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The Effect of Treatment-Related Outcome Expectations on Pain Perception after Spinal Manipulation in Patients with Non-Specific Low Back Pain: A Cohort Study

Nikolaos Zampetakis[1,2], Nektarios Martzoukos[1,2], Danai Paleta[1,2], Georgios Krekoukias[1,2], Stefanos Karanasios[1,2], George Gioftsos[1,2]

[1]Physiotherapy Department, University of West Attica, Athens, Greece
[2]Laboratory of Advanced Physiotherapy (LAdPhys), Physiotherapy Department, School of Health and Care Sciences, University of West Attica, Aigaleo, Greece
Email: skaranasios@uniwa.gr

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Abstract

Purpose: This cohort study aimed to investigate the effect of treatment-related outcome expectations on pressure pain thresholds (PPTs) immediately after a thrust manipulation in the lumbar spine in patients with chronic non-specific low back pain (NSLBP). **Methods:** Treatment-related outcome expectations were assessed using the Expectations for Treatment Scale (ETS). Pressure pain thresholds (PPTs) were measured at local and remote sites before and immediately after a lumbar thrust manipulation. The primary analysis examined the association between ETS scores and changes in PPTs using Spearman's rank correlation. Sensitivity analyses explored differences between groups with high and low treatment expectations. **Results:** A total of 56 patients were enrolled. No significant associations were observed between ETS scores and changes in PPTs at any measurement site. Sensitivity analyses using different ETS categorization thresholds produced similar findings. Statistically significant differences in PPTs pre- and post-intervention were observed only at the upper trapezius muscle bilaterally. **Conclusion:** The findings of this cohort study indicate that there is no discernible association between treatment-related outcome expectations and changes in mechanical sensitivity in individuals with chronic NSLBP undergoing a single lumbar thrust manipulation.

Keywords

Expectations, Low Back Pain, Pressure Pain Threshold, Spinal Manipulation

1. Introduction

Low back pain (LBP) is among the leading causes of disability worldwide, constituting a significant socioeconomic burden for many countries [1]. Its lifetime occurrence rate reaches as high as 84%, with approximately 23% of the cases evolving into a chronic condition [2]. LBP cases are considered chronic if the duration of symptoms exceeds 12 weeks [3]. The origin of LBP involves diverse contributing factors, including specific and non-specific factors [4]. LBP is considered non-specific (NSLBP) when its pathoanatomical cause cannot be determined [5]. NSLBP accounts for 90% of cases presenting to primary care facilities with LBP [3]. Chronic NSLBP often leads to considerable deterioration in physical function and impairment in quality of life [6] and it is usually linked to high levels of kinesiophobia [7]. Among non-pharmacological treatments for chronic NSLBP, exercise, patient education, and manual therapy appear to have a pronounced effect on pain reduction and improving function [8].

Manual therapy is considered a safe treatment modality [9]. Thrust techniques include high-velocity and low-amplitude (HVLA) manipulations whereas non-thrust techniques refer to mobilizations characterized by slower velocity movements [10]. Manipulation techniques are widely utilized for managing chronic NSLBP [11], particularly for reducing pain [12] and disability [13]. The mechanisms underlying the effectiveness of spinal manipulation treatment (SMT) are multifaceted, involving centrally mediated mechanisms along with complementary mechanisms influenced by contextual factors [14]. Significantly, SMT downregulates the C-fibers excitability and inhibits temporal summation, indicating changes in the pain modulatory system [15].

Although the effectiveness of spinal manipulation has been attributed to the interaction of multiple complementary mechanisms, patients' treatment expectations should not be underestimated [15]. Evidence suggests that contextual factors may have a significant effect on the therapeutic outcome when modulated [16] [17]. Contextual factors include diverse factors related to the treatment, such as patient and provider expectations, as well as the clinical setting [14]. Remarkably, high recovery expectations of patients with LBP receiving chiropractic care, have been correlated with decreased pain intensity and greater subjective improvement [17] [18]. To investigate further the association between psychological factors related to pain and hypoalgesia, Bialosky *et al.* reported significant decreases in pain thresholds after SMT in the lumbar spine in healthy individuals with negative treatment expectations, indicating the potential influence of expectations on the analgesic effect of SMT [15]. However, similar studies evaluating the effect of treatment-related expectations on mechanical pain sensitivity in patients with chronic NSLBP are missing.

Therefore, we aimed to investigate the effect of treatment-related outcome expectations on changes in mechanical pain sensitivity in patients with chronic NSLBP promptly after a therapeutic manipulation in the lumbar spine. We hypothesized that higher treatment expectations would be positively associated with

greater changes in pressure pain thresholds (PPTs).

2. Methods

2.1. Study Design

We carried out a prospective cohort study in a private physiotherapy clinic located in Athens, Greece, between April 2023 and June 2025. Participants' recruitment was conducted through invitations sent from the University of West Attica and referrals from private clinics located in Athens, Greece. Each participant signed an informed consent form in compliance with the World Medical Association Declaration of Helsinki (2013) [19]. A single physical therapist (ND), who had 23 years of clinical experience in musculoskeletal problems and had completed a 2-year postgraduate training in orthopedic manipulative therapy, conducted all treatments. The design of our study was in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [20].

To be included subjects should be between 18 and 60 years of age, with non-specific LBP, and without symptoms of lower-extremity radicular pain.

Subjects between 18 and 60 years of age with non-specific LBP without symptoms of lower-extremity radicular pain that exceeded 12 weeks were included in our study. Participants were excluded if they had LBP with neurological deficits, spinal fractures, trauma or surgery in the spine, cancer history, osteoporosis, prolonged steroid use, sudden weight loss, or cauda equina syndrome [2].

2.2. Procedures

The initial assessment was conducted by a musculoskeletal physiotherapist (SK) with 18 years of experience. Demographic characteristics such as sex, age, height, weight, symptom duration, and previous experience of lumbar spine manipulation were collected. Patients reported the pain intensity of their last episode of low back pain within the past 7 days, using a Numeric Rating Pain Scale (NRPS) from 0 to 10. Additionally, patients completed the Expectations for Treatment Scale (ETS) questionnaire and the Oswestry Disability Index (ODI) questionnaire.

Physical examination included patient history and observation, along with special tests, palpation, and movement examination. All the assessment procedures were aligned with the International Framework endorsed by the International Federation of Manual and Musculoskeletal Physical Therapists (IFOMPT) for identifying red flags for serious spinal pathologies [21]. Subsequently, all patients were familiarized with the PPTs testing procedure at both local and remote sites. An independent assessor (NZ) conducted all PPTs measurements at each site prior to and following the intervention.

2.3. Interventions

All patients were lying in a relaxed side-lying position. The treating physiotherapist (ND) performed a high-velocity, low-amplitude (HVLA) thrust at the most hypomobile segment of the lumbar spine as assessed by the same physiotherapist.

A second attempt was performed if needed, when the first application was not accompanied by an audible pop. We theorized that the sound of an audible pop was indicative of a successful attempt. PPTs were measured immediately after the technique application by the same assessor (NZ).

2.4. Outcomes

Participants completed the ETS and ODI questionnaires before baseline PPT testing. Baseline PPT assessment required approximately 10 - 15 minutes. The lumbar manipulation was then performed, and post-manipulation PPT measurements commenced immediately after the intervention and were completed within approximately 10 - 15 minutes.

Treatment-related outcome expectations were assessed by the ETS questionnaire. The ETS comprises 5 items that are intended to evaluate patients' expectations related to a specific treatment in terms of symptom reduction and general health status [22]. Each item is scored using a 4-point scale from 1 (partially disagree) to 4 (definitely agree). Consequently, the total score ranges from 5 to 20, with higher scores indicating higher treatment expectations. For this study, the Greek version of ETS was used. The Greek version of the ETS questionnaire has shown a high level of content validity, an excellent test-retest reliability (ICC: 0.96), and an acceptable internal consistency (Cronbach's alpha: 0.84) in patients with musculoskeletal conditions [23].

The ODI questionnaire is a short and simple to complete instrument that aims to assess self-reported disability in patients with low back pain. The ODI questionnaire consists of 10 items, with each of them can be scored on a 6-grade scale from 0 to 5. Total scores range from 0 to 50, with higher scores indicating greater disability and limitations. The final score is expressed as a percentage. The Greek version of the ODI questionnaire has shown good i nternal consistency (Cronbach's alpha: 0.833) in Greek-speaking patients with low back pain [24].

In this study, PPTs at both local and remote sites were measured. The algometer was placed at the spinous process of L5, at the paravertebral musculature bilaterally of L5, at the midpoint of the upper trapezius muscle bilaterally, and at the anterior tibialis muscle bilaterally.

All measurements were carried out in a seated and prone-lying position. The sites located in the lumbar spine were assessed in the prone-lying position, whereas anterior tibialis and upper trapezius were assessed in a seated position. For each site, three repetitions with a 30-second interval were applied, and the average value was recorded [25]. During the measurement, patients were guided to respond with the word "now" when the pressure stimulus became painful. The same procedure was held prior to and following the intervention, and all measurements were taken by the same blinded assessor (NZ). A hand-held digital algometer with a 1-cm diameter probe (Baoshishan ZP-1000 N 20/22806, Baoshishan, Shenzhen, China) was used for this study. Pressure application rate was set at 0.5 kgf/cm^2 per second (50 kPa/s) [25]. Based on an intra-rater reliability pilot-test conducted in healthy sub-

jects prior to the main study we found excellent intraclass correlation coefficient (ICC) values for L5 spinous process (ICC: 0.93), left (ICC: 0.89) and right (ICC: 0.97) paravertebral area, left (ICC: 0.89) and right (0.95) upper trapezius, left (ICC: 0.97) and right (0.89) tibialis anterior.

2.5. Blinding

Participants' history, physical examination, demographic characteristics, NRPS, ODI, and ETS scores were collected by an independent physiotherapist who did not participate in other measurements and treatment. Also, the PPTs assessor and treating physiotherapist were blinded to the participants' NRPS, duration of symptoms, ETS, and ODI scores. During the study, the PPTs assessor and treating physiotherapist were in different rooms in order to minimize possible interaction with the patients and to maximize adherence to the study protocol. Therapists followed the protocol by avoiding discussions about treatment expectations. While this raised ethical concerns by limiting the therapeutic relationship essential to patient care, it preserved the study's integrity and scientific rigor.

2.6. Sample Size

An a priori sample-size estimation was performed during study planning using G*Power (version 3.1.9.7). At the time of study design, no previous studies had evaluated the association between treatment-related outcome expectations and changes in pressure pain thresholds following spinal manipulation in patients with chronic NSLBP. Therefore, the calculation was based on the closest available evidence by Wang *et al.* (2012), reporting between-group differences in lumbar PPTs following spinal manipulation in healthy individuals [26]. Using an anticipated effect size (Cohen's d) of 0.70, power of 80%, and $\alpha = 0.05$, a minimum sample of 56 participants was estimated [27]. Because the present study primarily investigated associations between expectations and changes in PPTs rather than between-group differences, this calculation should be considered approximate. Accordingly, the study should be interpreted as exploratory and hypothesis-generating.

2.7. Statistical Analysis

The normality of the data was evaluated using the Shapiro-Wilk test, along with visual examination of Q-Q plots and boxplots as well. Normally distributed data were presented with mean values and standard deviations (SD), while non-normal data were presented with median values and interquartile ranges (IQR).

The primary outcome was the change in PPTs (post-intervention PPT minus pre-intervention PPT) following lumbar spinal manipulation. The primary hypothesis was that higher treatment-related outcome expectations, measured using the ETS, would be associated with greater increases in PPTs. Therefore, the primary analysis consisted of Wilcoxon signed-rank test was used to assess changes between ETS scores and changes in PPTs. Analyses based on ETS categorization (high versus low expectations) were considered exploratory sensitivity analyses.

Associations between the dichotomous variables of sex and previous experience

of manipulation with changes in PPTs and ETS scores were explored using the Mann-Whitney U test. Spearman's rank correlation coefficients (rho) were calculated to investigate associations between changes in PPTs and the following continuous variables: ETS score, NRPS, ODI score, age, body mass index (BMI), and symptom duration. Spearman's correlation coefficient was classified as weak (≤0.39), moderate (0.4 to 0.69), or strong (0.7 to 1.0) correlation (Dancey & Reidy 2007). Due to the absence of established cut-off points for the ETS score, sensitivity analyses (Mann-Whitney U test) were performed based on the mean value and the 33rd and 66th percentiles. It should be noted that the association between ETS scores and changes in PPTs constituted the primary analysis. All additional analyses examining individual body sites, demographic and clinical variables, previous manipulation experience, sex, and alternative ETS categorizations were considered exploratory.

All forementioned analyses were performed in SPSS (v25), with $p < 0.05$ considered significant.

3. Results

A total of 56 individuals (35 female) with chronic non-specific low back pain were included in this study. The median age was 26 (25 - 75% IQR: 22, 28) and the median duration of symptoms was 21 months (25 - 75% IQR: 6, 60). Twenty-four (42.9%) participants were familiar with the specific manipulation and had undergone spinal manipulation in the past. Detailed demographic characteristics can be found in Table 1.

Table 1. Demographic and clinical characteristics of patients with non-specific low back pain.

Characteristics	N	%	Mean	SD	Range	Median	25% - 75% IQR
Sex							
Female	35	62.5%					
Male	21	37.5%					
Age (years)					19 - 59	26	22 - 28
BMI (kg/m^2)			24.12	4.46	17.1 - 38.5		
ODI					0 - 42	11	6 - 17.5
NRS					1 - 8	4	3 - 5
ETS			12.7	2.95	7 - 20		
Expectations							
High	31	55.4%					
Low	25	44.6%					
Previous experience of spinal manipulation	24	42.9%					
Duration of symptoms (months)					3 - 240	21	6 - 60

Abbreviations: N, sample; kg/m^2, kilograms/meters^2; ODI, Oswestry disability index; ETS, expectation treatment scale; IQR, interquartile range; SD, standard deviation.

The median NRPS score of the group was 4/10 (25 - 75% IQR: 3, 5), and the median ODI score was 11/100 (25 - 75% IQR: 6, 17.5). The mean score of the ETS was 12.7 (SD: 2.95), and by using it (12.7) as a cut-off point, 31 (55.4%) participants were classified as having high treatment expectations (ETS > 12.7) towards the manipulation.

As for the effect of the manipulation on the PPTs, the Wilcoxon signed rank test for paired observations revealed a statistically significant increase at both the right and the left trapezius (z_{right} = −3.08, p = 0.002, z_{left} = −3.15, p = 0.002). No statistically significant difference was observed at the lumbar and tibial locations. The median values of PPTs at each site before and after the manipulation can be found in Table 2.

Table 2. Pressure pain thresholds (kg/cm^2) at baseline and after the lumbar HVLA thrust at local and distal sites of the body.

	Pre-PPTs	Post-PPTs	Difference	P-value
L5 spinous process	4.84 (3.49 - 6.25)	5.14 (3.55 - 6.46)	0.22 (−0.43, 0.67)	0.22
L5 paraspinal (left)	5.10 (3.61 - 6.37)	5.03 (3.66 - 6.65)	0.11 (−0.52, 0.70)	0.36
L5 paraspinal (right)	4.97 (3.72 - 6.29)	4.82 (3.72 - 6.70)	0.05 (−0.41, 0.62)	0.58
Upper trapezius (left)	3.33 (2.66 - 4.40)	3.53 (2.73 - 4.72)	0.27 (−0.06, 0.64)	**0.002**
Upper trapezius (right)	3.23 (2.65 - 4.27)	3.47 (2.75 - 4.56)	0.18 (−0.06, 0.60)	**0.002**
Tibialis anterior (left)	4.84 (4.00 - 6.50)	4.78 (3.76 - 6.16)	0.07 (−0.37, 0.84)	0.61
Tibialis anterior (right)	5.09 (4.17 - 6.43)	5.39 (4.07 - 6.72)	0.10 (−0.33, 0.50)	0.11

Values are expressed as median (25 - 75% IQR). Wilcoxon signed rank test for paired observations, pre- versus post-intervention measurements. Abbreviations: kg/cm^2, kilograms/centimeters^2; IQR, interquartile range; HVLA, high velocity low amplitude.

3.1. Primary Analysis

The prespecified primary analysis examined the association between treatment-related outcome expectations (ETS scores) and changes in PPTs following lumbar manipulation. No statistically significant associations were observed between ETS scores and PPT changes at any local or remote measurement site (Table 3).

3.2. Secondary Analysis

Secondary exploratory analyses examined associations between PPT changes and age, disability, pain intensity, BMI, symptom duration, sex, previous manipulation experience, and alternative ETS categorizations. A weak correlation between baseline ODI scores and changes in PPTs at the L5 spinous process was discovered (r = −0.273, p = 0.042), but this did not occur at any of the other sites. Similarly, no correlation was observed between age and PPTs changes, except at the left trapezius muscle, where a weak correlation was presented (r = 0.370, p = 0.005). Detailed results of the Spearman's RHO test are presented in Table 3. The dichoto-

mous variables of sex and previous experience of manipulation did not appear to correlate with the changes in PPTs across all measurement sites. The corresponding results of the Man-Whitney U test are presented in Table 4 and Table 5, respectively.

Table 3. Pressure pain thresholds (kg/cm^2) between pre- and post-HVLA thrust at local and distal sites ofthe body in patients with high and low treatment expectations.

	Age	BMI	Symptom duration	Pain intensity	ODI	ETS
L5 spinous process	r = 0.26 p = 0.06	r = −0.07 p = 0.59	r = −0.02 p = 0.86	r = −0.05 p = 0.70	r =−0.27 p =0.04	r = −0.04 p = 0.79
L5 paraspinal (left)	r = 0.14 p= 0.30	r = −0.13 p= 0.34	r = 0.12 p = 0.39	r = −0.16 p = 0.25	r= −0.22 p =0.11	r =0.01 p =0.92
L5 paraspinal (right)	r = 0.23 p= 0.10	r = −0.03 p = 0.82	r = 0.01 p = 0.94	r = 0.11 p = 0.42	r = −0.26 p = 0.05	r =−0.06 p= 0.67
Upper trapezius (left)	r = 0.37 p = 0.005	r = 0.12 p = 0.36	r = 0.12 p = 0.39	r = −0.04 p = 0.76	r= 0.01 p= 0.97	r =−0.09 p= 0.51
Upper trapezius (right)	r = 0.08 p = 0.54	r = 0.16 p = 0.25	r = 0.05 p = 0.71	r = 0.13 p = 0.33	r = 0.02 p = 0.87	r =0.04 p= 0.79
Tibialis anterior (left)	r = 0.22 p = 0.11	r = 0.20 p = 0.15	r = 0.03 p = 0.81	r = 0.17 p = 0.21	r =−0.12 p = 0.37	r= −0.02 p= 0.87
Tibialis anterior (right)	r = 0.10 p = 0.45	r = 0.21 p = 0.12	r = −0.03 p = 0.85	r = 0.08 p = 0.57	r = 0.05 p = 0.72	r = 0.08 p= 0.56

Abbreviations: r, correlation coefficient; p, p-value; kg/cm^2, kilograms/centimeters^2; ETS, expectations for treatment score; ODI, Oswestry disability index; BMI, body mass index.

Table 4. Pressure pain thresholds (kg/cm^2) between pre- and post-HVLA thrust at local and distal sites of the body in female and male patients.

	Female patients	Male patients	Mann-Whitney U[b]	P-value
	Post- pre PPTs[a] (N = 35)	Post- pre PPTs[a] (N = 21)		
L5 spinous process	0.24 (−0.63, 0.24)	0.20 (−0.35, 0.42)	339.500	0.64
L5 paraspinal (left)	0.10 (−0.47, 0.47)	0.12 (−0.57, 1.40)	342.500	0.67
L5 paraspinal (right)	0.03 (−0.37, 0.67)	0.08 (0.48, 0.62)	363.500	0.95
Upper trapezius(left)	0.17 (−0.10, 0.53)	0.40 (−0.04, 0.70)	325.000	0.47
Upper trapezius (right)	0.08 (−0.10, 0.54)	0.23 (0.07, 0.97)	295.000	0.22
Tibialis anterior (left)	−0.10 (−0.43, 0.63)	0.42 (−0.08, 1.09)	335.000	0.58
Tibialis anterior (right)	−0.10 (−0.34, 0.48)	0.16 (−0.32, 0.66)	273.500	0.11

[a]Values are expressed as median (25 - 75% IQR). [b]Mann-Whitney U test, between-group comparison of the change in PPTs at each site of measurement. Abbreviations: kg/cm^2, kilograms/centimeters^2.

Based on the sensitivity analyses, there was no difference in changes in PPTs between patients with low and high treatment expectations, irrespective of the cut-off point used. The results of the Man-Whitney U test using a cut-off of ETS = 12.7 are presented in Table 6. For the second analysis, the 33rd (ETS = 9.5) and the 66th (ETS = 14) percentiles were used to assign participants to low, medium, and high treatment expectations groups. The results of the second Mann-Whitney U test between high and low treatment expectation groups are presented in Table 7.

Table 5. Pressure pain thresholds (kg/cm^2) between pre- and post-HVLA thrust at local and distal sites in patients with and without previous experience of manipulation.

	Previous experience	No previous experience	Mann-Whitney U[b]	P-value
	Post- pre PPTs[a] (N = 24)	Post- pre PPTs[a] (N = 32)		
L5 spinous process	0 (0.10, 0.97)	0 −0.46, 0.50)	272.500	0.07
L5 paraspinal (left)	0.06 (−0.40, 0.88)	0.13 (−0.59, 0.40)	353.000	0.61
L5 paraspinal (right)	0.05 (−0.29, 0.85)	0.06 (−0.50, 0.54)	321.500	0.30
Upper trapezius (left)	0.27 (−0.06, 0.63)	0.27 (−0.08, 0.64)	365.500	0.76
Upper trapezius (right)	0.21 (−0.06, 0.49)	0.18 (−0.12, 0.70)	372.500	0.85
Tibialis anterior (left)	−0.05 (−0.41, 0.26)	0.14 (−0.33, 0.84)	348.000	0.55
Tibialis anterior (right)	0.15 (−0.52, 0.72)	0.02 (−0.29, 0.98)	364.500	0.75

[a]Values are expressed as median (25 - 75% IQR). [b]Mann-Whitney U test, between-group comparison of the change in PPTs at each site of measurement. Abbreviations: kg/cm^2, kilograms/centimeters^2.

Table 6. Pressure pain thresholds (kg/cm^2) between pre- and post-HVLA thrust at local and distal sites in patients with high and lowtreatment expectations (cut-off point = 12.7).

	High expectations	Low expectations	Mann-Whitney U	P value
	Post- pre PPTs (N = 31)	Post- pre PPTs[b] (N = 25)		
L5 spinous process	0.10 (−0.69, 0.53)	0.30 (−0.27, 0.78)	316.500	0.24
L5 paraspinal (left)	0.07 (−0.53, 0.47)	0.17 (−0.55, 1.03)	366.000	0.72
L5 paraspinal (right)	−0.17 (−0.42, 0.57)	0.23 (−0.52, 0.76)	321.000	0.27
Upper trapezius (left)	0.10 (−0.05, 0.45)	0.43 (−0.10, 0.80)	299.000	0.15
Upper trapezius (right)	0.20 (−0.05, 0.60)	0.15 (−0.12, 0.70)	378.500	0.88
Tibialis anterior (left)	−0.10 (−0.56, 0.48)	0.14 (−0.28, 0.52)	329.000	0.34
Tibialis anterior (right)	0.07 (−0.37, 0.87)	0.13 (−0.46, 1.00)	386.000	0.98

Values are expressed as median (25% - 75% IQR). Abbreviations: kg/cm^2, kilograms/centimeters^2.

Table 7. Pressure pain thresholds (kg/cm^2) between pre- and post HVLA thrust at local and distal sites in patients with high and low treatment expectations (High expectations > 14, Low expectations ≤ 9.5).

	High expectations	Low expectations	Mann-Whitney U	P value
	Post-pre PPTs (N = 16)	Post- pre PPTs (N = 14)		
L5 spinous process	0.06 (−0.49, 0.52)	0.03 (−0.38, 0.39)	102.500	0.69
L5 paraspinal (left)	0.01 (−0.43, 0.36)	−0.05 (−0.78, 0.77)	103.500	0.72
L5 paraspinal (right)	−0.20 (−0.37, 0.59)	0.42 (−0.83, 0.62)	111.500	0.98
Upper trapezius (left)	0.22 (−0.01, 0.84)	0.43 (−0.27, 0.80)	111.500	0.98
Upper trapezius (right)	0.22 (−0.08, 0.82)	0.12 (−0.18, 0.49)	96.500	0.52
Tibialis anterior (left)	0.16 (−0.62, 0.65)	0.10 (−0.52, 0.22)	104.500	0.76
Tibialis anterior (right)	0.12 (−0.27, 0.66)	−0.15 (−0.51, 0.51)	88.500	0.33

[a]Values are expressed as median (25% - 75% IQR). [b]Mann Whitney U test, between group comparison of the change in PPTs at each site of measurement. Abbreviations: kg/cm^2, kilograms/centimeters^2.

4. Discussion

Contrary to our hypothesis, treatment-related outcome expectations were not associated with changes in pressure pain thresholds following lumbar spinal manipulation. Although statistically significant increases in PPTs were observed at the bilateral upper trapezius muscles, no significant changes were identified at the lumbar spine or tibialis anterior sites. Therefore, the present findings provide limited evidence for immediate changes in mechanical pain sensitivity following a single lumbar manipulation in patients with chronic NSLBP.

Previous investigations in patients with LBP undergoing manipulative care reported a strong relation between high expectations regarding recovery and symptom improvement [18]. Similarly, patients with chronic non-specific neck pain who had positive expectations for cervical manipulation experienced an immediate hypoalgesic effect after a single manipulation [28]. Nonetheless, these relationships are not consistently observed, as several other studies have documented inconsistencies concerning the interaction between expectations and treatment outcomes [29] [30]. These discrepancies could be attributed to several methodological differences among the studies, including the treatment protocols, patients' characteristics, and instruments used to capture participants' expectations. For example, some studies employed a pragmatic clinical design including an increased number of treatment sessions [18] [29]. This clinical design is considered to lead to a better therapeutic alliance compared to a single intervention used in the present study. Evidence suggests that the interplay between therapeutic alliance and pre-treatment expectations can substantially contribute to treatment outcomes [31]. Another possible explanation for the inconsistencies among the different study results could be related to the heterogeneity of participants' characteristics, including patients presenting both low-back and leg pain, patients with LBP without

crisis [18] or non-chronic LBP [18] [29]. Research evidence suggests that duration of symptoms, type of onset, and the presence of radiating pain can substantially affect patients' recovery expectations and subsequently the treatment outcome [17]. Notably, our study included patients with chronic NSLBP, who did not necessarily present with pain on the day of the trial. Additionally, we did not impose a minimum eligibility threshold of NPRS or ODI scores.

In the studies assessing expectations in the context of manual therapy, there is a substantial variation in the treatment-expectation domains, instruments, and procedures used to measure or manipulate these expectations. Collectively, studies examining expectations in LBP and neck pain populations have investigated general recovery expectations [18], treatment preferences [29] or tried inducing expectations verbally [28] in relation to SMT outcomes. This variability in capturing expectations could explain why results differ across studies more than any other specific methodological factor. Even research in line with our findings measures different types of expectations, preventing meaningful comparison. The only study that clearly captured SMT-related expectations comparably to our study, but conducted in individuals with chronic neck pain, similarly failed to demonstrate an association between SMT-related expectations and immediate SMT-induced hypoalgesia [30]. Given the complexity of the expectations' formation, their accurate evaluation can be challenging. It is reasonable to assume that expectations can manifest in various forms, as thoroughly described by Thompson and Sunol [32]. In other clinical trials that intend to capture expectations, predicted expectations (what the patient anticipates will happen) are the most commonly assessed type, typically through Likert-type questions [33] [34] or an NRS questionnaire [17] [35]. However, these instruments lack validation for measuring pre-treatment expectations and have uncertain comparability, which may contribute to the inconsistent findings reported in prior studies. In contrast, our protocol included a recently developed instrument (ETS) that demonstrated adequate psychometric properties for this purpose in a population with musculoskeletal disorders [23].

The non-significant differences in PPTs found at local points in the lumbar spine or at remote sites in the tibialis anterior muscle bilaterally in our study were in agreement with previous study results suggesting no significant difference in PPTs at the spinous process after a lumbar manipulation in patients with chronic NSLBP [12] [25] [36]. However, based on another study in the same field, a single lumbar manipulation was found to produce an immediate post-intervention decrease in mechanical sensitivity both at the local lumbar sites and remote sites (deltoid muscle and lateral epicondyle) [37]. As Aspinall *et al.* suggested in their systematic review and meta-analysis there are several inconsistencies among the trials investigating the hypoalgesic effects following SMT in patients with LBP [38]. One factor that may contribute to these inconsistencies is the number of treatment sessions, as studies incorporating multiple single-thrust manipulation sessions have reported significant increases in PPTs at both local and remote sites [39] [40]. Furthermore, variation in participant characteristics across studies, including acute versus chronic LBP and the presence or absence of active symptoms, may also explain the hetero-

geneous findings [12] [25] [36] [37]. For example, studies reporting significant local hypoalgesic effects following SMT have often included more homogeneous samples with moderate-to-severe active pain symptoms [37].

In the present study, all participants met the criteria for chronic NSLBP; however, the presence of active low back pain on the day of testing was not specifically recorded. Consequently, some participants may have had minimal or no symptoms at the time of the intervention. Together with the relatively low pain intensity and disability levels observed in our sample, this may have reduced the potential for detecting local hypoalgesic responses and could partly explain the limited changes in PPTs observed following manipulation. Therefore, the characteristics of our sample should be considered when interpreting the absence of significant local PPT changes.

Statistically significant increases in PPTs were observed only at the bilateral upper trapezius muscles. While these findings may be consistent with mechanisms involving altered pain processing beyond the local treatment region, the absence of significant changes at other local and remote sites warrants cautious interpretation. Consequently, the present data do not allow firm conclusions regarding the mechanisms underlying manipulation-related changes in pain sensitivity. Previous studies have proposed that immediate changes at local sites may reflect alterations in muscle spindle sensitivity and spinal reflex pathways following SMT [41], whereas hypoalgesic responses at remote sites may be indicative of centrally mediated mechanisms [14] [40]. Changes in mechanical pain sensitivity assessed using algometry have also been linked to activation of descending inhibitory pathways [10] [42]. Given that individuals with NSLBP often demonstrate impaired endogenous pain modulation [43], it is conceivable that spinal manipulation may influence these mechanisms. However, the limited and site-specific findings of the present study do not permit direct inferences regarding these pathways.

The observation of increased PPTs only at the upper trapezius muscles, but not at other local or remote sites, highlights the complexity of the underlying mechanisms and suggests that factors beyond a simple local-versus-central explanation may be involved. Based on a meta-analysis [38] there is low quality evidence suggesting that SMT does not have a superior effect on local and remote PPT sites when compared with sham SMT, which could imply the involvement of other mechanisms not unique to SMT. Moreover, although statistically significant changes in the upper trapezius PPTs were observed, they did not exceed the proposed minimal detectable change [44]. Importantly, even when noticing statistically significant changes in PPTs, there is not enough data to connect such short-term changes with changes in clinically important outcomes over a substantial period of time [38]. Consequently, the clinical relevance of PPT is not yet established in the literature.

Limitations

The findings of this study should be interpreted with caution regarding its limitations. Our results can be generalized only in mostly young females with low levels of LBP-related disability and mild to moderate levels of pain intensity. In general,

chronic NSLBP population consists of patients typically older in age with greater levels of pain and disability [45]. Thus, our sample is not entirely representative of the population being studied.

Furthermore, multiple statistical tests were performed across several measurement sites and explanatory variables. As these analyses were exploratory and no formal adjustment for multiplicity was applied, there is an increased risk of Type I error. Therefore, isolated statistically significant findings, particularly those not directly related to the primary hypothesis, should be interpreted with caution and require confirmation in future studies.

We did a single SMT session and measured the PPTs immediately after, with no follow-up measurements. This could have influenced the ability of this study to detect any correlation between expectations and PPT changes, as the expectation-induced placebo analgesia can take up to a few minutes to begin manifesting, and it peaks several minutes after the intervention in some cases [46]. Also, it can be strengthened with repeated exposure to the intervention through conditioning and reinforcing expectations. Following the same trend, some data suggest that PPTs changes can be observed 5-30 minutes after lumbar SMT in healthy individuals [47].

5. Conclusion

In this cohort of patients with chronic NSLBP, treatment-related outcome expectations were not associated with immediate changes in PPTs following a single lumbar spinal manipulation. Significant increases in PPTs were observed only at the bilateral upper trapezius muscles, whereas no significant changes were detected at local lumbar sites or the tibialis anterior muscles. Given the limited and site-specific nature of these findings, the present study does not provide strong evidence for widespread immediate changes in mechanical pain sensitivity after lumbar spinal manipulation. Further research with larger samples and repeated follow-up assessments is needed to clarify the relationship between expectations and manipulation-related hypoalgesia.

Statement

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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