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Regional distribution of myoelectric median frequency in the erector spinae muscles under the influence of delayed-onset muscle soreness.

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Abstract

Delayed-onset muscle soreness (DOMS) is a non-invasive pain model offering a unique opportunity to study trunk neuromuscular adaptations. While prior research has examined regional muscle activation in the lumbar region, the spatial distribution of median frequencies (MF) under DOMS has not been explored. This study investigated the effect of DOMS-induced pain on the spatial distribution of MF in the lumbar erector spinae muscles and its association with trunk force variability during submaximal contractions. Twenty healthy adults completed two laboratory sessions: one pain-free and one under low back DOMS. High-density surface EMG was recorded bilaterally on the erector spinae during submaximal isometric trunk extensions. MF distribution was analyzed using centroid coordinates with and without DOMS, and force variability was assessed. DOMS significantly increased perceived muscle pain and soreness in the lumbar region. It also caused a cranial and medial shift of the MF centroid, significant on one side of the trunk. However, force variability remained stable between conditions. These results suggest that DOMS induces regional adaptations in lumbar muscle MF. The spatial distribution of MF may serve as a novel and sensitive marker of neuromuscular adaptation to pain, highlighting the trunk system's ability to maintain force steadiness despite pain and soreness.

Keywords: DOMS, high-density EMG, lumbar spine, pain, median frequency

Word Count: 3998

Introduction

Clinical low back pain (LBP) poses a significant challenge due to its multifactorial nature [1]. Experimental pain models, such as intramuscular injections of hypertonic saline or thermal cutaneous pain [2,3] have provided valuable insights into neuromuscular adaptations to pain. However, these methods present inherent limitations: hypertonic saline can excite motor axons, influencing lumbar sensorimotor control independent of pain processes [4,5], limiting the interpretability of results. In contrast, delayed onset muscle soreness (DOMS) offers a more representative model of LBP [6]. Unlike other pain models, DOMS does not involve invasive procedures or external stimuli that could confound the interpretation of neuromuscular adaptations. It enables the study of pain-induced changes in muscle recruitment pattern, proprioception, and functional performance over a prolonged period, providing insights into pain neuromuscular adaptations [7,8]. Moreover, the non-invasive nature of DOMS facilitates repeated measures and pre–post intervention studies, enhancing the ability to track the progression of pain and its effects on the musculoskeletal system [9]. This makes DOMS a unique pain model in understanding the mechanisms underlying LBP.

Recent research by Arvanitidis et al. (2024) showed that DOMS in the lumbar muscles lead to changes in lumbar electromyographic (EMG) patterns. Specifically, their research highlighted altered high-density surface EMG (HDsEMG) torque relationships and improvements in torque steadiness, despite muscle soreness, suggesting compensatory motor adaptations that maintain performance [10]. The authors focused on analyzing the HDsEMG signal amplitude. By generating topographical maps of EMG amplitude values, they explored the regional distribution of lumbar muscle activity under the influence of DOMS. In contrast, the present study uses another approach by focusing on the spatial distribution of median frequencies (MF) under the influence of DOMS. Specifically, how

pain and muscle soreness induced by DOMS influence the spatial recruitment of motor units, given that nociceptive input can alter motor unit discharge rate differently across the motor unit pool [10]. This is particularly relevant for the lumbar extensor muscles, which have a large and regionally distributed pool of motor units, allowing for flexible and spatially differentiated recruitment strategies [11]. This approach has previously been used for assessing how different muscle regions contribute to force production and how fatigue can lead to localized changes in muscle activity. Gallina et al. (2011) demonstrated that the myoelectric manifestations of fatigue are regionally distributed within the medial gastrocnemius muscle, with some areas showing more pronounced MF decreases during a fatigue task [12].

The physiological changes associated with DOMS, primarily muscle fiber damage and inflammation, affect excitation-contraction coupling, influencing muscle electrical activity [13]. Mechanical damage to type II fibers during eccentric contractions triggers an inflammatory response [6], leading to increased muscle stiffness, and the recruitment of additional motor units to compensate for the loss of force production from fatigued or damaged fibers [14]. Given the possible localized nature of muscle damage and inflammation in DOMS [10](Arvanitidis et al., 2024), changes in motor unit recruitment patterns and muscle activation strategies may result in regional differences in EMG frequencies [15].

In addition, a recent systematic review has reported significant impairments in force steadiness during both clinical and experimentally induced pain conditions [16]. However, minimal attention has been given to the effects of DOMS on trunk force steadiness [10].

The primary objective of this study is to investigate the impact of DOMS-induced pain on the recruitment strategies of the lumbar muscles. In particular, we aim to assess the spatial distribution of EMG frequencies with and without the influence of low back

DOMS. We hypothesize that DOMS-induced pain will trigger specific adaptations in muscle activation strategies, which may vary between low back regions. These adaptations are expected to manifest as shifts in the spatial distribution of MF. The secondary objective of this study is to explore how these strategies in response to DOMS influence force production.

Methods

Participants:

Participants were recruited via online advertisements (e.g., social media platforms) and word-of-mouth within the local community of Trois-Rivières (Québec, Canada). All experimental procedures and data collection were carried out between February and July 2023. Twenty adult participants, including 11 men and 9 women, with an average age of 26.05 ± 5.09 years, height of 1.72 ± 0.08 m, weight of 72.15 ± 16.54 kg, and BMI of 24.14 ± 4.65 kg/m², were enrolled in this study. Exclusion criteria included a history of LBP within the past year, spinal surgery, inflammatory arthritis affecting the axial skeleton, advanced osteoporosis, pregnancy, and severe incapacitating pain in regions other than the lower back that would hinder the ability to undergo the evaluation protocol in the laboratory. Thus, all participants were pain-free at the time of the study. Sample size estimation was based on a previous study using a similar protocol involving trunk extension contractions in the same position and experimental pain induced by electrical stimulation [17]. In that study, a significant spatial shift in lumbar muscle activity was observed under the influence of pain, with reported effect sizes ranging from moderate to large ($\eta^2 = 0.066$ to 0.232). Accordingly, an a priori power analysis was conducted using G*Power 3.1 software [18], assuming a moderate effect size (Cohen's $d = 0.6$), a power of

80%, an alpha level of 0.05, and the primary outcome variable the centroid location of the MF distribution.

Design:

This study adopts a within-subject design with repeated measures. Approval for the research protocol was obtained from the Research Ethics Board for Human Research at the Université du Québec à Trois-Rivières (CER-22-290-07.11). Participants gave written informed consent, acknowledging their right to withdraw from the experiment without prejudice, which align with the Declaration of Helsinki (2013) [19]. The study design and reporting followed recommendations from the STROBE guidelines for observational research.

Experimental Protocol:

The experimental protocol comprised two distinct sessions, with each session involving a voluntary isometric contraction protocol to assess the neuromuscular strategies of the lumbar muscles. In the initial session (no DOMS condition), participants completed a voluntary isometric contraction protocol. This was followed by a validated DOMS-inducing protocol to ensure the occurrence of experimental LBP in the second session [20]. The second session took place 24-36 hours later because it coincides with the peak manifestation of low back DOMS effects.

Participants were positioned on a custom-designed apparatus to perform isometric contractions at 45° of trunk flexion in a semi-seated posture (Fig. 1). Real-time measurement of the target trunk flexion position was facilitated using a digital inclinometer (precision of ± 0.1°, model 40–6067, Johnson Level & Tool Mfg. Co., Inc. Mequon, WI) positioned on the L3 vertebra. Once the target 45° trunk flexion position was reached, a belt was placed on the participant's shoulders and adjusted to the correct

length. This belt was connected to a load cell (Model LSB350; Futek Advanced Sensor Technology Inc, Irvine, CA, USA) to record the force exerted during the isometric contractions.

Myoelectric activity of the lumbar muscles on both the right and left sides was recorded using two HDsEMG arrays, each consisting of 64 electrodes arranged in an 8x8 matrix with a 10 mm space between electrodes (semidisposable adhesive matrix; model ELSCH064, OTBioelettronica, Torino, Italy). Before electrode placement, the skin was prepared by shaving, gently abrading with fine-grade sandpaper (Red DotTrace Prep; 3M, St. Paul, MN), and cleaning with rubbing alcohol (ethyl alcohol 70%). The electrode grids were aligned with the orientation of the muscle fibers and consistently positioned across participants to minimize variability. The center of the grid was positioned at L3, with the medial edge about 1 cm from spinous process of this vertebra. A reference electrode was positioned over the right iliac crest, and hypoallergenic ink marks were used to ensure identical electrode placements across both sessions. Additionally, the same investigator performed all electrode placements across sessions ensuring test-retest reliability [21].

*(***Figure 1 near here***)*

Participants performed five-second maximal voluntary isometric contractions (MVIC) of trunk extension in the previously explained position, with one minute of rest between repetitions. The highest MVIC value was used to standardize the subsequent submaximal isometric contractions, ensuring the target torque exerted was performed based on each individual's MVIC.

Participants executed a 20-second submaximal isometric contraction of trunk extension, maintaining 20% of their MVIC without a specific ramp-up phase. This force level reflects the typical intensity of ES contractions during daily activities [22]. Participants

175 received real-time visual feedback displayed on a monitor at eye level. The visual
176 feedback consisted of a line representing the target force level (20% MVC). Participants
177 were instructed to maintain their force as steadily as possible.

178 A validated DOMS-inducing protocol was used to induce experimental pain in the lumbar
179 muscles [20]. Participants first familiarized themselves with the apparatus and then
180 performed three MVICs of trunk extension in a prone position on a 45° inclined Roman
181 chair, exerting maximal force against a belt connected to a load cell (Model LSB350;
182 Futek Advanced Sensor Technology Inc., Irvine, CA, USA). A one-minute rest interval
183 minimized muscle fatigue between MVICs, and the highest MVIC value was used to set
184 the DOMS-inducing load. The DOMS-inducing protocol involved four sets of 25 trunk
185 flexion–extension movements with one-minute rest intervals, executed in the same
186 configuration as the MVIC protocol, with an additional load equivalent to 10% of MVIC
187 applied. Straps at the hip level were used to minimize pelvic tilt. Participants followed a
188 3-3-1 tempo (three seconds eccentric contraction, three-second static hold, one second
189 concentric contraction) with auditory feedback and verbal encouragement throughout.

190 Data Collection and Analysis:

191 Sociodemographic information, including age, sex, weight, and height, was collected
192 from all participants. Low back pain and muscle soreness levels were collected on the
193 second session using a numerical rating scale, anchored between 0 (no pain; no soreness)
194 and 10 (worst possible pain; worst possible soreness).

195 Lumbar pressure pain sensitivity was assessed at the beginning of both sessions (DOMS
196 and no DOMS). A handheld dynamometer (MicroFet 2, Hoggan Industries Inc., West
197 Jordan, UT, USA) was used to apply constant pressure at specific sites on the lumbar
198 muscles (bilaterally at L2 and L4) and on the vastus medialis (control site). Participants

reported when they first perceived pain. Pressure pain thresholds (PPT) were used to identify the presence and localization of DOMS-induced muscle soreness and mechanical hyperalgesia [23].

HDsEMG data were analyzed separately for the left and right lumbar muscles. The signals were digitally band-pass filtered using a 4th-order Butterworth filter (30–400 Hz) to remove noise and artifacts, and notch filters were applied to eliminate 60 Hz power line interference. The signals were imported and analyzed using Matlab (version R2023b; The MathWorks, Natick, MA). A detailed visual examination of the raw HDsEMG signals was conducted to identify electrodes with contact issues. Problematic electrodes were addressed by replacing them through an interpolation technique that used data from neighboring electrodes. Specifically, the interpolation was conducted by averaging the values from the electrodes located directly above and below the faulty one along the craniocaudal axis (aligned with the muscle fibers). In cases where there were no neighboring electrodes above or below, such as in the first and last rows of the grid, these problematic electrodes were excluded from the analysis to maintain data integrity. Following the recommendations of Gallina et al. (2022) [24], recordings were excluded from the analysis if the number of removed electrodes exceeded 10% of the total electrodes. The central 10 seconds of each signal during the isometric contraction were analyzed and segmented into 0.5-second windows, following previous methodology[25].

To assess the impact of DOMS-induced pain on neuromuscular recruitment strategies, we analyzed the spatial distribution of MF, with lower frequencies often associated with changes in action potential propagation [12,24]. By calculating the MF across all channels, we were able to generate topographical maps showing how MF were distributed across the ES muscles during the isometric contractions. The mean of MF on each side and both conditions was also computed.

To compute the spatial distribution of MF, we first performed a Fast Fourier Transform on the HDsEMG signals to obtain the power spectrum for each channel. We analyzed the medio-lateral and cranio-caudal coordinates of the centroid of MF, defined as the average position of the channels with MF values exceeding 70% of the maximum observed across all channels [12,24]. Right-side data were mirrored along the x-axis for clarity, ensuring that higher x-coordinates indicated a more medial location of the MF centroid on both sides.

Force signals were low-pass filtered at 10 Hz using a 2nd-order Butterworth filter to smooth the data and remove high-frequency noise. Force variability was computed using the coefficient of variation (CV) to account for variations in force levels, using the formula: CV = (SD / Mean) × 100, where SD is the standard deviation of the filtered force signal and Mean is the corresponding average force during the analyzed data.

Statistical Analysis:

All statistical analyses were conducted using SPSS, version 28 (SPSS Inc., IBM Corp., Armonk, NY, USA). Parametric tests were chosen based on the normal distribution of the data, as determined through the Kolmogorov-Smirnov test and visual inspection. T-tests for dependent sample were performed to assess the impact of experimental pain (no pain vs. DOMS-induced pain) on mean of MF, MF centroid coordinates (mediolateral and craniocaudal axes), force variability, and pressure pain threshold. To identify potential side differences in pain sensitivity, paired-sample t-tests were conducted to compare DOMS PPTs between both sides. A significance threshold of $p < 0.05$ was used for all statistical analyses. Effect sizes were indicated using Cohen's d with classifications as follows: small (d = 0.2), medium (d = 0.5), and large (d = 0.8) [26]. The presentation of results includes mean and standard deviation (SD).

RESULTS

At the beginning of the second post-test session (DOMS condition), the average level of muscle soreness was 4.35 (SD = 1.91) and the average mean pain in the lumbar region was 1.4 (SD = 1.90), indicating that participants perceived low level of pain.

Results showed significant reductions in PPTs under pain conditions compared to no-pain conditions in all the pressure points except the control region (Table 1). No significant differences were observed between sides (L2 left vs. L2 right: $p = 0.613$; L4 left vs. L4 right: $p = 0.162$) following the DOMS protocol.

*(***Table 1 near here***)*

Results showed no significant difference of the MF mean between conditions on both sides. More precisely, on the left side, MF means were 87.72 (SD = 10.01) without DOMS and 86.37 (SD = 10.26) with DOMS ($p = 0.511$). On the right side, MF means were 89.49 (SD = 11.30) without DOMS and 86.47 (SD = 9.74) with DOMS ($p = 0.168$).

Centroid coordinates of the MF along the mediolateral axis (Figures 2 and 3) showed no significant differences between DOMS and no-DOMS conditions on the left side ($p = 0.764$; Cohen's d = 0.068) while a significant difference was observed on the mediolateral axis on the right side between pain conditions ($p = 0.020$; *Cohen's d* = 0.566). Results indicate that the MF centroid shifted medially under pain conditions (~35mm).

For the craniocaudal axis (Figures 2 and 3), a significant difference was found ($p = 0.013$; Cohen's d = -0.609) on the left side, showing that the MF centroid shifted cranially under pain conditions (~27mm). No significant difference was observed on the right side ($p = 0.241$; Cohen's d = -0.270).

(***Figure 2 near here***)

Force variability, assessed via CV, was 3.40 (± 1.69) in the no-DOMS condition and 3.01 (± 1.24) in the DOMS condition. This difference was not statistically significant (95% CI: -0.31 to 1.09, t(19) = 1.17, p = 0.256; Cohen's d = 0.27).

(***Figure 3 near here***)

DISCUSSION

This study investigated the impact of DOMS on the recruitment strategies of the lumbar muscles, emphasizing spatial adaptations in muscle fiber activation and their effects on force variability. Using HDsEMG, this study provides insights into how DOMS-induced pain influence trunk neuromuscular control. While a spatial shift of MF was observed under the influence of DOMS, lumbar muscle force variability remained unaffected.

Significant reductions in PPTs across all pressure points, except for the control region, confirm the sensitivity of lumbar muscles to DOMS-induced pain. The lack of changes in the control region suggests that the pain response remains localized to the lumbar area, minimizing systemic nociceptive effects. This observation reinforces the specificity of DOMS as a model for studying localized muscle pain and its implications for neuromechanical adaptations. These results align with prior research indicating that DOMS heighten pressure sensitivity through localized inflammation [6,14]. Additionally, no PPT differences between the left and right lumbar sides were observed, suggesting that DOMS-induced hyperalgesia was similar across sides. Participants reported an increase in lumbar muscle soreness and muscle pain in the second session (DOMS condition). This increase highlights the development of DOMS, characterized by localized discomfort and stiffness commonly associated with intense or unfamiliar physical activity. The average pain level of approximately 2/10 aligns with reports from other studies in which delayed onset muscle soreness (DOMS) was used to induce low back pain [27 28 29]. However, the

295 average pain score is below the typical pain intensity scores of people with acute clinical
296 pain. Further research is needed to confirm our results in people with higher pain scores.

297 Our study revealed a cranial and medial migration of the centroid of MF under DOMS-
298 induced pain conditions, only significant on one side. It is well known that acute or
299 experimental muscle pain induces motor adaptations, such as a redistribution of muscle
300 activity between or within the muscles [31]. For example, Tucker et al. demonstrated that
301 deep-tissue pain in the quadriceps and flexor pollicis longus induces specific shifts in
302 motor unit recruitment patterns as a compensatory response to discomfort, enabling the
303 preservation of function [32]. In the lumbar region, similar adaptations have been observed,
304 where pain induces spatial redistribution of muscle activity [17]. Notably, these changes
305 appear to vary between individuals, suggesting distinct neuromuscular adaptation
306 strategies in response to pain [17].

307 Unlike prior studies that assessed muscle activity patterns, such as spatial redistribution
308 of muscle activity amplitude, the present study's focus on spatial changes in MF which
309 provides a novel perspective on how the lumbar muscles adapt to DOMS-induced pain.
310 Another group of researchers has used this approach to explore the specific roles of
311 muscle subregions in generating force and to understand how fatigue impacts muscle
312 activity in a localized manner. For instance, Gallina et al. (2011) found that fatigue-related
313 myoelectric signals vary across the medial gastrocnemius, with certain areas experiencing
314 greater reductions in MF during sustained exertion [12]. The current study suggests that
315 muscle fibers with higher frequency discharge were mainly recruited in the cranial and
316 medial region of the lumbar muscle under the influence of DOMS. Before the onset of
317 DOMS, participants may have predominantly recruited the lumbar muscle region that was
318 biomechanically most favorable for the task, as evidenced by a relatively localized MF
319 centroid. In the lumbar region, where multiple muscle segments contribute to trunk

stabilization and movement, the presence of DOMS may disrupt typical motor patterns, leading to a redistribution of fiber recruitment across different lumbar regions. Yet it is important to note that this adaptation was only significant on one side of the trunk. Previous studies have reported distinct trunk neuromuscular adaptations between the left and right sides of the lumbar muscles during symmetrical tasks [11,17,33]. These asymmetries may be explained by side dominance in the lumbar musculature, which has been observed in response to muscle fatigue and perturbation tasks [34,35]. Our findings support the idea that the lumbar muscles can modulate their activation strategy independently on each side, potentially as a functional adaptation to pain. This highlights the relevance of analyzing each side separately when investigating trunk neuromuscular responses. Further research is warranted to better understand the origin and functional implications of these asymmetrical adaptations.

The cranial shift in MF centroid observed in this study may reflect an adaptive motor strategy to redistribute load and reduce discomfort during DOMS. Falla et al. (2014) reported that reduced centroid migration during a repetitive lifting task in low back pain individuals [36]. These findings suggest that spatial adaptations in muscle activation may play a protective role. The absence of a shift in patients with chronic low back pain may either be caused by their pain or result from it. Determining which occurs first remains challenging. Arvanitidis et al. (2022) identified cranial shifts in lumbar ES activity in individuals with chronic low back pain during submaximal contractions, highlighting region-specific neuromuscular strategies to redistribute load and avoid exacerbating pain in caudal regions [37]. Although the present study focuses on acute DOMS-induced pain, the MF spatial redistribution observed may represent a shared neuromuscular adaptation to maintain functionality under DOMS conditions.

The present study found that force variability during submaximal isometric contractions showed negligible changes under DOMS conditions. The non-significant reduction in force variability suggests that compensatory neuromuscular adaptations effectively mitigate the impact of DOMS pain on force variability. These findings reinforce the robustness of the trunk neuromuscular system in maintaining task performance despite low back discomfort and pain. Supporting this idea, Mista et al. (2015) analyzed the modulation of motor variability related to experimental muscle pain during elbow flexion contractions and observed that, despite the presence of pain, the neuromuscular system adjusted motor control strategies to maintain force stability [38]. Similarly, Cleary et al. found that acute experimental pain in the tibialis anterior muscle alters the recruitment strategies in the vastus lateralis and vastus medialis, but participants were still able to maintain the force target [39]. However, a systematic review by Arvanitidis et al. (2024), which examined the effects of experimental pain on force steadiness across various muscle groups and tasks, concluded that pain generally increases force variability, particularly in clinical contexts [16]. Nonetheless, the review also highlighted substantial variability among tasks and individuals, suggesting that the specific characteristics of DOMS and the nature of the submaximal tasks assessed in the present study may contribute to the observed stability in force variability.

The findings of this study have important implications for understanding trunk neuromuscular control in the presence of experimental pain. The observed spatial adaptations in MF distribution and the maintenance of force production stability underscore the adaptability of the neuromuscular system under pain conditions. The spatial redistribution of muscle activity observed under DOMS suggests that the central nervous system may selectively recruit new muscle regions to preserve force control. The

next step will be to identify whether these strategies differ in individuals with chronic low back pain, as the long-term effects of chronic pain may lead to distinct trunk adaptations.

While this study provides valuable insights, a few limitations should be acknowledged. First, the sample size was relatively small and comprised mainly of young adults, potentially limiting the generalizability of the findings. Second, the focus on a single muscle group (lumbar muscles) may not fully capture the systemic effects of DOMS on the trunk musculoskeletal system. Third, the assessors were not blinded to the experimental condition during EMG analysis. However, automated algorithms procedures were implemented to minimize the influence of subjective interpretation. Another limitation is the timing of the post-intervention assessment, which was conducted 24 to 36 hours after the DOMS-inducing protocol. While this timeframe corresponds to the typical peak of muscle soreness [20], it is possible that different temporal windows (e.g., earlier or later phases of recovery) might produce distinct neuromuscular responses. Additionally, the observed neuromuscular adaptations may not be generalizable to conditions involving higher levels of perceived pain. Furthermore, the study focused exclusively on EMG activity of the lumbar muscles, without including complementary measurements such EMG recordings from lower limb or abdominal muscles. This limits our ability to fully characterize the trunk neuromuscular adaptations under DOMS condition. Finally, while previous studies have established the reliability of traditional EMG measures, such as amplitude or amplitude spatial distribution using HDsEMG [21,40] in the thoracolumbar erector spinae, the test-retest reliability of the spatial distribution of the MF remains to be established.

This study highlights the impact of DOMS-induced pain on neuromuscular control, revealing spatial adaptations in MF distribution of the ES and the maintenance of force production stability. These findings underscore the importance of understanding localized

pain mechanisms to develop targeted interventions that optimize functional performance and recovery following intense exercises.

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Data Statement

Citation Diversity Statement

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Tables

Table 1. Pressure Pain Thresholds Results

Pressure Point	**No Pain (Mean ± *SD*)**	**Pain (Mean ± *SD*)**	**Change (Mean ± *SD*)**	**95% *CI* Lower**	**95% *CI* Upper**	***t***	***p***	**Effect Size *(Cohen's d)***
L2 left	10.99 ± 5.88	7.21 ± 3.84	3.79 ± 3.24	2.28	5.31	5.24	<0.001	1.17
L2 Right	10.49 ± 6.02	7.40 ± 4.50	3.09 ± 3.19	1.60	4.58	4.33	<0.001	1.09
L4 Left	10.39 ± 6.07	7.44 ± 3.83	2.95 ± 3.37	1.37	4.53	3.92	0.001	0.98
L4 Right	9.96 ± 5.48	7.05 ± 3.63	2.91 ± 2.45	1.76	4.05	5.31	<0.001	1.20
Control Region	10.70 ± 5.23	10.36 ± 4.55	0.34 ± 2.48	-0.82	1.50	0.62	0.544	0.08

Table 1. Pressure pain threshold at different points and control region. Units are expressed in kilograms-force (kgf).