Short-Term Effects of Different Rates of Thoracic Mobilization on Pressure Pain Thresholds in Asymptomatic Individuals: A Randomized Crossover Trial

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ABSTRACT

Objective: The primary aim of this study was to determine the effects of different rates of thoracic spine passive accessory intervertebral mobilization (PAIVM) on pressure pain threshold (PPT) at T4. The secondary aim was to investigate the widespread effects of different rates of thoracic PAIVM.

Methods: Twenty asymptomatic participants were randomly assigned to 3 experimental conditions: posteroanterior rotatory thoracic PAIVM at 2 Hz, 0.5 Hz, and placebo. Each participant received all 3 experimental conditions in a random order with a washout period of at least 48 hours between each procedure. The PPT was measured in 3 different points: pre-treatment, immediately after, and 15 minutes after the treatment at C7 and T4 spinous process, first interosseus dorsal on the right and left hands and tibial tuberosity bilaterally. A repeated-measures analysis of covariance adjusted by baseline values was used to assess between-group differences at each point. Pairwise comparisons were adjusted for multiple tests with a Bonferroni correction. A P value $< .05$ was considered significant.

Results: There was no between-group differences on PPT at T4 when comparing 0.5 Hz (mean difference -0.29; 95% CI -0.99 to 0.42; $P = .999$) or 2 Hz (mean difference -0.37; 95% CI -1.1 to 0.33; $P = .528$) to placebo.

Conclusion: None of the mobilization techniques in this study (0.5 Hz, 2 Hz, and placebo) showed a significant change of PPT both locally and at distant sites at any point in asymptomatic participants. (J Chiropr Med 2019;18:33-41)

Key Indexing Terms: Musculoskeletal Manipulations; Thoracic Vertebrae; Pain Measurement; Pain Threshold

INTRODUCTION

Passive accessory intervertebral mobilizations (PAIVM) are widely used by practitioners who perform spinal mobilization in the management of neuromusculoskeletal disorders.¹ Currently, there is evidence demonstrating that

such techniques can produce hypoalgesic effects in both asymptomatic participants²⁻⁴ and patients.⁵⁻⁸

The mechanisms that could explain the positive effects after spinal mobilizations have not been clearly elucidated yet. Some hypotheses have been suggested, including direct biomechanical⁹ and neurophysiological effects at peripheral, spinal, and supraspinal levels.¹⁰ At the supraspinal level, the activation of the dorsolateral periaqueductal gray matter, resulting in excitation of the sympathetic nervous system and activation of descending nonopioid inhibitory pathways, has been pointed to as a potential mechanism of action of PAIVM.¹⁰⁻¹⁴

The sympathetic outflow to the head, upper trunk, and upper limbs is provided by the thoracic ganglia.¹⁵ Hence, this region can be implicated in conditions of the upper quarter involving sympathetic-related symptoms, such as the T4 syndrome.¹⁶⁻¹⁸ Moreover, the role of the thoracic spine in conditions affecting the upper quadrant has been highlighted by several studies,^{19,20} and manipulative treatment delivered to this spinal region has proven to be clinically beneficial for neck pain²¹⁻²³ and shoulder impingement syndrome.^{24,25}

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Despite this clinically important relationship, the thoracic spine has been underexplored.²⁶ Several studies investigated the effects of PAIVM on pressure pain threshold (PPT) in the cervical^{5,7,27-29} and lumbar spine.^{3,4,30} Nevertheless, a much smaller number of studies were conducted for this purpose in the thoracic spine.^{26,31} For instance, Salom-Moreno et al³² reported that central posterior-anterior thoracic PAIVM induces statistically, although clinically small, widespread increase in PPT in neck pain patients.

Clinicians often rely on concepts such as stability and irritability to determine the parameters of treatment with PAIVM,¹ but a better understanding of the contribution of different parameters to the clinical observed effect of PAIVM has the potential to improve the clinical decision-making process and improve clinical outcomes.²⁷ In this sense, there is a growing interest in determining the optimal dose of treatment with PAIVM,^{3,4,27,30,33-35} which comprises different parameters, such as the direction and magnitude of the applied force applied by the therapist, the frequency of oscillation, the amplitude of displacement, the number of repetitions, and the treatment time.^{1,35}

A single study³⁰ reported no differences between 30 or 60 seconds of lumbar mobilization in asymptomatic participants, but suggested that at least 4 sets of mobilization would be required to produce hypoalgesia. In relation to the magnitude of force employed, 2 studies observed no differences in lumbar and neck PPT after PAIVM with different forces of application in both asymptomatic participants³ and patients with neck pain.²⁷ To date, there is a paucity of research on the effects of different rates of PAIVM and their role on local and widespread hypoalgesia in patients and asymptomatic participants. Willett et al³ conducted a repeated-measures randomized controlled trial to compare the hypoalgesic effects of a quasi-static, 1 Hz, or 2 Hz PAIVM applied to the lumbar spine of asymptomatic participants. That study did not find significant differences between these rates of mobilization. Although this study³ investigated the effects of lumbar PAIVM on PPT, there is a gap of evidence regarding the ability of the rate of thoracic mobilization in producing hypoalgesic responses. Therefore, the primary objective of this study was to determine the effects of different rates of thoracic spine PAIVM on PPT at T4. The secondary objective was to investigate the widespread effects of different rates of thoracic PAIVM.

METHODS

Registration

This randomized crossover trial was prospectively registered at [ClinicalTrials.gov](https://clinicaltrials.gov) (registration number: NCT02163590) and was reported following the recommendations from the Consolidated Standards of Reporting Trials recommendations.³⁶ The Universidade Federal de

Ciências da Saúde de Porto Alegre human research ethics committee approved the study. All participants provided written informed consent before entering the study.

Sample Size Calculation

An a priori sample size calculation, considering a minimal detectable difference of 1.58 kg/cm² between PPT means³⁷ and within-patient standard deviation (SD) of 1.5 points, and 2-tailed test, adopting 5% as the significance level and 80% as the statistical power, determined that 17 individuals would be required. The sample was increased to 20 individuals, considering an anticipated dropout rate of 15%.

Participants

Participants were recruited through online advertisements. We included participants aged between 18 and 40 years, with body mass index ranging from 18.5 and 25 kg/m², without any pain complaints in any spinal region at the time of study. We excluded participants who had undergone any spinal surgeries or who had any prior traumas in the spine or any contraindications to mobilizations of the thoracic spine. To avoid differences in the magnitude of the force delivered, we only included participants whose body mass index was within a range from 18 kg/m² to 25 kg/m², as suggested by Willett et al.³

Research Design

This study used a double-blind, randomized, within-subjects, crossover design in which each participant experienced all 3 experimental conditions in a random order established by a researcher not involved in any other research procedure. Participants were randomized using a computerized-based software (www.random.org). Sequentially numbered, opaque, and sealed envelopes containing the order of randomization were used to conceal the allocation and order of treatments. The outcome assessor was blinded to group assignment. Participants were unaware of the type of technique they would receive and were therefore blinded to group assignment. Participants received each experimental condition on 3 separate occasions with a minimum of 48 hours between each procedure to avoid carryover effects, as reported previously.^{3,4} The study flow diagram is illustrated in [Figure 1](#).

Experimental Procedure

Data were collected in a silent room with controlled temperature and humidity. The intervention procedure was delivered by a physiotherapist postgraduated in neuromusculoskeletal manual therapy with 7 years of clinical experience. A grade-III rotatory posteroanterior PAIVM was applied ([Fig 2](#)), as performed previously.¹⁸ In this

Fig 1. Research design and participants flow diagram. *Each of the 20 participants experienced all 3 experimental conditions in a random order.

technique, the costovertebral joints at the T4 segment were contacted bilaterally with a pisiform grip, and both posteroanterior and rotary pressures were applied; the rotary movement was achieved as the force applied by each of the therapist's hands was directed to a different direction—while one of the hands applied a force from caudal to cephalad, the other hand applied a force from cephalad to caudal.¹ This technique is thought to produce localized segmental joint glide at the costovertebral, costotransversal, intervertebral, and facet joints of the thoracic spine.^{1,18} This approach is intended to promote, in addition to a mechanical stimulus, effects on the sympathetic nervous system owing to the anatomical location of the thoracic ganglia.¹⁵

The treatment time was standardized across the experimental conditions: the intervention was performed for 3 sets of 1 minute, with 1 minute of interval between sets, as described in previous studies.^{3,4,18,27} The rates of PAIVM

were 2 Hz, 0.5 Hz, or *quasi-static* 0 Hz (only manual contact without oscillation, considered a placebo intervention). To standardize the rate of force application, a digital metronome was used and the therapist received auditory feedback from it. The volunteers were comfortably positioned in prone-lying, with both arms extended alongside the body. The physiotherapist was always positioned at the right side of the individual.

A calibrated commercial uniaxial load cell (Miotoool SDS 1000/Miotec, Porto Alegre/RS, Brazil) with a nominal capacity of 200 kg and resolution of 0.1 kg was attached over the surface of the treatment table and connected to a data acquisition system (analog-to-digital converter - Miotoool 400, Miotec) linked to a computer screen (Miotec Suite 1.0 software). This method provided real-time visual feedback of the applied force during the intervention, improving the accuracy of the manually applied forces during the mobilizations.³⁸ The amplitude of the applied

Fig 2. Posteroanterior passive accessory intervertebral mobilization (PAIVM) performed at the T4 level with participant in prone-lying position.

force was standardized to range between 100 N and 200 N for the 2 Hz and 0.5 Hz, respectively. This range of force application characterized a large amplitude mobilization, whereas in the placebo intervention a quasi-static 50-N force was applied constantly. The load cell was calibrated before each intervention.

Outcome Measures

The PPT, which is defined as the least mechanical stimulus required to change the sensation of pressure to a sensation of pain,³⁹ was measured with a handheld digital algometer (Wagner FDX-10, Wagner Instruments, Greenwich, Connecticut), with a 1-cm² round rubber tip. The force was always applied perpendicularly to the skin surface, and the rate of force application was approximately 1 kg/s. This measurement quantifies pain and tenderness reliably.⁴⁰⁻⁴⁴

Data were collected on 3 different points (baseline, immediately post-intervention, and 15 minutes after the intervention) in 6 different landmarks: C7 spinous process; T4 spinous process, first interosseal dorsal on the right and left hands; and tibial tuberosity on the right and left lower limbs with the participants comfortably seated (Fig 3). A mean of 3 measurements in each point with 30 seconds of interval between each attempt was calculated. The measurements were collected by the same trained evaluator who was blinded to group assignment. The outcome evaluator was trained to increase the force application at a rate of approximately 1 kg/cm² per second. Before data collection, 3 PPT measurements in the left forearm were performed for

the participant to be familiarized with the procedure. Participants were instructed to say “pain” as soon as the pain threshold was reached. At this moment, the pressure was released and the displayed value (kg/cm²) was recorded. The algometer was calibrated before data collection.

Data Analysis

Data normality was checked with the Shapiro-Wilk test, which revealed a nonparametric distribution for some variables. A repeated-measures analysis of covariance adjusted for baseline scores was employed. The use of analysis of covariance adjusted by baseline values is a recommended statistical approach to deal with nonparametric data without introducing bias in effect estimates while maintaining the statistical power achieved by nonparametric statistical tests (Vickers⁴⁵). We reported the results as between-group differences (95% CI) and applied a Bonferroni correction procedure to account for multiple comparisons. A *P* value < .05 was considered statistically significant. All analyses were carried out using SPSS Version 20.0 (IBM Corp, Armonk, New York).

RESULTS

Participants were screened for eligibility between March and July 2014. Twenty (10 men) healthy and asymptomatic volunteers participated in this study, with a mean $\pm$ SD age of 24.4 ± 3.6 years and mean $\pm$ SD body mass index of 22.3 ± 2.6 kg/m². No participant was excluded. Baseline

Fig 3. Pressure pain threshold measurement.

characteristics are described in Table 1. All included participants received treatment according to their initial group assignment (Fig 1). There were no dropouts during the study period. There were no statistically significant differences in all PPT measures across conditions in the pre-intervention point (Table 2).

The PPT values at the T4 level were not different from placebo when compared to 0.5 Hz ($P = .99$) or 2 Hz ($P = .52$) immediately after the intervention. After 15 minutes of the intervention, there were no differences in PPT at T4 when comparing the 0.5 Hz ($P = .9$) and 2 Hz ($P = .99$) to placebo.

There were no between-group differences among the 0.5 Hz (P value = .99), 2.0 Hz ($P = .52$) mobilizations, and the placebo group. Fifteen minutes after the application of the technique, there was no regional effect between groups either.

Table 1. Baseline Characteristics of the Participants ($n = 20$)

Female, n (%)	10 (50)
Age (y)	24.4 $\pm$ 3.6
Weight (kg)	67.4 $\pm$ 11.5
Height (m)	1.69 $\pm$.09
Body mass index (kg/m ²)	22.3 $\pm$ 2.6

Age, weight, height, and body mass index are presented in mean $\pm$ standard deviation.

Table 2. Baseline, Immediate Post-Intervention, and Follow-up Scores of Each Treatment Group for Pressure Pain Threshold

Anatomic Landmark	Baseline	Immediate Post-Intervention	15-Min. Follow-up
C7			
Placebo	4.26 (0.51)	4.52 (0.46)	4.85 (0.54)
0.5 Hz	3.92 (0.50)	4.50 (0.50)	4.76 (0.49)
2.0 Hz	4.20 (0.65)	4.88 (0.62)	5.22 (0.59)
T4			
Placebo	4.50 (0.28)	4.81 (0.38)	4.93 (0.42)
0.5 Hz	4.13 (0.45)	4.75 (0.47)	5.09 (0.45)
2.0 Hz	4.64 (0.57)	5.31 (0.53)	5.85 (0.52)
RI			
Placebo	4.50 (0.41)	4.47 (0.43)	4.65 (0.45)
0.5 Hz	4.17 (0.31)	4.46 (0.41)	4.43 (0.41)
2.0 Hz	4.49 (0.51)	4.71 (0.48)	4.97 (0.48)
LI			
Placebo	4.69 (0.45)	4.60 (0.44)	4.46 (0.42)
0.5 Hz	4.15 (0.30)	4.35 (0.40)	4.68 (0.39)
2.0 Hz	4.57 (0.51)	5.03 (0.55)	4.97 (0.49)
RT			
Placebo	8.91 (0.59)	8.70 (0.59)	8.53 (0.58)
0.5 Hz	8.61 (0.57)	8.02 (0.55)	8.39 (0.53)
2.0 Hz	8.44 (0.59)	8.63 (0.65)	8.59 (0.61)
LT			
Placebo	8.44 (0.52)	8.54 (0.56)	8.37 (0.55)
0.5 Hz	7.64 (0.46)	7.87 (0.49)	8.09 (0.52)
2.0 Hz	8.23 (0.58)	8.40 (0.67)	8.48 (0.65)

C7, seventh cervical vertebra; LI, left interossei dorsal; LT, left tibial tuberosity; RI, right interossei dorsal; RT, right tibial tuberosity; T4, fourth thoracic vertebra. Data are presented in mean (standard error). Post-treatment and follow-up scores were adjusted for baseline scores; placebo (placebo group), 0.5 Hz (0.5 Hz group), 2 Hz (2 Hz group).

The effect was not significant in both upper limbs, immediately and at 15 minute follow-up, for all 3 groups. Compared to placebo, immediate effects of 0.5 Hz ($P = .98$) or 2.0 Hz ($P = .99$) at right interossei dorsal and 0.5 Hz ($P = .82$) or 2.0 Hz ($P = .13$) at left interossei dorsal were no different.

Table 3. Adjusted Between-Group Mean Differences (95% CI)

Anatomic Landmark	Post-Immediate			15-Minute Follow-up											
	Placebo vs 0.5 Hz			0.5 Hz vs 2.0 Hz			Placebo vs 0.5 Hz			Placebo vs 2.0 Hz			0.5 Hz vs 2.0 Hz		
	Mean Difference (95% CI)	P Value	Mean Difference (95% CI)	Mean Difference (95% CI)	P Value	Mean Difference (95% CI)	Mean Difference (95% CI)	P Value	Mean Difference (95% CI)	Mean Difference (95% CI)	P Value	Mean Difference (95% CI)	Mean Difference (95% CI)	P Value	
C7	-0.28 (-1.024 to 0.469)	.999	-0.41 (-1.16 to 0.33)	.528	-0.14 (-0.88 to 0.61)	.999	-0.19 (-1.26 to 0.89)	.999	-0.42 (-1.49 to 0.65)	.999	-0.23 (-1.31 to 0.84)	.999			
T4	-0.29 (-0.99 to 0.42)	.999	-0.37 (-1.1 to 0.33)	.528	-0.85 (-0.79 to 0.62)	.999	-0.46 (-1.38 to 0.41)	.999	-0.80 (-1.69 to 0.10)	.999	-0.32 (-1.21 to 0.58)	.999			
RI	-0.29 (-1.02 to 0.44)	.980	-0.25 (-0.98 to 0.48)	.999	0.43 (-0.69 to 0.77)	.999	-0.91 (-0.88 to 0.70)	.999	-0.34 (-1.12 to 0.45)	.999	-0.25 (-1.03 to 0.54)	.999			
LI	-0.29 (-0.95 to 0.36)	.828	-0.54 (-1.12 to 0.11)	.132	-0.25 (-0.91 to 0.40)	.999	-0.70 (-1.46 to 0.06)	.081	-0.61 (-1.36 to 0.15)	0.156	0.92 (-0.66 to 0.85)	.999			
RT	0.43 (-0.70 to 1.155)	.999	-0.34 (-1.47 to 0.79)	.999	-0.76 (-1.89 to 0.36)	.298	-0.99 (-1.23 to 1.03)	.999	-0.45 (-1.57 to 0.68)	.999	-0.35 (-1.47 to 0.78)	.999			
LT	-0.15 (-0.98 to 0.69)	.999	-0.72 (-0.90 to 0.75)	.999	0.74 (-0.75 to 0.90)	.999	-0.48 (-1.51 to 0.55)	.760	-0.31 (-1.34 to 0.72)	.999	0.17 (-0.86 to 1.20)	.999			

C7, seventh cervical vertebra; *CI*, confidence interval; *LI*, left interosseus dorsal; *L/T*, left tibial tuberosity; *RI*, right interosseus dorsal; *RT*, right tibial tuberosity; *T4*, fourth thoracic vertebra. Between-group mean differences and CIs were adjusted for multiple comparisons (Bonferroni correction); Placebo (placebo group), 0.5 Hz (0.5 Hz group), 2Hz (2 Hz group).

C7, seventh cervical vertebra; CI, confidence interval; LI, left interosseus dorsal; LT, left tibial tuberosity; RI, right interosseus dorsal; RT, right tibial tuberosity; T4, fourth thoracic vertebra. Between-group mean differences and CIs were adjusted for multiple comparisons (Bonferroni correction); Placebo (placebo group), 0.5 Hz (0.5 Hz group), 2 Hz (2 Hz group).

The immediate and 15-minute follow-up effect between groups in lower limbs did not present any difference. Either at right lower limb comparing 0.5 Hz ($P = .99$) or 2.0 Hz ($P = .99$) to placebo, or at left lower limb comparing 0.5 Hz ($P = .999$) or 2.0 Hz ($P = .99$) to placebo, no significant effects were found (Table 3).

DISCUSSION

This trial aimed to determine the effect of different rates of T4 mobilization on local and widespread PPT in asymptomatic individuals. Our main findings provided evidence that thoracic PAIVM, independently of the rate of mobilization, did not significantly increased PPT neither locally nor at distant points. Although an overall increase of PPT occurred after all procedures, these changes were not significantly different between groups. In addition, thoracic PAIVM applied at 0.5 Hz, 2 Hz, and a quasi-static placebo intervention did not increase PPT neither immediately nor 15 minutes after the intervention.

Similarly to our findings, Willett et al³ did not find differences in lumbar PPT after PAIVM applied at different rates (1 Hz, 0.5 Hz, or quasi-static) in an asymptomatic sample. In contrast, Chiu and Wright⁴⁶ demonstrated that a 2-Hz grade III cervical mobilization resulted in a significant increase in skin conductance compared to a 0.5 Hz PAIVM and a control condition in asymptomatic individuals. However, this study did not directly assess hypoalgesia-related outcomes as we did. Nonetheless, the body of evidence regarding the effects of different rates of vertebral mobilization is still scarce, and, to the best of our knowledge, our trial is the first to assess the effects of different rates of PAIVM directed at the thoracic spine on local and widespread PPT.

Previous research have also reported no between-group differences in PPT after PAIVM techniques.^{3,4,27,28} Two trials compared another parameter of PAIVM, the magnitude of force applied,^{4,27} and reported no difference in neck PPT after PAIVM with high or low mobilization forces and a detuned laser placebo in a sample of patients with neck pain²⁷ and no significant between-group differences in lumbar PPT after PAIVM with different magnitudes of forces in a sample of asymptomatic participants.⁴

One weakness of our study was that outcomes were measured after only a single session. La Touche et al⁵ found that 3 sessions of anterior-posterior mobilization of the upper cervical spine, at 0.5 Hz, in patients with craniofacial pain resulted in a progressive increase in PPT over the sessions. Our study assessed the effects of PAIVM on PPT both immediately and 15 minutes after the intervention, differently from previous studies that measured only immediate effects after PAIVM.^{3,4} Our results have shown that some PPT values (eg, at T4) increased at 15 minutes of follow-up compared with the immediate point. Yet, this observed increase did not reach statistical significance.

The effects of thoracic PAIVM on skin conductance in asymptomatic participants were investigated by Slater et al⁴⁷ and Jowsey and Perry.¹⁸ Both studies demonstrated a side-specific significant increase on upper limb skin conductance. Reis et al,⁴⁸ in a sample of women with fibromyalgia undergoing thoracic PAIVM, observed no effects on the numeric pain rating scale, but noted significant improvement in heart rate variability, an autonomic nervous system mediated outcome. The results of these 3 studies reinforce the current concept that PAIVM influences sympathetic nervous system activity and that it could be a part of the descending pain modulation system.^{12,49}

To our knowledge, it is the first study to investigate the influence of different rates of thoracic mobilization on PPT. Our findings contribute to the growing interest in the mechanical parameters that form the basis of the mobilization treatment dose. Although we did not observe statistically significant differences between the different rates of thoracic PAIVM, these findings are a first step for future investigations on these parameters applied in samples with different clinical conditions.

Limitations

This trial was conducted under high methodological standards, with adequate randomization and allocation concealment procedures. Furthermore, by adopting a placebo-controlled design, we eliminated confounders related to either selection bias or unspecific effects of the intervention.⁴⁹ However, our trial had some limitations.

Caution is needed in the interpretation and generalization of the results because of the small sample of asymptomatic individuals. Nevertheless, studies in asymptomatic populations can provide important insights that warrant further investigation in different musculoskeletal conditions. In this sense, future studies assessing the effect of different rates of mobilization in symptomatic populations must be conducted to determine whether the findings of this trial can be applied to such populations. A potential problem in conducting research with patients presenting with thoracic pain is the low prevalence of this condition in clinical practice. Nevertheless, future studies should address the extent to which different mechanical properties of PAIVM can influence treatment responses in this specific population.

The thoracic PAIVM applied in our study was not joint-specific because the technique is also known for promoting movement in surrounding joints, such as the costovertebral and costotransversal joints. Although one may argue that the choice of a different PAIVM technique could have resulted in different results, based on current evidence this assertion is merely speculative and should therefore be investigated by future high-quality studies. The magnitude of the force application during the treatments and placebo was monitored in real time with a uniaxial load cell. However, it was not possible to control neither the direction of the force

applied nor the magnitude of displacement, which can vary according to characteristics of each participant, such as the stiffness of the segment being mobilized. To minimize the interference of such characteristics, we chose only to include participants with similar body mass index within a limited range of values. Finally, the expectations regarding the treatment might have influenced the results because the 3 conditions were presented as true interventions.

CONCLUSION

This study showed that neither 2 Hz nor 0.5 Hz thoracic PAIVM were able to significantly promote hypoalgesic effects compared to placebo in asymptomatic participants. Independently of the rate of mobilization, PPT did not statistically increase at local and widespread sites, neither immediately after nor 15 minutes after the intervention.

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CONTRIBUTORSHIP INFORMATION

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Practical Applications

- The rate of thoracic PAIVM is an important mechanical property regarding hypoalgesic effects in asymptomatic participants.
- Thoracic PAIVM produces local and wide-spread hypoalgesic effects compared with placebo independently of the rate of mobilization.
- Two Hz of PAIVM produced superior local hypoalgesic response compared with the 0.5 Hz of PAIVM.

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