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Tactile acuity and temporal summation as measures of central sensitisation in individuals with adhesive capsulitis: a pilot study

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Abstract

Introduction. This study aimed to assess and compare tactile acuity and temporal summation between individuals with unilateral adhesive capsulitis and healthy age- and gender-matched controls.

Methods. A cross-sectional study was undertaken. Based on the inclusion and exclusion criteria, participants were recruited from tertiary care hospitals. The study consisted of two groups: 16 participants in the adhesive capsulitis group and 16 age- and gender-matched healthy individuals in the control group. A two-point discriminator was used to assess tactile acuity, and a nylon monofilament was used to assess temporal summation.

Results. The Mann–Whitney *U* test was used to analyse the data. The results showed a significant difference in tactile acuity values in the anterior ($p < 0.001$), middle ($p = 0.001$) and posterior ($p = 0.001$) aspects of the shoulder between the adhesive capsulitis and control groups. A significant difference in temporal summation ($p < 0.001$) was also observed between the adhesive capsulitis and control groups.

Conclusions. The study demonstrated altered tactile acuity and temporal summation in individuals with adhesive capsulitis compared to healthy age- and gender-matched controls. These findings suggest that adhesive capsulitis may be accompanied by maladaptive neuroplastic changes, leading to central sensitisation.

Key words: adhesive capsulitis, tactile acuity, temporal summation

Introduction

Adhesive capsulitis is a condition in which individuals experience pain and restriction of both active and passive shoulder range of motion. It has a prevalence rate of 2–4% and is predominantly seen in individuals aged 40 to 65 years [1]. Approximately 70% of subjects with adhesive capsulitis are female, with men tending to recover more slowly and exhibiting greater disability [2]. Studies have shown that adhesive capsulitis is characterised by the presence of pain-producing chemicals and inflammatory mediators, such as cytokines. As a result, dorsal horn neurons and spinal cord glial cells may become stimulated, boosting synaptic effectiveness and neuronal excitability, which can lead to central sensitisation [2, 3].

The term "central sensitisation" refers to the amplification of neural signals that causes pain hypersensitivity within the central nervous system [4]. It is a physiological process in which nociceptive neurons in the central nervous system become more responsive to normal or subthreshold afferent input. In cases where central sensitisation is present, even minimal mechanical pressure – due to a minor soft tissue injury or sensory input without soft tissue injury – can trigger pain perception. Alterations in neuronal membrane properties, synaptic strength and inhibitory tone within the nociceptive pathway, orchestrated by the central nervous system, can contribute to the development of central sensitisation [5, 6]. Glial activity may also play a role in this process [7].

Various assessment tools have been used to measure central sensitisation. Temporal summation and tactile acuity are objective tools commonly used to assess this phenomenon. Tactile acuity is the precise ability to feel the sensation of touch [8]. It is assessed via two-point discrimination and serves as a surrogate marker for neuronal activity within the primary somatosensory cortex (S1). Clinically, reduced tactile acuity signifies S1 reorganisation in the corresponding somatotopic map [9]. Notably, the degree of S1 reorganisation correlates directly with pain intensity [10].

Temporal summation of pain is a quantitative metric used to assess the pain experienced in response to short, repeated, noxious stimuli. It indicates an increase in dorsal horn excitability and occurs when postsynaptic potentials overlap and summate as high-frequency action potentials are fired by presynaptic neurons [11].

There is sufficient evidence to support the presence of central sensitisation in various chronic pain conditions such as fibromyalgia, low back pain and osteoarthritis [8]. However, there is conflicting evidence regarding the presence of altered tactile acuity and temporal summation in shoulder impingement syndrome [5], and a lack of literature on the role of central sensitisation in individuals with adhesive capsulitis. In addition to conventional therapy, determining the presence of central sensitisation in adhesive capsulitis could help guide physical therapy efforts towards central nervous system-focused techniques such as pain neuroscience education and graded motor imagery [12]. It is hypothesised that individuals with adhesive capsulitis would exhibit altered tactile acuity and temporal summation compared to healthy individuals.

Hence, this study aimed to assess and compare tactile acuity and temporal summation between individuals with unilateral adhesive capsulitis and healthy age- and gender-matched controls.

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Subjects and methods

A cross-sectional study with a sample size of 32 was conducted (16 individuals with unilateral adhesive capsulitis and 16 healthy age- and gender-matched individuals as controls). The individuals were recruited from the outpatient departments of orthopaedics and physiotherapy at tertiary care hospitals through convenience sampling. Outcome measures used were tactile acuity and temporal summation.

Participants aged 40–65 years, both male and female, with unilateral adhesive capsulitis for a duration of 1–9 months were included in the study.

The study excluded participants with peripheral neuropathy, sensory loss, cervical radiculopathy, other shoulder conditions such as arthritis, neurological disorders, psychological disorders or disturbances and patients with diabetes whose HbA1c was more than 7% or whose fasting blood sugar levels were more than 126 mg/dl.

Sample size estimation

Based on the study by Holla et al. [13], the sample size was calculated for comparison of means to test for a deviation mean difference of 30%, assuming an effect size of 0.8 and a power of 80%. The minimum estimated sample size was 52, with 26 in each group.

Due to difficulty in achieving the estimated sample size because of the COVID-19 pandemic, the sample size was recalculated with a deviation mean difference of 30%, an alpha error of 1% and a power of 99%, using a two-sided test (instead of an alpha error of 0.05 and power of 80% as assumed earlier). Based on this calculation, the estimated sample size was 30, with 15 subjects in each group.

Procedure for data collection

Based on the inclusion criteria, participants were screened, and eligible subjects were recruited for the study. All participants received an explanation of the study, and those who volunteered to participate were enrolled after providing signed informed consent. A detailed assessment of the shoulder was conducted, which included a history of the presenting illness, pain assessment, observation and palpation, range of motion and flexibility assessment, screening for neurological deficits and systemic illnesses and pre-screening of sensation for light touch, pressure and vibration for all participants. Tactile acuity and temporal summation were assessed in individuals with adhesive capsulitis and healthy age/gender-matched controls.

Participant recruitment

Subjects with adhesive capsulitis were recruited from the outpatient department of physiotherapy in tertiary care hospitals. A total of 35 individuals with symptoms of adhesive capsulitis were screened, of which 16 met the inclusion criteria and were included in the study. The control group consisted of 16 age- and healthy gender-matched individuals.

Tactile acuity

The two-point discriminator (Baseline Aesthesiometer) was used to measure tactile acuity. The participants were assessed in a sitting position. The tactile acuity values of the anterior, middle and posterior aspects of the shoulder were measured at three different points: 5 cm below the anterior edge of the acromion, at the midpoint of the lateral border and at the posterior edge of the acromion process. Participants were familiarised with the resultant light touch sensation of the aesthesiometer before starting the study. The aesthesiometer was placed at each point, lightly touching the skin, and examined until the participants felt two points. The participants were instructed to report “one” if only one point was felt, “two” if two points were felt or “don’t know” if unsure. The distance at which the participants felt the two points was noted. The distance was compared between individuals with unilateral adhesive capsulitis and healthy age- and gender-matched controls [14].

Temporal summation

A nylon monofilament (Baseline monofilament, size 6.45 and force 300 g) was used to measure the temporal summation of pain. The participants were assessed in a supine position at the glenohumeral joint line. Prior to the study, participants were provided with the Numerical Pain Rating Scale (NPRS) and instructed to rate their intensity of pain. The monofilament was then positioned perpendicular to the skin’s surface, and 300 g of pressure was applied till the monofilament bends. The monofilament was calibrated to bend when a force of 300g is applied. Participants were then asked to rate the single stimulus pain severity on the NPRS. Subsequently, ten stimuli were applied, one every second. After the ten repetitions of the stimuli, participants were again instructed to rate their level of pain on the NPRS. The NPRS values obtained after the application of one stimulus (1st scale) and after 10 repetitive stimuli (2nd scale) were compared. An increase in the value of the 2nd scale compared to the 1st scale indicates the presence of temporal summation [15].

Statistical analysis

The normality of the data was assessed using the Shapiro–Wilk test. Non-parametric tests were used for data analysis because the data were not normally distributed. Descriptive statistics were used to describe demographic characteristics, tactile acuity and temporal summation. Median and interquartile range (IQR) were used to describe descriptive statistics. The Mann–Whitney *U* test was used to compare tactile acuity and temporal summation between individuals with unilateral adhesive capsulitis and healthy age- and gender-matched controls. Statistical software SPSS version 16 was used for analysis, and Microsoft Word and Excel were used to generate tables and graphs.

Results

Demographic data of individuals with adhesive capsulitis and age/gender-matched controls

There were 16 individuals in both the adhesive capsulitis group and the control group, of which 56.3% were women and 43.8% were men (Table 1). The standard deviation was 7.28, and the mean age was 51.31 years. The data were homogeneous.

Descriptive statistics of the tactile acuity

Table 2 shows the median and IQR of tactile acuity in individuals with adhesive capsulitis and healthy age- and gender-matched controls. In the adhesive capsulitis group, the median and IQR were 38.50 (36, 45) for the anterior aspect of the

Table 1. Demographic data of individuals with adhesive capsulitis and age/gender-matched controls

Variables	Adhesive capsulitis group (n = 16)	Control group (n = 16)
Age (years, mean ± *SD*)	51.31 ± 7.282	51.31 ± 7.282
Gender (female)	56.3%	56.3%
Gender (male)	43.8%	43.8%

Table 2. Descriptive statistics of the tactile acuity

Variables	Adhesive capsulitis group (n = 16) Median (IQR)	Control group (n = 16) Median (IQR)
Tactile acuity anterior (mm)	38.50 (36, 45)	30 (27.25, 33.75)
Tactile acuity middle (mm)	39 (34, 44)	30 (26, 31)
Tactile acuity posterior (mm)	41.50 (34.75, 46.75)	30 (27, 32.75)

Table 3. Descriptive statistics of the temporal summation

Variables	Adhesive capsulitis group (n = 16) Median (IQR)	Control group (n = 16) Median (IQR)
Temporal summation (cm)	3 (2.25, 4.75)	2 (1.25, 2)

Table 4. Comparison of tactile acuity and temporal summation between individuals with unilateral adhesive capsulitis and healthy age- and gender-matched controls

Variables	Mann–Whitney U	Z	Asymp. sig. (2-tailed)
Tactile acuity anterior	33.500	–3.810	< 0.001
Tactile acuity middle	46.000	–3.456	0.001
Tactile acuity posterior	46.000	–3.312	0.001
Temporal summation	39.000	–3.519	< 0.001

$p < 0.05$ is statistically significant

shoulder, 39 (34, 44) for the middle and 41.50 (34.75, 46.75) for the posterior aspect of the shoulder. In the healthy age- and gender-matched controls, the median and IQR were 30 (27.25, 33.75) for the anterior, 30 (26, 31) for the middle and 30 (27, 32.75) for the posterior aspects, respectively.

Descriptive statistics of the temporal summation

Table 3 shows the median and IQR of temporal summation in individuals with unilateral adhesive capsulitis and healthy age- and gender-matched controls. The temporal summation values were 3 (2.25, 4.75) and 2 (1.25, 2), respectively.

Comparison of tactile acuity and temporal summation between individuals with unilateral adhesive capsulitis and healthy age- and gender-matched controls

A significant difference in temporal summation (p = 0.001) and tactile acuity was noted in the anterior aspect of the shoulder (p = 0.001), middle (p = 0.001) and posterior shoulder (p = 0.001) between the adhesive capsulitis group and the control group.

Discussion

Central sensitisation refers to the amplification of neural signals within the central nervous system, leading to pain hypersensitivity [4]. The presence of central sensitisation can be assessed through temporal summation and tactile acuity.

The objective of this study was to compare tactile acuity and temporal summation in individuals with adhesive capsulitis and healthy age- and gender-matched controls.

The study revealed that, compared to healthy age- and gender-matched controls, subjects with adhesive capsulitis had altered tactile acuity and temporal summation. The findings demonstrated a statistically significant difference in tactile acuity between the adhesive capsulitis group and the control group in the anterior aspect of the shoulder (p = 0.001), the middle aspect (p = 0.001) and the posterior aspect of the shoulder (p = 0.001). Temporal summation values also showed a significant difference between the adhesive capsulitis group and the control group (p = 0.001).

The study's findings on tactile acuity align with those of a recent study by Horno et al. [16], in 2020, which revealed that tactile acuity is lower in individuals with frozen shoulder compared to healthy controls. These results also corroborate findings from a comprehensive analysis examining tactile acuity in individuals with chronic musculoskeletal pain [17], where lower tactile acuity was observed in individuals with arthritis, complex regional pain syndrome and chronic low back pain [17]. The reduced tactile acuity observed in this study may result from disturbances in the somatosensory representations in the primary somatosensory cortex of the affected shoulder because tactile acuity clinically represents the S1 cortex [9]. The hypothesis of S1 cortical map disturbance is supported by evidence from studies on complex regional pain syndrome [18] and chronic back pain [19].

Another possible explanation for the differences in temporal summation and tactile acuity between individuals with adhesive capsulitis and healthy controls is the presence of inflammatory mediators, such as cytokines and pain-producing chemicals, during the early stages of adhesive capsulitis. Inflammatory mediators may stimulate dorsal horn neurons, and spinal cord glial cells may also become activated [2]. This glial cell activation enhances synaptic efficacy and neural excitability. Changes in the functional status of neurons and the nociceptive pathway – resulting from increased membrane excitability, synaptic efficiency or decreased inhibition – can lead to central sensitisation [6].

According to the study's findings, the temporal summation values of the adhesive capsulitis group differed from those of the healthy age- and gender-matched control group (p = 0.001). This result is consistent with findings from an earlier study by Thompson et al. [20], in 2019, which found that subjects with persistent pelvic pain exhibited temporal summation. The Thompson et al. study [20] also revealed the presence of allodynia, further suggesting central sensitisation in chronic pelvic pain. The results of the present study align with a study conducted by Staud R et al. [21], in 2014, which showed that individuals with fibromyalgia demonstrated a temporal summation that accelerated linearly with increasing stimulus intensity, compared to healthy controls.

Increased pain perception, resulting from the activation of either C- or A-fibres by repeated, constant-intensity noxious stimuli, may also contribute to the observed increase in temporal summation in adhesive capsulitis. The neurotransmitters glutamate/aspartate, tachykinins and substance P, released from C-fibre terminals, can progressively activate N-methyl-D-aspartate receptors in dorsal horn neurons by removing the

magnesium block from the ion channel. Once glutamate binds to the receptor, it generates an internal current and allows calcium influx. This influx of calcium ions activates several intracellular pathways that help maintain central sensitisation [22].

The results of this study indicate that central nervous system changes are associated with adhesive capsulitis, suggesting the need for treatments that aim to reverse these changes. Treatment options for adhesive capsulitis may include pain neuroscience education, graded motor imagery to rebuild proprioceptive and motor cortical networks, sensory discrimination training targeting somatosensory changes or a combined approach alongside standard manual therapy techniques such as Gong's mobilisation and the Spencer technique [12, 23].

A notable strength of this study was the use of force-calibrated monofilaments to accurately control the application force for temporal summation assessment. Another strength was the homogeneity of the data between the adhesive capsulitis group and the control group.

Limitations and recommendations

A change in tactile acuity in adhesive capsulitis may indicate alterations in the somatosensory homunculus, but it could also result from delayed processing, issues with coordination, concentration or decision-making, as noted by Catley et al. [16]. These confounding factors, which might have affected the findings, were not considered in the study. The assessor's subjective decision on when to evaluate temporal summation could have introduced assessor bias. In addition, the level of pain was not consistent across all subjects during testing. Variations in pain levels may have affected our findings because both tactile acuity and temporal summation are potentially pain-dependent.

Further research in the shoulder area could focus on calculating the standard error of measurement for tactile acuity or the reliable change index. Future studies should also investigate the differences in central sensitisation between acute and chronic adhesive capsulitis.

Conclusions

Compared to healthy age- and gender-matched controls, this study found that people with adhesive capsulitis had impaired tactile acuity and temporal summation. These findings suggest that adhesive capsulitis may be associated with maladaptive neuroplastic alterations resulting in central sensitisation. Therefore, treatments targeting the correction of these alterations to improve clinical outcomes should be implemented alongside conventional therapy for adhesive capsulitis.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the institution ethics approval number is MSRMC/EC/AP-06/03-2020.

Informed consent

Informed consent has been obtained from all individuals included in this study. The authors attest that they obtained all relevant subject permission. The patient(s) has provided written permission for his/her images and clinical information to be published in the publication. The patients understand that their names and initials will not be published, and that while every effort will be made to keep their identities hidden, anonymity cannot be guaranteed.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflicts of interest

The authors state no conflicts of interest.

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