eligible for the study in order to limit the potential impact of these symptoms on PPT values. Individuals experiencing delayed DOMS at the time of measurement were also excluded, as this condition could lower PPT values [22].

Research describes multiple anatomical sites for PPT measurement using an algometer. In the present study, we applied a technique involving the averaging of measurements from two points on the upper limb and two points on the lower limb, with all

Table 4. Relationships between pressure pain threshold (PPT) values for upper and lower limbs and duration and intensity of physical activity

Variable	Average intensity of physical activity		Average weekly time of physical activity	
PTT value	*r*-value	*p*-value	*r*-value	*p*-value
Upper limb	0.30	0.016	0.30	0.01
Lower limb	0.27	0.056	0.29	0.03

The p-value was calculated using Spearman's rank correlation.

Table 5. Summary of the multiple linear regression including intensity of physical activity, average weekly time, and period of activity in years

Parameter	*p*-value of the model	Average intensity of physical activity		Average weekly time of physical activity		Period of regular training (years)	
PTT value		β (95% CI)	*p*-value	β (95% CI)	*p*-value	β (95% CI)	*p*-value
Upper limb	0.0975	0.1168 (–0.1713 to 0.4050)	0.4191	0.07579 (–0.0771 to 0.2287)	0.324	–0.1117 (–0.2402 to 0.01688)	0.0871
Lower limb	0.0248	0.2315 (–0.1186 to 0.5816)	0.1901	0.08383 (–0.1019 to 0.2696)	0.3689	–0.1829 (–0.3391 to –0.0267)	0.0227

CI – confidence interval

measurements performed on the right side of the body. A similar methodology was employed by Jones *et al.* [23], who measured PPT in the trapezius, biceps brachii, rectus femoris, and tibialis anterior muscles. Averaged values from the trapezius and biceps were used to define upper-limb PPT, whereas averaging measurements from the rectus femoris and tibialis anterior defined lower-limb PPT. In the present study, PPT values were determined from the supraspinatus muscle, 2 cm distal to the lateral epicondyle of the humerus, the gluteal region, and the medial knee region. These points correspond to selected tender points proposed by the ACR in 1990 [19]. Although initially developed for the diagnosis of fibromyalgia, these points are widely used in research on other conditions as well as in healthy individuals [19,24–26].

As expected, the results of the present study demonstrated a statistically significant difference in upper-limb PPT values between individuals with high and low levels of physical activity ($p = 0.04$). Furthermore, men exhibited significantly higher lower-limb PPT values compared with women ($p = 0.04$). Weak but statistically significant positive correlations were observed between average weekly physical activity time and upper-limb PPT ($p = 0.01$), average training intensity and upper-limb PPT ($p = 0.016$), and average weekly physical activity time and lower-limb PPT ($p = 0.03$). Surprisingly, data concerning physical activity intensity, weekly duration of physical activity, and years of physical activity participation predicted pain – a longer history of regular physical activity was a significant predictor of a lower pain threshold in the lower limb. However, no differences were detected in lower-limb PPT between high- and low-activity groups, nor in upper-limb PPT between men and women. The association between training intensity and lower-limb PPT also did not reach statistical significance.

Jones *et al.* [23] conducted a study involving 24 healthy individuals, in which PPT was measured in the upper and lower limbs using a methodology similar to that applied in the present study. Measurements were performed before and after six weeks of aerobic training in an experimental group and in a control group maintaining their usual level of physical activity. The study results indicated that six weeks of aerobic training did not produce statistically significant changes in PPT for either the upper or lower limbs. Similarly, the present study did not observe differences in lower-limb PPT between the analyzed groups. However, a significant difference was noted in upper-limb PPT according to physical activity level, which contradicts the findings of Jones *et al.* [23].

A meta-analysis by Tesarz *et al.* [15] included nine studies comparing PPT in athletes and individuals engaging in normal, non-specialised physical activity. The results regarding PPT were inconsistent: five studies reported significantly higher PPT values in athletes, four found no significant differences between groups, and one reported the opposite effect. Half of the studies in the meta-analysis demonstrated significantly higher PPT in athletes, which aligns with the observed relationship between training intensity and upper-limb PPT in the present study. Conversely, 40% of analysed studies did not report statistically significant differences between groups, which is consistent with the lack of a significant correlation between training intensity and lower-limb PPT in our study.

Hakansson *et al.* [27] examined the impact of training intensity on PPT. Twenty-eight overweight men were randomly assigned to either a high-intensity interval training (HIIT) program or a moderate-intensity continuous training (MICT) program. After six weeks of exercise, the MICT group showed a significant increase in lower-limb PPT, whereas no changes were observed in the HIIT group. No significant differences in upper-limb PPT were detected, regardless of training type. These findings contrast with the observations of the present study, in which no significant differences were found between physical activity level and lower-limb PPT, while significant differences were observed in the upper limb. However, Hakansson *et al.* [27] demonstrated an increase in PPT following moderate-intensity training compared with high-intensity training, whereas our study revealed a weak positive association between training intensity and upper-limb PPT.

Similarly to the results of the present study, Chesterton *et al.* [28] observed differences in PPT between women and men. Their findings showed a significantly lower PPT in women, which is consistent with the trend observed for lower-limb PPT in the present study.

The study by Anders *et al.* [29], conducted on a group of 26 elite athletes and 26 recreationally active individuals, demonstrated stronger somatosensory responses in electroencephalography to mechanical and thermal pain stimuli in athletes compared to the control group, despite no differences in subjective pain ratings. This may indicate the presence of central sensitization in the athlete group. These findings may partially correspond to the negative effect of the duration of regular physical activity on lower-limb PPT observed in the present study. A longer training history may induce changes responsible for the faster onset of pain in physically active individuals.

Recent scientific studies have investigated the mechanisms potentially underlying exercise-induced hypoalgesia. The mechanisms most frequently reported include the activation of the opioid and cannabinoid systems, a reduction in central nervous system sensitivity at spinal and supraspinal levels, modulation of the immune system through decreased levels of pro-inflammatory cytokines and increased levels of anti-inflammatory cytokines, as well as psychological factors that alter pain perception [30,31].

Despite numerous studies examining PPT in various populations, the results remain inconsistent. Previous studies on the relationship between PPT and physical activity indicate factors that can make it difficult to clearly identify such correlations. Control of all these factors was limited because individual differences in pain perception are influenced by many biological and psychosocial variables, including age, sex, race, stress, genetic, cultural, and environmental factors [32].

As previously mentioned, studies on PPT show significant variability in methodology, study population selection, and type of intervention. Measurement outcomes can be influenced by factors such as the anatomical location of measurement points, the procedure used, as well as the presence of comorbidities, previous injuries, or DOMS during assessment [15,21,22]. According to Chesterton *et al.* [28], sex may also influence PPT values. Therefore, study groups should be balanced by sex, or research should be conducted in a single-sex cohort to minimize the impact of this variable. These factors were controlled in the present study to standardise the participant group.

The study by Hennings *et al.* [33] demonstrated that patients with depression exhibited lower PPT values compared with a control group, suggesting that participants' mental state may significantly affect PPT measurements. Recent research indicates that personality traits can also influence pain perception. Nakae *et al.* [34] assessed hormonal changes and their relationship with personality traits and differences in pain perception in response to thermal stimulation. Individuals scoring higher on neuroticism exhibited elevated cortisol reactivity during exercise, which may be associated with reduced pain sensitivity. Conversely, individuals with lower scores on the same scale showed decreased cortisol reactivity, potentially resulting in lower pain thresholds. Consequently, individual differences in personality structure may correlate with differential hormonal responses, which could translate into varied pain perception. These factors were not considered in the present study; however, future research examining physical activity and PPT should also incorporate psychological and personality components. Currently, studies exploring these aspects remain limited, and knowledge in this area is insufficient, despite their potential significant influence on pain perception. Identifying these mechanisms could provide valuable contributions to the understanding of pain modulation.

Study limitations

Several important limitations of the present study should be emphasized, as they may affect the interpretation of the results. The first limitation is the relatively small sample size, with 53 participants included. Although this number is comparable to, or even larger than, some similar studies, it may still limit the statistical power and the universality of the findings to a broader population.

Another limitation is the use of a subjective measurement tool – PPT assessment with a pressure algometer. While this method is widely used in scientific research, it relies on the participant's subjective response to the stimulus, which may introduce a margin of error. Currently, there is no fully objective method for assessing PPT, making this tool the standard in such measurements [2–8].

Finally, individual differences in pain perception are conditioned by many biological and psychosocial factors. These may have influenced the results and controlling for all of them was limited. Such variables include heterogeneity in terms of sex, mental state, personality, genetic, cultural, and environmental factors, as well as numerous possible anatomical locations for PPT assessment. These factors were described in detail in the discussion section and may significantly modify the perception of painful stimuli independently of physical activity level.

Despite these limitations, the results provide a valuable contribution to the discussion regarding the relationship between physical activity and pain perception, highlighting directions for future, more extensive research.

Conclusions

In summary, results of the present study suggest that a high level of physical activity may be associated with higher PPT values. However, considering the overall data obtained and the existing research, it is not possible to unequivocally determine the nature of the relationship between physical activity level and PPT values.

The intensity and duration of physical activity, as well as the duration of regular physical activity, may influence PPT values. The findings of this study indicate that higher intensity and longer duration of training may correlate with higher PPT values, whereas longer duration of regular physical activity may correlate with lower PPT, although the observed relationships were weak. Additionally, the study found higher PPT values in the lower limb among men compared to women, regardless of physical activity level.

Nevertheless, further research is needed to assess the relationship between these variables more precisely, as well as to account for and control potential confounding factors.

References

1. **International Association for the Study of Pain Subcommittee on Taxonomy**. *Pain terms: a list with definitions and notes on usage.* Recommended by the IASP Subcommittee on Taxonomy. Pain 1979; 6: 249.
2. **Raja SN, Carr DB, Cohen M, et al.** *The revised International Association for the Study of Pain definition of pain: concepts, challenges, and compromises.* Pain 2020; 161: 1976–1982.
3. **Bhattacharyya A, Hopkinson LD, Nolet PS, Srbely J.** *The reliability of pressure pain threshold in individuals with low back or neck pain: a systematic review.* Br J Pain 2023; 17: 579–591.
4. **Potter L, McCarthy C, Oldham J.** *Algometer reliability in measuring pain pressure threshold over normal spinal muscles to allow quantification*

of anti-nociceptive treatment. Int J Osteopath Med 2006; 9: 113–119.

5. **Chesterton LS, Sim J, Wright CC, Foster NE.** *Interrater reliability of algometry in measuring pressure pain thresholds in healthy humans, using multiple raters.* Clin J Pain 2007; 23: 760–766.
6. **Walton DM, Macdermid JC, Nielson W, Teasell RW, Chiasson M, Brown L.** *Reliability, standard error, and minimum detectable change of clinical pressure pain threshold testing in people with and without acute neck pain.* J Orthop Sports Phys Ther 2011; 41: 644–650.
7. **Zamani S, Okhovatian F, Naimi SS, Akbarzadeh Baghban A.** *Intra-examiner and between-day reliability of algometer for pressure pain threshold and pain sensitivity in upper trapezius muscle in asymptomatic young adult women.* J Clin Physiother Res 2017; 2: 15–20.
8. **Vanderweeën L, Oostendorp RA, Vaes P, Duquet W.** *Pressure algometry in manual therapy.* Man Ther 1996; 1: 258–265.
9. **Sumizono M, Sakakima H, Otsuka S, et al.** *The effect of exercise frequency on neuropathic pain and pain-related cellular reactions in the spinal cord and midbrain in a rat sciatic nerve injury model.* J Pain Res 2018; 11: 281–291.
10. **Ray CA, Carter JR.** *Central modulation of exercise-induced muscle pain in humans.* J Physiol 2007; 585: 287–294.
11. **Nijs J, Kosek E, Van Oosterwijck J, Meeus M.** *Dysfunctional endogenous analgesia during exercise in patients with chronic pain: to exercise or not to exercise?* Pain Physician 2012; 15: ES205–ES213.
12. **Abdelmohsen AM, Nabil Abd El-Maboud BA.** *Impact of a targeted 8-week exercise program on pain measures and isokinetic muscle strength in females with patellofemoral pain syndrome: a randomized controlled trial.* Physiother Res Int 2025; 30: e70093. DOI: 10.1002/pri.70093.
13. **Santos PJ, Aragão-Santos JC, Santos TS, et al.** *Effects of 2 training protocols on aspects of pain in older women with chronic low back pain: a randomized clinical trial.* J Manipulative Physiol Ther 2025; 48: 47–56.
14. **González-Álvarez ME, Riquelme-Aguado V, Rossettini G, Fernández-Carnero J, Villafañe JH.** *Exercise intervention in women with fibromyalgia and its influence on pain, psychological variables, and disability: an observational study.* Life (Basel) 2024; 15: 40. DOI: 10.3390/life15010040.
15. **Tesarz J, Schuster AK, Hartmann M, Gerhardt A, Eich W.** *Pain perception in athletes compared to normally active controls: a systematic review with meta-analysis.* Pain 2012; 153: 1253–1262.
16. **Meeus M, Nijs J.** *Central sensitization: a biopsychosocial explanation for chronic widespread pain in patients with fibromyalgia and chronic fatigue syndrome.* Clin Rheumatol 2007; 26: 465–473.
17. **Treede RD, Rief W, Barke A, et al.** *Chronic pain as a symptom or a disease: the IASP classification of chronic pain for the International Classification of Diseases (ICD-11).* Pain 2019; 160: 19–27.
18. **World Health Organization.** *WHO guidelines on physical activity and sedentary behaviour.* Geneva: WHO; 2020.
19. **Wolfe F, Smythe HA, Yunus MB, et al.** *The American College of Rheumatology 1990 criteria for the classification of fibromyalgia.* Report of the multicenter criteria committee. Arthritis Rheum 1990; 33: 160–172.
20. **Ayadh M, Guillermin A, Abellan MA, Bigouret A, Zahouani H.** *The assessment of natural human skin tension orientation and its variation according to age for two body areas: forearm and thigh.* J Mech Behav Biomed Mater 2023; 141: 105798. DOI: 10.1016/j.jmbbm.2023.105798.
21. **Kasch H, Stengaard-Pedersen K, Arendt-Nielsen L, Staehelin Jensen T.** *Pain thresholds and tenderness in neck and head following acute whiplash injury: a prospective study.* Cephalalgia 2001; 21: 189–197.
22. **Fleckenstein J, Simon P, König M, Vogt L, Banzer W.** *The pain threshold of high-threshold mechanosensitive receptors subsequent to maximal eccentric exercise is a potential marker in the prediction of DOMS associated impairment.* PLoS One 2017; 12: e0185463. DOI: 10.1371/journal.pone.0185463.
23. **Jones MD, Booth J, Taylor JL, Barry BK.** *Aerobic training increases pain tolerance in healthy*

individuals. Med Sci Sports Exerc 2014; 46: 1640–1647.

24. **Incel NA, Erdem HR, Ozgocmen S, Atalay Catal S, Yorgancioglu ZR.** *Pain pressure threshold values in ankylosing spondylitis.* Rheumatol Int 2002; 22: 148–150.
25. **Knapstad MK, Glad Nordahl SH, Fjell Naterstad I, Ask T, Skouen JS, Goplen FK.** *Measuring pressure pain threshold in the cervical region of dizzy patients – the reliability of a pressure algometer.* Physiother Res Int 2018; 23: e1736. DOI: 10.1002/pri.1736.
26. **Maquet D, Croisier JL, Demoulin C, Crielaard JM.** *Pressure pain thresholds of tender point sites in patients with fibromyalgia and in healthy controls.* Eur J Pain 2004; 8: 111–117.
27. **Hakansson S, Jones MD, Ristov M, et al.** *Intensity-dependent effects of aerobic training on pressure pain threshold in overweight men: a randomized trial.* Eur J Pain 2018; 22: 1813–1823.
28. **Chesterton LS, Barlas P, Foster NE, Baxter DG, Wright CC.** *Gender differences in pressure pain threshold in healthy humans.* Pain 2003; 101: 259–266.
29. **Anders M, Dreismickenbecker E, Fleckenstein J, et al.** *EEG-based sensory testing reveals altered nociceptive processing in elite endurance athletes.* Exp Brain Res 2023; 241: 341–354.
30. **Sluka KA, Frey-Law L, Hoeger Bement M.** *Exercise-induced pain and analgesia?* Underlying mechanisms and clinical translation. Pain 2018; 159: S91–S97. DOI: 10.1097/j.pain.0000000000001235.
31. **Vaegter HB, Jones MD.** *Exercise-induced hypoalgesia after acute and regular exercise: experimental and clinical manifestations and possible mechanisms in individuals with and without pain.* Pain Rep 2020; 5: e823. DOI: 10.1097/PR9.0000000000000823.
32. **Fillingim RB.** *Individual differences in pain: understanding the mosaic that makes pain personal.* Pain 2017; 158: S11–S18. DOI: 10.1097/j.pain.0000000000000775.
33. **Hennings A, Schwarz MJ, Riemer S, Stapf TM, Selberdinger VB, Rief W.** *The influence of physical activity on pain thresholds in patients with depression and multiple somatoform symptoms.* Clin J Pain 2012; 28: 782–789.
34. **Nakae A, Bu-Omer HM, Kishimoto C, Chang WC, Sumioka H.** *Personality and its influence on pain sensitivity based on different hormonal responses to individual vs.* group exercise styles. Life (Basel) 2025; 15: 222. DOI: 10.3390/life15020222.