Mechanical hyperalgesia in athletes’ shoulder: integrative review

ABSTRACT

BACKGROUND AND OBJECTIVES: Chronic shoulder pain in throwing athletes is a common complaint in everyday practice. Despite the growing number of publications, it is unclear whether these athletes have mechanical hyperalgesia associated with pain, which could alter the treatment options undertaken. The aim of the study was to summarize the results of the main evidence found on the pressure pain threshold in the shoulder, to compare these results in athletes of different sports.

METHODS: Electronic search via PubMed/Medline, PEDro, SPORTDiscus, Web of Science and Scielo databases was done verifying studies in English or Portuguese. The keywords: pressure pain threshold; athletes; shoulder; pressure algometry and its derivations were searched in both languages. The articles should have included athletes from sports that use upper limbs and that assess the pressure pain threshold in the shoulder. Five studies were included for analysis.

RESULTS: Athletes with shoulder pain had a lower pressure pain threshold. In swimmers, changes in mechanical sensitivity to pain seem to be related to weekly training hours, years of sports practice and age group. Sports competitions apparently have an influence on the reduction of pressure pain threshold in amateur tennis players.

CONCLUSION: Swimming athletes have a lower pressure pain threshold and this is related to the volume and time of training in the modality. This variable seems to be sport-dependent, and the absence of a greater number of studies in sports such as tennis and wheelchair basketball limits conclusions on this subject.

Keywords: Athletes, Hyperalgesia, Shoulder, Trigger points.

INTRODUCTION

Chronic pain (CP) of the shoulder is a condition commonly reported by athletes who practice overhead sports. In adolescent judo, handball, and basketball athletes, there is a 63.8% prevalence of shoulder overload injuries, and a high rate is also present in athletes with more than 5 years of sports practice at university level. In professional athletes, shoulder CP represents approximately 19% of the injuries in volleyball and between 52% and 58% of complaints at some point of the season in handball.
The pain is considered chronic when persistent for a period longer than three months\(^\text{13}\), being defined as primary when not explained by the presence of another clinical condition, or chronic disease, relating to emotional suffering or functional disability\(^\text{13,14}\). On the other hand, secondary chronic pain is usually related to another pathological event, being initially a symptom, but persistent even after the successful treatment of the underlying disease\(^\text{13}\).

Alterations in neural sensitization are described in pain pictures and are generally natural responses to an injury\(^\text{15}\). Peripheral sensitization can be defined as an increase in the peripheral nociceptive response due to a stimulus in its receptive fields, presenting, in sensitized nerves, altered action potentials, but normal nerve conduction\(^\text{16}\). Central sensitization (CS) is represented by an increase in the central nervous system neuronal response due to a painful afferent stimulus\(^\text{16}\) or stimuli that are generally non-painful, inducing exacerbated and diffuse pain responses\(^\text{17}\).

The evaluation of the pressure pain threshold (PPT) is one of the ways to estimate the mechanical sensitivity to pain, which corresponds to the moment when the pressure exerted on a tissue becomes a painful stimulus\(^\text{18,19}\). In cases of unilateral shoulder pain, a low PPT in the affected limb compared to the unaffected one indicates the presence of peripheral sensitization\(^\text{15}\). In contrast, low PPT in tissues remote to the affected site (tibialis anterior, contralateral upper limb) suggests the presence of central sensitization\(^\text{15}\), one of the mechanisms suggested for the development of CP\(^\text{15,20}\).

According to a systematic review with meta-analysis that evaluated studies involving individuals with CP of several etiologies, the PPT in these populations was lower compared to asymptomatic control groups, showing generalized mechanical hyperalgesia in CP subjects\(^\text{21}\). Therefore, reviews on the presence of PPT in patients with shoulder CP are already available\(^\text{22,23}\), showing that individuals with tendinopathy or overload lesion in the upper limbs presented bilateral hypersensitivity during PPT measurement, when compared to asymptomatic individuals, but this finding showed low to moderate quality of evidence\(^\text{23}\). Furthermore, patients with shoulder pain did not present changes in the PPT, only changes in the supra-threshold of pain to heat (hypersensitivity) when compared to asymptomatic patients\(^\text{22}\).

However, PPT is still a variable that should be further explored in athletes, because with the growing number of publications on the subject there is a need to organize the results of the main evidence found.

The purpose of this study was to synthesize the main results of existing research about PPT in the shoulder of athletes and to compare the results of PPT in athletes from different sports.

**METHODS**

An integrative review was carried out with the objective of identifying the existing works in the national and international literature on the theme "shoulder PPT in athletes". Without filters to determine the period, Pubmed, PEDro, Scielo, SPORTDiscus and Web of Science databases were searched. The MeSH terms and keywords combinations were used: pressure pain threshold AND athletes; pressure pain threshold AND shoulder; pressure algometry AND shoulder; pressure algometry AND athletes. In the Scielo database searches, the following combinations of keywords in Portuguese were also used: limiar de dor a pressão AND atletas; limiar de dor a pressão AND ombro; algometria por pressão AND ombro; e algometria por pressão AND atletas.

This study included scientific articles published in English or Portuguese that evaluated PPT in the shoulder region and that involved athletes from all competitive levels, from sports that predominantly use the upper limbs in the sportive gesture and, therefore, had high prevalence of shoulder injuries, such as swimming\(^\text{24}\), volleyball\(^\text{25}\), rugby\(^\text{26}\), handball\(^\text{27}\), tennis\(^\text{28,29}\) and baseball\(^\text{30}\). Studies that evaluated PPT in other body segments in athletes or shoulder PPT in non-athletes, or that used other forms of pain assessment in athletes other than PPT were excluded. PPT measurements at points distal to the shoulder, to assess the presence or absence of pain in athletes were not considered an exclusion factor.

The search for the studies occurred in the following order: search of the databases using MeSH terms and keywords, reading of the titles, selection and reading of the abstracts of the pre-selected studies. Then, the papers that fit the inclusion criteria were selected for full reading. The extraction of data from the full reading was performed to fill a table with the eligibility criteria; after the final selection of studies, an integrative review was performed with critical analysis of the results.

**RESULTS**

Initially, 1,374 studies were found, and 19 duplicate studies were manually excluded, resulting in 1,355 studies. Of these, 1,341 were excluded in the reading of titles and abstracts. This left 14 studies for full-text review. Of these, a total of nine were excluded for evaluating PPT in other body segments of athletes or for evaluating thermal sensitivity in athletes rather than mechanical pain sensitivity. At the end of this review, five studies that met the eligibility criteria were included (Figure 1).

Three of the included studies were present in Pubmed, SPORTDiscus, and Web of Science databases, one was present in both Pubmed and Web of Science, and one was present in Web of Science alone.

The publications date from the period of 2011 to 2020, with studies from Spain, Belgium, Brazil, and Turkey. Swimming\(^\text{31-33}\), wheelchair basketball\(^\text{34}\) and tennis\(^\text{35}\) athletes were evaluated. Regarding the competitive level, two studies evaluated elite athletes\(^\text{33,34}\), one evaluated competitive sportsmen\(^\text{31}\), one evaluated competitive and amateur sportsmen\(^\text{32}\), and another study evaluated amateur university athletes\(^\text{35}\) (Table 1). The competitive level of the participants was defined differently in each publication. For swimmers, those who trained at least 4 hours a week and participated in competitions at regional, national, and/or international level\(^\text{31}\) - as well as those who trained at least 3 times a week, swam at least 4000 meters a day, and participated in some professional competition for at least
Table 1. Characteristics of the studies included in this review

<table>
<thead>
<tr>
<th>Authors</th>
<th>Sport</th>
<th>Methodology</th>
<th>Competitive level</th>
<th>Participants</th>
<th>Average training time (years)</th>
<th>Average training time (hours/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuppens et al.31</td>
<td>Swimming</td>
<td>Observational study</td>
<td>Competitive</td>
<td>Mean age of 15.5±2.7 years 102 healthy swimmers (54 males and 48 females)  Age range between 10 and 25 years</td>
<td>Data not provided by the study</td>
<td>11.6±4.6 weekly training hours</td>
</tr>
<tr>
<td>Hidalgo-Lozano et al.33</td>
<td>Swimming</td>
<td>Observatio- nal study</td>
<td>Elite</td>
<td>Age range between 18 and 28 years 17 swimmers with pain - mean age 21±3 years (9 men and 8 women)  18 without shoulder pain - mean age 20±3 years (9 males and 9 females)  15 healthy athletes - mean age 23±4 years (7 men and 8 women) from other sports (athletics and skiing) as control group</td>
<td>Swimmers with shoulder pain: 11.6±3.4 years of training in the sport  Swimmers without shoulder pain: 8.9±2.7 years of training in the sport  Control group: 11.1±5.5 years of training</td>
<td>Swimmers with shoulder pain: 26.8±4.8 hours per week  Swimmers without shoulder pain: 26.1±5.5 hours training per week  Control group: 23.4±4.2 hours of training</td>
</tr>
<tr>
<td>Habechian et al.32</td>
<td>Swimming</td>
<td>Observational study</td>
<td>Competitive and amateur</td>
<td>Mean age between 8 and 15 years 30 not practicing sports - mean age 11.50±1.94 years (14 girls and 16 boys)  30 amateur swimmers - mean age 11.56±1.81 years (18 girls and 12 boys)  30 competitive swimmers - mean age 12.63±2.02 (17 girls and 13 boys)</td>
<td>Amateur swimmers: 4.36±2.91 years of training in the sport</td>
<td>Data not provided by the study</td>
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</table>

PPT was also evaluated over four consecutive days of amateur tennis competition35 and there was a PPT reduction throughout the competition.
Table 1. Characteristics of the studies included in this review – continuation

<table>
<thead>
<tr>
<th>Authors</th>
<th>Sport</th>
<th>Methodology</th>
<th>Competitive level</th>
<th>Participants</th>
<th>Average training time (years)</th>
<th>Average training time (hours/week)</th>
</tr>
</thead>
</table>
| Ortega-Santiago et al.34 | Wheelchair Basketball | Observational study | Elite             | Age range 18-50 years
18 wheelchair basketball players with shoulder pain - mean age 30±8 years
22 wheelchair basketball players without shoulder pain - mean age 32±10 years
20 traditional basketball players - mean age 31±7 years | Data not provided by the study | Data not provided by the study |

Kafkas et al.35

<table>
<thead>
<tr>
<th>Authors</th>
<th>Sport</th>
<th>Methodology</th>
<th>Participants</th>
<th>Average training time (years)</th>
<th>Average training time (hours/week)</th>
</tr>
</thead>
</table>
| Tennis                | Experimental study   | Amateur college students | Age range 19-30 years
58 tennis players:
25 females - mean age 24.35±5.42 years
34 men - average age 25.10±6.05 years | Data not provided by the study | Data not provided by the study |

Table 2. Goals, methods, results and conclusion of the included articles.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Goals</th>
<th>Methods</th>
<th>Results</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuppens et al.31</td>
<td>To evaluate the relationship between pain threshold and training volume in competitive swimmers, using static (pressure pain threshold - PPT) and dynamic (conditioned pain modulation) measurement tools.</td>
<td>Digital Algometer (Wagner Instruments, Greenwich, CT, USA). PPT measurement sites: upper trapezius, dorsal side of the middle phalanx of the third finger, proximal third of the calf muscle.</td>
<td>Average swimming training: 11.6 h/week. PPT associated with conditioned pain modulation: external painful stimulus applied to the upper portion of the non-dominant upper limb during PPT reassessment was superior to isolated PPT measurement; Swimmers exposed to a higher volume of training showed higher PPT, indicating less sensitization to pain in these athletes; Swimmers with lower training volume obtained lower PPT; There was no correlation between training volume and conditioned pain modulation as a measure of endogenous pain modulation capacity.</td>
<td>Pain perception may be influenced by the volume of swim training; Swimmers who had a greater number of hours of training obtained higher PPT in various parts of the body, indicating less sensitization to pain and possible training-induced hypoaesthesia; No associations were found between training load and measures of endogenous pain inhibition.</td>
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Hidalgo-Lozano et al.33

<table>
<thead>
<tr>
<th>Authors</th>
<th>Goals</th>
<th>Methods</th>
<th>Results</th>
<th>Conclusion</th>
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<tbody>
<tr>
<td>To evaluate and compare PPT, presence of active and latent trigger points in elite swimmers with and without shoulder pain and in healthy elite athletes.</td>
<td>Mechanical pressure algometer (Pain Diagnosis and Treatment Inc., Great Neck, NY, USA). PPT measurement sites: Elevator of the scapula, Sternocleidomastoid, Upper trapezius, Scalar, Infra-spinal, Subscapular, Tibialis anterior</td>
<td>Swimmers in pain: 65% had pain during training; PPT lower than the control group; Fewer active trigger points. Swimmers without pain: Lower PPT than the control group in the upper trapezius, subscapular, and anterior tibial muscles; Higher number of latent trigger points. No significant difference in PPT and trigger points between the groups with and without pain; Higher number of trigger points in the groups with and without pain than in the control group (healthy athletes from other sports).</td>
<td>Elite swimmers with and without shoulder pain showed lower PPT values compared to the group of healthy athletes; Low PPT values were also found in the tibialis anterior in swimmers with and without shoulder pain, suggesting the presence of CS in these athletes; Elite swimmers with and without pain showed peripheral and central sensitization; Findings of active trigger points in the shoulder/neck directly contributed to pain complaint in elite swimmers; Similar PPT were found between the two groups of swimmers, suggesting that elite swimmers may be predisposed to develop a degree of mechanical sensitization related to the specific physical demands of swimming.</td>
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Press pain threshold, training volume and sports competitions

The training volume in competitive swimmers was directly proportional to PPT\(^1\). Thus, swimmers with more hours of weekly training had higher PPT, which indicates less mechanical pain sensitivity and possible hypoalgesia induced by the training itself\(^1\). In non-athletes, aerobic exercise reduces mechanical pain sensitivity in healthy adults\(^36\), and aerobic, isometric and resistance exercises have transient effects on pain reduction in this population\(^37\). It is worth mentioning that the appropriate dose of exercises to induce hypoalgesia is not clear\(^37,38\), and it has been suggested that for individuals with CP it is more effective to increase the frequency of weekly exercise sessions\(^34\).
Although high training loads are associated with higher injury risks, especially when there is a rapid increase in training loads, PPT was higher in swimmers who trained more hours per week. Physical training is based on the overload principle, so that in order to increase athlete performance, his activity must exceed the adaptive capacity of the tolerated load. However, the load must be properly managed to avoid the negative effects of training that, when excessive, can lead to overtraining and fatigue; but, when insufficient, results in the athlete not being fully prepared for competition. Possibly, the training performed in the study with swimmers was adequate to develop the physical abilities that enhanced performance and acted preemptively against injuries.

The effects of overload can also be observed during sports competitions on consecutive days. One of the included studies measured the PPT during a four-day amateur tennis competition. After the second, third and fourth days of competition, there was a reduction of the PPT at the lateral epicondyle, trapezius and deltoid, as well as a reduction of the PPT at the supraspinatus after the third day of competition in the female group and after the fourth day in the male group. There was also a reduction in palm grip strength after the second, third and fourth days of competition in female athletes and after the third and fourth days in male athletes. In this same period, in both groups there was an increase in pain intensity. Considering the lower muscle mass in women, it is likely that this accumulation of sequential matches on consecutive days probably generated greater muscle damage in the upper limbs of female athletes compared to male athletes, which reduced the PPT.

Studies evaluating shoulder range of motion in tennis players during two consecutive matches on the same day identified reduced range of motion of the rotations and also reduced strength of the ring two consecutive matches on the same day identified reduced strength. Studies evaluating shoulder range of motion in tennis players during two consecutive matches on the same day identified reduced range of motion of the rotations and also reduced strength of the ring two consecutive matches on the same day identified reduced strength.

Musculoskeletal adaptations such as reduction of the subacromial space and increase of the shoulder anteriorization postural changes in swimmers when compared to healthy athletes from other sports. The result in young swimmers without complaints is contrary to that found in a recent systematic review, which showed in competitive adolescent swimmers a higher prevalence of shoulder pain, with moderate evidence for association with the volume of swimming training. This lower sensitization in these athletes can be explained by the shorter time practicing the sport, and swimmers with shoulder pain have an average of 11.6 years of practice, while those without shoulder pain have an average of 8.9 years of training. These data corroborate a previous research that found a positive relationship between years of competitive swimming training and reduced supraspinatus tendon thickness, which are self-reported measures of shoulder pain and function.

Pressure pain threshold and basketball
Wheelchair basketball athletes with shoulder pain had reduced PPT in all tested areas, in addition to the presence of a higher number of active trigger points when compared to athletes of the same sport and traditional basketball athletes. Shoulder pain is a common condition in these athletes, and in men there is an association between shoulder pain and older age, lower functional skills and more years of experience in the sport, while in women, a longer time of practice tends to moderate shoulder pain.

Pressure pain threshold and trigger points
The presence of active trigger points (TP) is common in professional basketball players with unilateral shoulder pain, similar to what has been found in wheelchair basketball players and swimmers with shoulder pain, who also present a reduced PPT and the presence of central and peripheral sensitization. Thus, it is possible that there is a relationship between the presence of active TP, shoulder pain, and low PPT.

The presence of active TP may be related to the presence of central and peripheral sensitization in the studied athletes. In individuals with unilateral subacromial pain syndrome, the presence of bilateral active TP and increased myofascial pain in the affected limb was related to the presence of peripheral sensitization. In subjects with tension headache, a relationship has been established between the number of active TPs in the cervical and shoulder regions and diffuse pain sensitivity (central sensitization).

The small number of publications included in the review can be mentioned as a study limitation, in addition to the fact that the studies included did not evaluate athletes from the same modality, with a predominance of studies with swimmers of various age groups and competitive levels. In addition, a limited number of publications on the theme was identified, making this review
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CONCLUSION

Athletes with shoulder pain have lower PPT. However, the PPT in athletes shows conflicting results across sports, indicating the possibility of being sport-dependent. In swimmers, changes in mechanical pain sensitivity seem to be related to weekly training hours, years of sports practice, and age group. In amateur tennis players, consecutive days of competition contributed to reduced PPT in the shoulder and elbow.

AUTHORS’ CONTRIBUTIONS

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Data Collection, Writing - Preparation of the original, Writing - Review and Editing
Luis Ulisses Signori
Writing - Preparation of the original, Writing - Review and Editing
Michele Forgiarini Saccol
Conceptualization, Writing - Preparation of the original, Writing - Review and Editing

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