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Immediate Effects of Home-Based Lumbar Unloading With or Without Heat Application on Paraspinal Muscle Properties in Physically Active Rural Adults With Chronic Low Back Pain

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Abstract:

Abstract: Background: Chronic low back pain (LBP) is common among individuals performing intensive physical labor, particularly in rural areas. This study evaluated the immediate effects of lumbar unloading, with or without heat, on paraspinal muscle properties in physically active adults with chronic LBP. Methods: Forty-two adults with chronic LBP were randomly assigned to lumbar unloading alone (Group 1) or unloading combined with heat (Group 2). Paraspinal muscle tone, stiffness, and logarithmic decrement were assessed using MyotonPRO before and immediately after a single 20-minute intervention. Pre–post changes were compared between groups. Results: Group 1 showed small increases, whereas Group 2 showed small decreases in all parameters. No significant between-group differences were found for tone (Δ = −0.39 Hz, 95% CI: −0.97 to 0.18; p = 0.171), stiffness (Δ = −7.00 N/m, 95% CI: −23.31 to 9.31; p = 0.391), or logarithmic decrement (Δ = −0.05, 95% CI: −0.12 to 0.02; p = 0.162). Effect sizes were small (Cohen's d = −0.43, −0.27, and −0.44, respectively). Conclusions: A single 20-minute session of lumbar unloading, with or without heat, did not produce significant between-group differences in paraspinal muscle properties. The reductions observed in the heat group are exploratory and do not demonstrate a beneficial effect of heat. As only immediate biomechanical responses were assessed and no validated clinical outcomes were included, the clinical significance of the findings remains unclear. Further studies with larger samples, longer or repeated interventions, appropriate controls, and clinical outcomes are warranted.

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INTRODUCTION

Chronic low back pain (LBP) represents one of the most prevalent health issues among the adult population, leading to substantial functional limitations, reduced quality of life, and decreased physical performance [1]. This condition frequently occurs among individuals engaged in intensive physical labor who are exposed to prolonged musculoskeletal overload, such as residents of rural areas. Despite the high level of physical activity inherent to their occupational demands, daily farming activities often contribute to excessive loading of the lumbar spine, potentially leading to persistent pain and stiffness in the lumbar region [2]. In addition to occupational work, many rural residents also participate in recreational physical activity. Although such activity promotes general fitness, it may further increase spinal loading, particularly in the absence of appropriate recovery strategies and access to professional physiotherapeutic care [3]. Limited access to physiotherapy services in rural areas often necessitates the use of conservative and home-based self-management strategies [4,5]. Therefore, simple, safe, and easily applicable interventions that can be performed independently at home are of particular interest. Among these, positioning techniques and thermotherapy have gained attention because of their potential to promote muscle relaxation and influence biomechanical tissue properties. Heat has been proposed as a potential adjunct to self-management strategies for chronic LBP because of its possible effects on local circulation and muscle tone [6]. Previous research has also examined the effects of thermal interventions on muscle tone and stiffness during recovery, although the observed responses may depend on the intervention and the clinical context [7]. Maintaining optimal biomechanical properties of the paraspinal muscles is particularly important in physically active individuals, as excessive muscle stiffness or tone may impair movement efficiency, increase spinal loading, delay recovery, and potentially contribute to recurrent low back symptoms. Therefore, simple strategies that can be performed at home are of practical interest for further investigation in physically active populations.

The evaluation of changes in muscle biomechanical properties requires objective and reproducible measurement methods. In the present study, the MyotonPRO device was used for the quantitative assessment of muscle biomechanical properties, including stiffness, tone, and elasticity [8]. Previous research has also used myotonometric assessment to investigate changes in muscle tone and stiffness associated with physical loading and recovery [9]. Myotonometry provides non-invasive and objective measurements of biomechanical tissue properties, reducing the influence of subjective assessment. Consequently, this method enables quantitative evaluation of changes in paraspinal muscle properties following home-based self-therapy interventions. Because access to physiotherapy services is often limited in rural areas, there is a need for simple self-management strategies that can be performed safely and independently at home. The present study therefore focused on the immediate effects of a single session of lumbar unloading self-therapy, reflecting the way such interventions may be used in everyday practice. Rather than evaluating the cumulative effects of a treatment series, the intention was to determine whether a single, easily applicable session could induce measurable biomechanical changes. If perceived as beneficial, this type of self-therapy could potentially be repeated by physically active individuals according to their individual recovery needs following occupational or recreational physical activity.

The aim of the present study was to evaluate the immediate effects of a simple home-based lumbar unloading self-therapy, performed with or without an additional thermal stimulus, on the biomechanical properties of the paraspinal muscles in physically

active adults with chronic low back pain residing in rural areas and regularly engaged in occupational and recreational physical activity.

MATERIAL AND METHODS

Participants

The study included 42 physically active participants (27 men and 15 women). Participants were recruited and data were collected in July 2025. Group 1 included 14 men and 7 women, whereas Group 2 included 13 men and 8 women. All participants were residents of rural areas and were regularly engaged in physical work associated with farming activities. In addition to their occupational workload, all participants declared regular participation in recreational physical activity. Therefore, the term "physically active" in the present study refers to individuals performing both routine farm-related physical labor and additional recreational exercise. Individuals were eligible for inclusion if they met the following criteria: age between 40 and 60 years, body mass index (BMI) ranging from 18.5 to 29.9 kg/m^2, and the presence of chronic low back pain managed conservatively for at least five years. All participants had been diagnosed with M54.5 (low back pain) according to the ICD-10 classification by a specialist physician. At the time of the study, all participants reported experiencing their typical symptoms of lumbar discomfort or pain, accompanied by stiffness and increased paraspinal muscle tension. Exclusion criteria comprised acute or post-traumatic back pain, symptoms of sciatica, a history of spinal surgery, and the use of medications aimed at reducing muscle tone. Participants were instructed to avoid engaging in any physical activity for 24 hours before the experiment. All participants were previously informed about the nature and course of the study and provided written informed consent to participate. Participation was voluntary, and each individual retained the right to withdraw at any stage of the study.

Study design

This was a randomized, parallel-group, two-arm experimental study conducted in the participants' homes. The study compared two active intervention procedures: lumbar unloading alone (Group 1) and lumbar unloading combined with heat application (Group 2). The intervention was designed as a home-based self-management procedure that could be independently reproduced by the participants after standardized instruction. The study initially assessed 50 physically active adults with chronic low back pain for eligibility. After screening, 8 individuals were excluded (5 did not meet the inclusion criteria, 2 declined to participate, and 1 was excluded for other reasons). The remaining 42 eligible participants provided written informed consent and were allocated in a 1:1 ratio to Group 1 or Group 2 according to a predetermined randomization sequence generated by the principal investigator using the random number generator available at Randomized.org. The principal investigator also performed participant eligibility assessment and enrollment and assigned eligible participants to the intervention groups according to the predetermined randomization sequence after confirmation of eligibility and provision of informed consent. No formal allocation concealment procedure was used. A physiotherapist trained in myotonometric assessment performed all MyotonPRO and lumbar skin-surface temperature measurements before and after the intervention. Before the intervention, a physiotherapist provided standardized verbal and practical instructions regarding the therapeutic position and demonstrated the procedure. The participant then independently assumed and maintained the prescribed position for 20 minutes. The physiotherapist supervised the participant during positioning to ensure correct and consistent execution of the protocol. The MyotonPRO measurements and lumbar skin-surface temperature

measurements were performed by the physiotherapist immediately before and after the intervention in the participant's home. The participant flow through the study is presented in Figure 1.

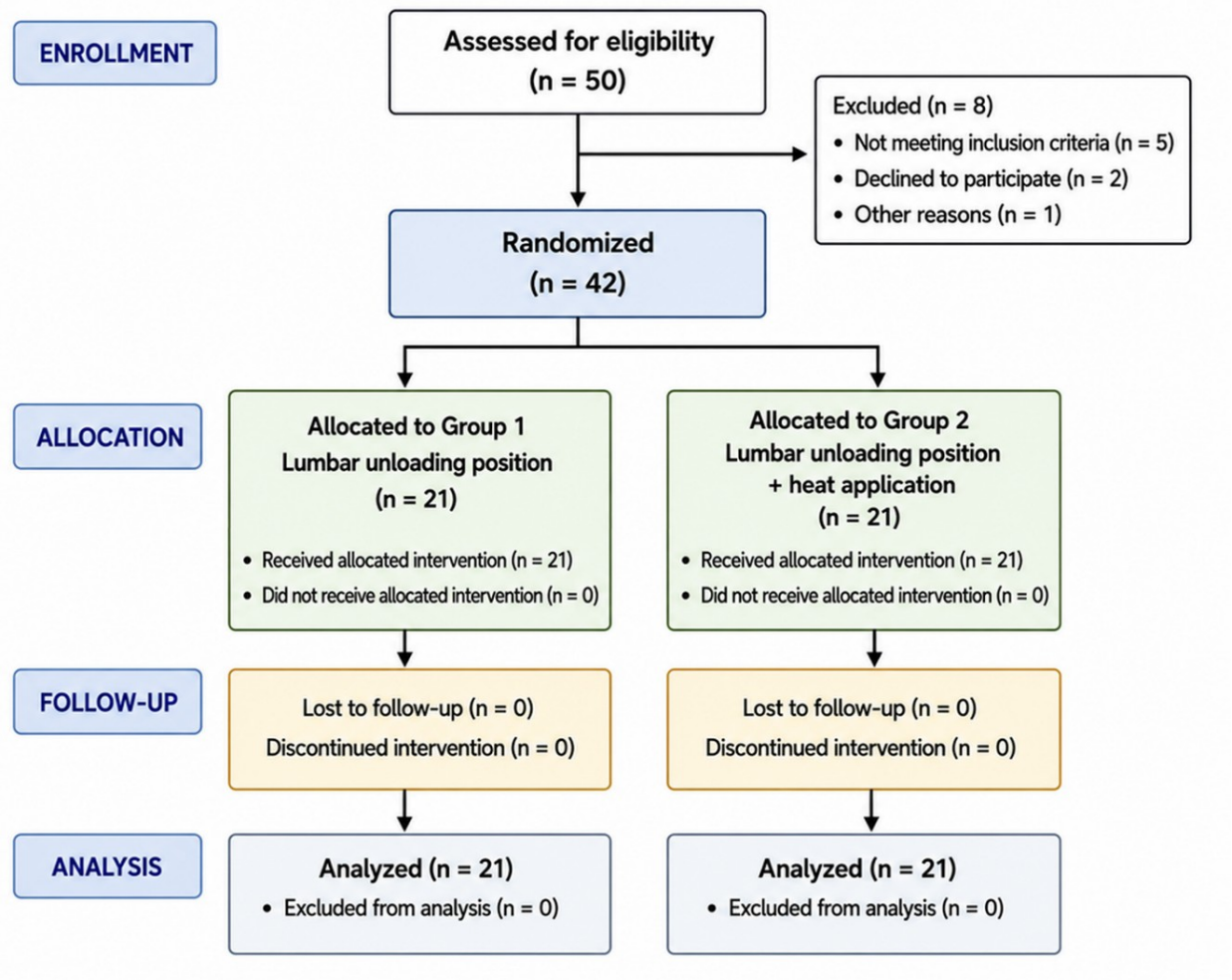


Figure 1. Flow diagram of participant recruitment, allocation, follow-up, and analysis.

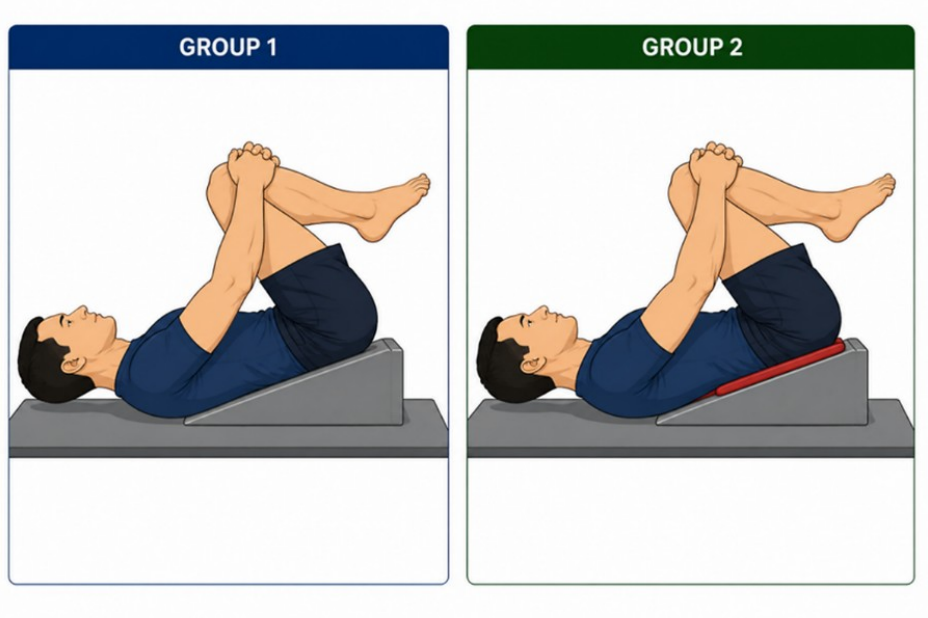


Figure 2. Therapeutic interventions performed in the two study groups.

Ethics approval

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by the Bioethics Committee for Scientific Research at the University of Physical Education in Warsaw (approval reference number: 202506WAM04). Before participation, all participants received detailed information about the study protocol and provided written informed consent. The study was not prospectively registered in a public trial registry.

Therapeutic Interventions

Participants adopted a therapeutic position for the lumbar spine for a duration of 20 minutes. The position involved lying supine, with the lower limbs maximally flexed at the hip and knee joints, abducted, and drawn toward the chest with the assistance of the upper limbs [8]. A rehabilitation wedge-shaped cushion (dimensions: 60 × 40 × 20 cm) was placed beneath the lumbar region, with its flat end oriented cranially. The wedge-shaped cushion supported the lumbar spine, reduced lumbar lordosis, and maintained the lumbar region in a kyphotic alignment. This position was intended to facilitate decompression of the intervertebral joints and stretching of the paraspinal muscles. In Group 2, two flat gel heating pads (ARmedical CHP-2030 Cold-Hot Compress – Maxi, 20 × 30 cm) were additionally placed on the wedge-shaped cushion. The gel pads were heated to a target temperature of 45°C, and their temperature was measured using an infrared thermometer immediately before application to the lumbar region. Thus, 45°C represented the measured temperature of the heated gel pads at the beginning of the intervention. The temperature of the gel pads was not continuously monitored during the 20-minute intervention. Two pads were used to ensure complete coverage of the cushion surface. A single layer of cotton fabric was placed between the heating pads and the skin as an insulating layer. The thermal intervention was applied for the same 20-minute period as the lumbar unloading intervention. The therapeutic intervention was performed in the supine position, which differed from the prone position used for MyotonPRO measurements and lumbar skin-temperature assessment. The therapeutic interventions performed in both study groups are illustrated in Figure 2.

Myotonometric Measurements

The biomechanical properties of the muscles were evaluated using the MyotonPRO device (Myoton, Estonia). This myotonometer operates on the Mechanical Dynamic Response (MDR) principle, which enables non-invasive, precise assessment of tissue characteristics. The method involves the application of a brief mechanical impulse to the targeted tissue, followed by the recording of its dynamic response as displacement and oscillation acceleration. Based on these signals, the device automatically calculates parameters describing muscle biomechanical behavior: tone (Hz), stiffness (N/m), and logarithmic decrement, the latter reflecting tissue elasticity, with lower values indicating greater elasticity. During operation, the device first applies a pre-load force of 0.18 N to ensure proper contact and, after automatic calibration, delivers five short impulses of 0.4 N each, with a duration of 15 ms, to induce tissue deformation [10]. Oscillatory responses are captured by an integrated accelerometer. To ensure data reliability, the coefficient of variation (CV) was monitored for each measurement series; if the CV exceeded 3%, the procedure was repeated once. All MyotonPRO measurements were performed with participants lying in the prone position, with a bolster placed under the feet to maintain physiological lumbar lordosis. MyotonPRO measurements were performed at 10 predefined anatomical locations corresponding to the bilateral paraspinal muscles at five vertebral levels (L1–L5), 2.5 cm lateral to the spinous processes [11]. Each measurement sequence lasted approximately 3–5 seconds. The measurement sites were identified and marked on the skin before the measurements to ensure consistent localization during the pre- and post-intervention assessments. One MyotonPRO measurement was obtained at each anatomical location, resulting in a total of 10 measurements per assessment. The 10 measurements were averaged for each MyotonPRO parameter, and the resulting mean value was used for statistical analysis. All measurements were performed by the same physiotherapist, who conducted both the pre- and post-intervention assessments. The MyotonPRO device demonstrated good to excellent intra-rater reliability and good to excellent inter-rater reliability in assessing lumbar erector spinae muscle stiffness. The Intraclass Correlation Coefficient (ICC) values ranged from 0.88 (95% CI: 0.76–0.94) to 0.91 (95% CI: 0.82–0.96) for intra-rater measurements and from 0.84 (95% CI: 0.68–0.92) to 0.96 (95% CI: 0.92–0.98) for inter-rater measurements [12].

Temperature measurements

Skin surface temperature was measured in Group 2, as this group received the thermal intervention. Measurements were performed in the lumbar region immediately before and after the 20-minute intervention. Participants were positioned in the prone position with a bolster under the feet, consistent with the position used for the MyotonPRO assessment. Measurements were taken bilaterally at paraspinal locations adjacent to the lumbar spine using a Berrcom JXB-182 infrared thermometer. The thermometer was held at a distance of approximately 3–5 cm from the skin surface, according to the manufacturer's recommendations. Each measurement was performed once on each side, and the mean of the two readings was calculated as the representative lumbar skin surface temperature. The skin was dry, clean, and free from clothing or other external heat sources. The gel compress was heated in a microwave oven to a target temperature of 45°C, and its temperature was measured using the same infrared thermometer immediately before application to the lumbar region. The measured temperature represented the temperature of the heated compress at the beginning of the intervention. The temperature of the compress was not continuously monitored during the 20-minute intervention. The compress was separated from the skin by a layer of material throughout the intervention. Lumbar skin surface temperature increased from 34.08°C before the intervention to 40.17°C immediately after the 20-minute intervention. The thermal intervention itself was

performed with participants in the supine position, with the lower limbs flexed and a wedge placed beneath the lumbar region. Thus, the intervention position differed from the prone position used for MyotonPRO and skin-temperature measurements. The thermal intervention lasted 20 minutes.

Statistical analysis

Statistical analyses were performed using PQStat version 1.8.6. Because the primary research question was whether the addition of heat to lumbar unloading resulted in a different pre–post change in paraspinal muscle properties compared with lumbar unloading alone, the primary analysis focused on the between-group difference in pre–post change. For each outcome (muscle tone, stiffness, and logarithmic decrement), the change score was calculated as the post-intervention value minus the pre-intervention value (Δ = post − pre). The primary treatment effect was then evaluated by comparing the change scores between the two groups using an independent-samples Student's t-test. In a two-group, two-time-point design, this comparison directly tests the group × time interaction, i.e., whether the magnitude and direction of change over time differed between the intervention groups. The assumptions for the primary analysis were assessed using the Shapiro–Wilk test for normality of the change scores and Levene's test for homogeneity of variances between groups. Where the assumptions of the independent-samples t-test were satisfied, the parametric analysis was retained. Within-group pre–post comparisons using paired-samples Student's t-tests were considered secondary and descriptive, and were not used to determine whether the addition of heat produced a differential treatment effect. Likewise, comparisons between groups at individual time points were not considered the primary test of treatment efficacy.

For the primary between-group comparison, the mean difference in change (Group 2 − Group 1) was reported together with its 95% confidence interval (CI) and p-value. The standardized magnitude of the between-group treatment effect was quantified using Cohen's d, calculated from the between-group difference in change scores using the pooled standard deviation of the change scores, and reported with its 95% CI. Cohen's d was interpreted using conventional thresholds based on the absolute value of the effect size: <0.20, trivial; 0.20–<0.50, small; 0.50–<0.80, moderate; and ≥0.80, large [13]. All statistical tests were two-sided, and statistical significance was set at $p < 0.05$. As an additional analysis, the pre–post change in lumbar skin surface temperature in Group 2 was assessed using a paired-samples Student's t-test.

Sample size was determined a priori using G*Power software (version 3.1.9.7; Heinrich Heine University Düsseldorf, Germany; http://www.gpower.hhu.de) [14] based on a two-sample independent t-test, assuming a large standardized between-group effect (Cohen's d = 0.90), based on previously reported differences in lumbar paraspinal muscle stiffness measured using the MyotonPRO device [14], $\alpha = 0.05$, and 80% statistical power, resulting in a required sample of 42 participants (21 per group). A sensitivity analysis showed that, with 21 participants per group, the study had approximately 80% power to detect an effect of approximately Cohen's d = 0.89. Thus, the sample size was appropriate for detecting the large effect assumed in the original calculation, but the study had limited power to detect smaller effects. This limitation was considered when interpreting the non-significant findings. Therefore, non-significant between-group findings should not be interpreted as evidence of equivalence or as demonstrating the absence of an effect, particularly for effects smaller than those detectable with the available sample size.

RESULTS

The mean age of participants in Group 1 was 49.76 ± 3.96 years, while in Group 2 it was 50 ± 3.79 years. The difference between the groups was not statistically significant ($p = 0.843$). The mean body mass index (BMI) was 25.74 ± 4.05 [kg/m^2] in Group 1 and 25.73 ± 3.51 [kg/m^2] in Group 2, with no statistically significant difference observed ($p = 0.993$). The mean skin surface temperature in the lumbar region in Group 2, measured before the therapeutic procedure, was 34.08 ± 0.36 °C. It increased significantly ($p < 0.001$) following the therapeutic procedure, reaching 40.17 ± 0.39 °C.

Biomechanical parameters of the lumbar paraspinal muscles, including tone, stiffness, and logarithmic decrement, were assessed using the MyotonPRO device before and after the therapeutic intervention in both study groups. The results are presented in Table 1, including pre- and post-intervention values, within-group changes, and between-group differences in pre–post change. Figure 3 presents the between-group differences in pre–post change (Group 2 − Group 1) with corresponding 95% confidence intervals for each biomechanical parameter.

In Group 1 (unloading alone), muscle tone increased from 16.74 ± 1.64 to 16.93 ± 1.69 Hz (Δ = +0.19 Hz), while stiffness increased from 331.90 ± 56.96 to 337.79 ± 64.40 N/m (Δ = +5.88 N/m). Logarithmic decrement increased slightly from 1.36 ± 0.23 to 1.37 ± 0.22 (Δ = +0.01). In Group 2 (unloading + heat), muscle tone decreased from 17.25 ± 1.61 to 17.05 ± 1.67 Hz (Δ = −0.21 Hz), stiffness decreased from 335.84 ± 59.45 to 334.72 ± 49.70 N/m (Δ = −1.12 N/m), and logarithmic decrement decreased from 1.48 ± 0.24 to 1.44 ± 0.19 (Δ = −0.04).

Table 1. Paraspinal muscle biomechanical properties before and after intervention and between-group differences in pre-post change.

Parameter	Group 1 Unloading alone			Group 2 Unloading + heat			Between-group difference in change	p	Cohen's d
	Pre	Post	Δ	Pre	Post	Δ			
Tone (Hz)	16.74 ± 1.64	16.93 ± 1.69	+0.19	17.25 ± 1.61	17.05 ± 1.67	−0.21	−0.39 (−0.97 to 0.18)	0.171	−0.43 (−1.04 to 0.18)
Stiffness (N/m)	331.90 ± 56.96	337.79 ± 64.40	+5.88	335.84 ± 59.45	334.72 ± 49.70	−1.12	−7.00 (−23.31 to 9.31)	0.391	−0.27 (−0.88 to 0.34)
Logarithmic decrement	1.36 ± 0.23	1.37 ± 0.22	+0.01	1.48 ± 0.24	1.44 ± 0.19	−0.04	−0.05 (−0.12 to 0.02)	0.162	−0.44 (−1.05 to 0.17)

Note: Values are presented as mean ± SD. Δ represents the within-group pre–post change (post-intervention minus pre-intervention). The between-group difference in change was calculated as ΔGroup 2 − ΔGroup 1. p-values correspond to the between-group comparison of pre–post change, representing the group × time effect. Cohen's d represents the standardized between-group difference in pre–post change.

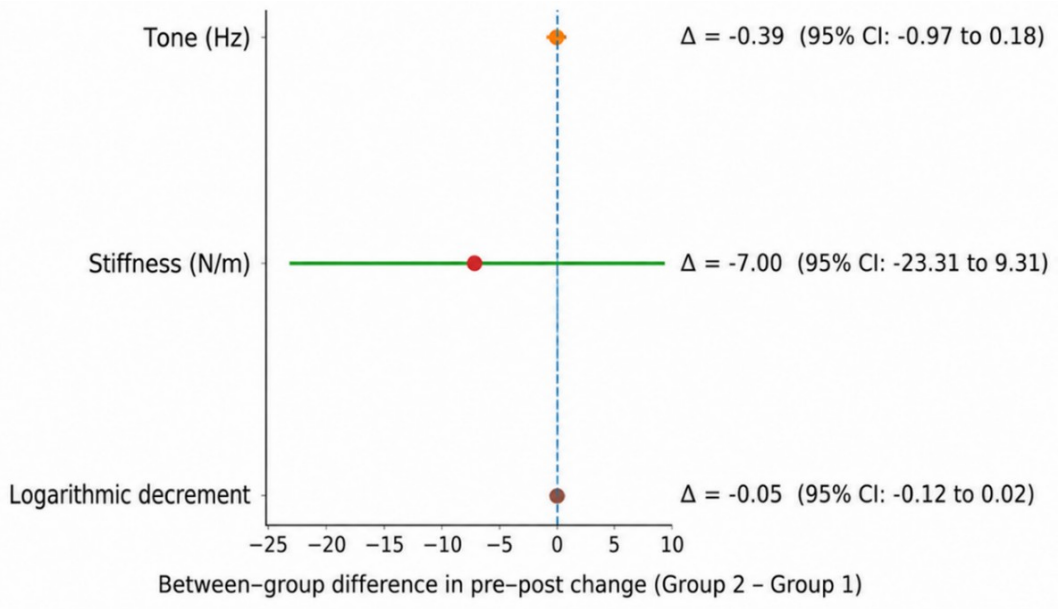


Figure 3. Between-group differences in pre–post changes in lumbar paraspinal muscle properties.

The primary between-group analysis focused on the difference in pre–post change between the two interventions (Group 2 − Group 1). For muscle tone, the between-group difference in change was −0.39 (95% CI −0.97 to 0.18; p = 0.171). For stiffness, the corresponding difference was −7.00 N/m (95% CI −23.31 to 9.31; p = 0.391), while for logarithmic decrement it was −0.05 (95% CI −0.12 to 0.02; p = 0.162). Thus, none of the between-group differences in pre–post change reached statistical significance. In all three cases, the 95% confidence intervals included zero, indicating that the observed differences between the interventions were compatible with no differential treatment effect.

The standardized between-group effect sizes were small for all three parameters: Cohen's d = −0.43 (95% CI −1.04 to 0.18) for tone, d = −0.27 (95% CI −0.88 to 0.34) for stiffness, and d = −0.44 (95% CI −1.05 to 0.17) for logarithmic decrement. All corresponding confidence intervals included zero, further indicating substantial uncertainty regarding the magnitude and direction of any difference between the two interventions.

Overall, although the descriptive changes showed different directions between groups, with slight increases in tone, stiffness, and logarithmic decrement following unloading alone and slight decreases following unloading combined with heat, these patterns did not translate into statistically significant between-group differences in pre–post change. Therefore, the present findings do not provide statistically significant evidence that the addition of heat to lumbar unloading produces a greater immediate change in paraspinal muscle tone, stiffness, or logarithmic decrement than lumbar unloading alone.

DISCUSSION

The present study investigated the immediate effects of a single 20-minute lumbar unloading intervention performed with or without an additional thermal stimulus on the biomechanical properties of the lumbar paraspinal muscles in physically active adults with chronic low back pain. The primary comparison concerned whether the addition of heat resulted in a different pre–post change in muscle tone, stiffness, or logarithmic decrement compared with lumbar unloading alone. The between-group analysis of change scores

showed no statistically significant differences for any of the assessed parameters. The descriptive changes showed different directions between the two groups. Because lower logarithmic decrement values are generally interpreted as indicating greater tissue elasticity, the direction of the logarithmic decrement change in Group 2 is descriptively consistent with increased elasticity. However, these directional changes represent descriptive observations and should not be interpreted as evidence of clinical improvement or therapeutic efficacy.

The between-group effect estimates were small to moderate, with confidence intervals crossing zero. Thus, the magnitude and direction of any differential response remain uncertain, and the findings do not establish a clinically meaningful advantage of adding heat. The increase in mean lumbar skin surface temperature from 34.08°C before the intervention to 40.17°C immediately after the 20-minute intervention confirms that the thermal application produced a measurable local temperature increase. However, because temperature was measured only immediately before and after the intervention, the temperature profile of the gel pads throughout the 20-minute application cannot be determined. No adverse events, skin irritation, burns, or excessive discomfort were reported during the study. These observations should not be interpreted as evidence of clinical safety or effectiveness beyond the conditions examined in the present protocol. The temperature of the heated gel pads was measured immediately before application but was not continuously monitored during the 20-minute intervention. Therefore, the 45°C value represents the measured temperature of the pads at the beginning of the intervention and does not establish the temperature profile of the pads throughout the entire application period. No adverse events, skin irritation, burns, or excessive discomfort associated with the thermal intervention were reported during the study. Nevertheless, these observations should not be interpreted as evidence of the clinical safety or effectiveness of thermotherapy beyond the conditions examined in the present protocol.

The absence of a statistically significant differential effect between the interventions is consistent with previous research showing that a single intervention may not necessarily produce measurable changes in paraspinal muscle properties. For example, nonsurgical spinal decompression did not result in significant changes in mechanical parameters or muscle morphology following a single intervention [8]. Similarly, other research has reported no significant differences in electromyographic activity of the lumbar erector spinae between groups exposed to traction and control conditions [16]. These findings suggest that immediate exposure to a mechanical unloading stimulus may not be sufficient to produce detectable changes in muscle biomechanical characteristics, particularly when assessed after only one treatment session.

Previous studies have also demonstrated that responses of the lumbar paraspinal muscles may vary according to the type and duration of intervention, participant characteristics, and measurement conditions. Abnormally elevated muscle stiffness and tone have been discussed as factors associated with altered spinal biomechanics and chronic low back pain [17]. However, the present study does not establish that a short-term reduction in these parameters results in improvement of pain, disability, function, or quality of life. The MyotonPRO measurements provide information about selected biomechanical properties of the assessed tissues, but these outcomes should not be regarded as substitutes for patient-reported clinical outcomes. Studies investigating longer or multimodal physiotherapy interventions have reported improvements in clinical outcomes among individuals with low back pain. Kuliński and Kibler reported improvements in quality of life, pain, and analgesic requirements following a 15-day program combining electrotherapy, laser therapy, ultrasound, and kinesitherapy [18]. Similarly, Matusiak et al. reported improvements in mobility and reductions in pain following a comprehensive physiotherapy program in patients with lumbosacral spine pain [19]. A review of

balneotherapy and physiotherapy interventions also suggested potential benefits of combined treatment approaches for chronic lumbosacral pain [20]. However, these findings cannot be directly compared with the present results because those studies involved longer and/or multimodal interventions and included clinically relevant outcomes. Therefore, they should not be interpreted as evidence that the single-session intervention evaluated here produces comparable clinical benefits. Participant characteristics may also contribute to variability in muscle biomechanical responses. Wu et al. [21] reported that lumbar erector spinae tone and stiffness may increase with age and may differ between men and women. Such factors could influence the magnitude of an individual's response to a short-term intervention. However, the present study was not designed or powered to investigate potential moderation of treatment effects by age or sex. Consequently, any influence of these characteristics on the observed responses remains speculative.

Similarly, Zhang et al. [22] demonstrated that lumbar erector spinae stiffness increases with increasing isometric trunk-extension intensity. This finding highlights the sensitivity of paraspinal muscle stiffness to loading conditions and supports the importance of standardized measurement procedures. In the present study, the MyotonPRO assessments were performed in a standardized prone position, whereas the therapeutic intervention was performed in the supine position with the lower limbs flexed and the lumbar region supported by a wedge. Although this distinction was intentional, differences between the measurement and intervention positions may have influenced the immediate biomechanical response and should be considered when interpreting the findings. From a methodological perspective, the reliability of MyotonPRO measurements of the lumbar erector spinae has been supported by previous studies. Valenti et al. [11] reported good to excellent reliability of erector spinae stiffness measurements, supporting the reproducibility of myotonometric assessment. Li et al. [14] additionally reported that erector spinae stiffness may vary according to body position and was higher on the painful side in individuals with chronic low back pain, particularly in the sitting position. These findings highlight the importance of standardized testing conditions when assessing lumbar muscle biomechanical properties. Nevertheless, measurement reliability does not establish clinical relevance. Changes in MyotonPRO-derived parameters cannot by themselves demonstrate improvements in patients' symptoms, disability, or functional status.

Several possible physiological mechanisms could theoretically contribute to changes in muscle tone or stiffness following unloading and thermal stimulation. These may include changes in muscle spindle activity, stretch-reflex responses, gamma-loop modulation, or local and central relaxation processes. However, none of these mechanisms were directly assessed in the present study. Therefore, they should be regarded only as possible explanations derived from previous physiological concepts and should not be interpreted as mechanisms demonstrated by the present data. Future studies incorporating electromyography, neurophysiological measurements, or other mechanistic outcomes could determine whether such pathways contribute to the response to lumbar unloading or thermotherapy.

The study has several methodological limitations. First, the relatively small sample limits statistical power and the precision of the estimated effects, particularly for smaller effects. Second, the intervention consisted of a single 20-minute session without long-term follow-up, so the persistence or clinical relevance of any immediate biomechanical response cannot be determined. Third, validated patient-reported and functional outcomes were not collected, and baseline pain intensity and disability were not systematically quantified using validated clinical instruments. Other potentially relevant characteristics, including occupational workload, recreational physical activity, previous

physiotherapy, and comorbidities, were also not comprehensively characterized. Fourth, the absence of a no-treatment, sham-heat, or usual-care control condition means that the study cannot distinguish the specific effects of unloading or heat from nonspecific effects such as rest, positioning, repeated measurement, or participant expectations. Participants and assessors were also not blinded. These limitations restrict causal and clinical interpretation of the findings. The findings should therefore be regarded as preliminary and hypothesis-generating. The descriptive reduction in logarithmic decrement observed in the heat group may provide a basis for further investigation, but it should not be interpreted as evidence of therapeutic efficacy. Future randomized studies should include appropriate control conditions, larger samples, repeated or longer intervention protocols, longer follow-up, and validated measures of pain, disability, function, and patient-reported outcomes to determine whether changes in biomechanical muscle properties are associated with clinically meaningful benefits.

CONCLUSION

A single 20-minute session of lumbar unloading, performed either alone or in combination with a thermal stimulus, did not result in statistically significant between-group differences in pre–post changes in paraspinal muscle tone, stiffness, or logarithmic decrement. Although the heat group showed descriptive reductions in all three biomechanical parameters, these findings do not provide evidence of an additional beneficial effect of heat application and should be interpreted as preliminary and hypothesis-generating.

Because the study assessed only immediate biomechanical responses and did not include validated measures of pain, disability, functional performance, or quality of life, the clinical significance of the observed changes cannot be established. Further randomized studies with larger samples, appropriate control conditions, repeated or longer interventions, longer follow-up, and clinically relevant patient-reported outcomes are warranted to determine whether these approaches can produce reproducible and clinically meaningful effects in individuals with chronic low back pain.

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