TENS Attenuates Repetition-Induced Summation of Activity-Related Pain Following Experimentally Induced Muscle Soreness

Tsipora Mankovsky-Arnold,* Timothy H. Wideman, * Christian Larivièreme, and Michael J. L. Sullivan*

*Department of Psychology, McGill University, Montreal, Quebec, Canada.
Department of Psychology, McGill University, Montreal, Quebec, Canada. 

Abstract: This study sought to determine whether repetition-induced summation of activity-related pain (RISP) could be demonstrated in healthy individuals in response to experimentally induced musculoskeletal pain. This study also assessed the effects of transcutaneous electrical nerve stimulation on RISP. The relation between the index of RISP and psychological factors such as catastrophizing and fear of pain was also explored. The sample consisted of 56 healthy (35 women, 21 men) participants who underwent 2 testing sessions, separated by 24 hours. In the first session, musculoskeletal pain was induced with a delayed-onset muscle soreness protocol. During the second session, participants were randomly assigned to the transcutaneous electrical nerve stimulation or placebo condition and were asked to rate their pain as they lifted a series of 18 weighted canisters. An index of RISP was derived as the change in pain ratings across repeated lifts. Approximately 25% of participants showed evidence of RISP. Results also revealed that transcutaneous electrical nerve stimulation attenuated the RISP effect. Psychological measures (fear of pain, catastrophizing) were not significantly correlated with the index of RISP, but the index of RISP was significantly correlated with a measure of physical tolerance. Discussion addresses the clinical implications of the findings as well as the potential mechanisms underlying RISP.

Perspective: This study showed that RISP could be demonstrated in healthy individuals in response to experimentally induced musculoskeletal pain with delayed-onset muscle soreness. Transcutaneous electrical nerve stimulation led to a significant reduction in RISP.

Key words: Evoked pain, activity-related pain, pain summation, delayed-onset muscle soreness, transcutaneous electrical nerve stimulation.

There is increasing evidence that dynamic changes in evoked pain might represent a dimension of pain experience that is distinct, in terms of both mechanisms and prognostic value, from static measures of spontaneous pain. Individuals who show hyperalgesic responses to repeated evoked pain have lower pain thresholds, have more widespread pain, and have more severe disability. Current research and theory suggest that hyperalgesic responses to repeated evoked pain might arise as the result of dysfunction in central pain inhibitory systems. Research from our laboratory has recently described a phenomenon that has been termed “repetition-induced summation of activity-related pain” (RISP). RISP is defined as an increase in pain severity following exposure to repetitive physical activity. In one study, patients with whiplash injuries rated their pain while lifting 18 weighted canisters. An index of RISP was computed by subtracting the mean pain ratings provided for the last 3 canister lifts from the mean pain ratings provided for the first 3 canister lifts. Approximately 30% of the sample showed increases in pain severity of 2 points or greater across successive lifts of the canisters. Depending on initial pain scores, a RISP value of 2 or greater can represent an increase in pain ranging from 30 to 80%.

Received August 21, 2012; Revised July 9, 2013; Accepted July 15, 2013.
This research was supported by grants from the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST), the Fonds de recherche santé Québec (FRSQ), and the Canadian Institutes of Health Research (CIHR).
The authors have no conflicts of interest with this study.
Address reprint requests to Michael J. L. Sullivan, PhD, Department of Psychology, McGill University, 1205 Docteur Penfield, Montreal, Quebec, H3A 1B1, Canada. E-mail: Michael.Sullivan@McGill.ca
1526-5900/$36.00
© 2013 by the American Pain Society
http://dx.doi.org/10.1016/j.jpain.2013.07.019
To date, RISP has been studied in several pain populations including individuals with chronic low back pain,43 individuals with whiplash injuries,39 and individuals with fibromyalgia.44 RISP has been shown to be associated with measures of functional disability such as lifting tolerance, self-reported disability, and perceived work demands.24,39 RISP is more pronounced in individuals with long-standing chronic pain, and research has shown that RISP might be augmented by psychological variables such as pain catastrophizing or fear of movement.24,39,43

A question of interest is whether susceptibility to RISP exists prior to the onset of a persistent pain condition or whether RISP arises as a consequence of persistent pain. One approach to answering this question is to examine whether RISP can be observed in healthy individuals. However, a challenge to this approach is that the lifting task used to assess RISP does not elicit pain in healthy individuals. Physical activity is a noxious stimulus only for individuals who are already experiencing musculoskeletal pain. As such, to study RISP in healthy individuals, it was first necessary to experimentally induce musculoskeletal pain.

The first objective of the present study was to examine whether RISP could be demonstrated in healthy individuals in whom musculoskeletal pain had been experimentally induced. Musculoskeletal pain was induced with a delayed-onset muscle soreness (DOMS) protocol.40 DOMS is characterized by soreness, swelling, stiffness, and strength loss in the 24- to 48-hour period following a strenuous bout of exercise.27 The pathophysiology of DOMS has been shown to be similar to acute musculoskeletal pain. As such, to study RISP in healthy individuals, it was first necessary to experimentally induce musculoskeletal pain.

The second objective of the study was to examine whether transcutaneous electrical nerve stimulation (TENS) was effective in attenuating RISP. Reduction of RISP through TENS would suggest that TENS might be an effective intervention for individuals with clinical pain conditions who show evidence of RISP. Reduction of RISP through TENS might also suggest potential mechanisms that underlie RISP. Finally, the relation between sex and RISP was examined based on previous research demonstrating sex differences in pain summation phenomena.20

Methods

Participants

Study participants were recruited through advertisements posted on the classified ads section of the McGill University website. Screening for inclusion and exclusion criteria was conducted during an initial telephone interview. Individuals were considered for participation if they were right hand dominant, engaged in physical exercise less than once per week, and had not engaged in resistance training of the upper body musculature in the previous 6 months. Respondents were excluded if they were suffering from a pain condition or any musculoskeletal, cardiovascular, neurological, or systemic disorder that might be exacerbated by strenuous exercise (eg, recent injury, chronic pain, heart disease). Potential medical contraindications to the study’s exercise protocols were further assessed by the Physical Activity Readiness Questionnaire.44

An initial sample of 84 undergraduate students participated in the experiment. Participants were excluded if they rated their pain as 4/10 or greater in response to lifting a 2.9-kg canister prior to the DOMS protocol (n = 3). Participants who rated their pain as 4/10 or greater in response to lifting the 2.9-kg canister were considered to have a preexisting pain condition. Participants were also excluded if they had previous experience with TENS (n = 3) or if DOMS was not successfully induced (n = 22). The success of the DOMS protocol was defined as the increase in pain ratings of 2 points or greater between the lifts of a 2.9-kg canister performed at the beginning of sessions 1 and 2. The final sample analyzed consisted of 56 participants (35 women, 21 men). The mean age of the sample was 23.4 years, with a range of 18 to 41 years.

Measures

Pain Severity

Participants were asked to provide verbal ratings on the severity of their pain while lifting the weighted canisters. Pain ratings were made on an 11-point numerical rating scale with the endpoints 0 (no pain) and 10 (excruating pain).

Catastrophizing

The Pain Catastrophizing Scale (PCS)38 was used to assess catastrophic thinking related to pain. The PCS consists of 13 items describing different thoughts and feelings that individuals may experience when in pain. The PCS has been shown to have high internal consistency (coefficient alpha = .87) and to be associated with heightened pain and disability.38,41,42

Fear of Pain

The Fear of Pain Questionnaire–Short Form (FPQ-SF)6 was used to measure pain-related fears. The FPQ-SF is a 20-item self-report inventory designed to measure an individual’s fear of a variety of different stimuli that elicit pain. Research supports the internal consistency and construct validity of the FPQ-SF.6

Mean Activity-Related Pain

Participants were asked to rate their pain on an 11-point scale (0 = no pain, 10 = excruciating pain) as they lifted each of the canisters (described below). Participants’ pain ratings were averaged across lifts to yield an overall mean of activity-related pain (MARp). MARP was used as a static measure of pain and was used to determine whether RISP-related processes were distinct from those of static measures of pain.

Procedure and Apparatus

This study received ethical approval from the Faculty of Medicine’s institutional review board at McGill
University. Participants underwent 2 testing sessions, with the second session conducted 24 hours after the first. In session 1, the DOMS protocol was administered. Participants were asked not to take any pain medication between sessions 1 and 2. In session 2, RISP was assessed under TENS or placebo conditions. At the beginning of session 2, participants were assigned to the TENS (n = 26) or placebo (n = 30) conditions using simple randomization based on a computer-generated random number list.

**Session 1**

Participants were provided with a brief explanation of the study procedures and were invited to sign a consent form. Anthropometric measures were taken including height, weight, and standing elbow height (a measure used to standardize the height of the table used for procedures involving canister lifts). Participants completed the PCS, FPQ-SF, followed by the DOMS protocol (see below). Prior to the DOMS protocol, participants were asked to rate their pain (baseline pain) as they lifted a 2.9-kg canister with arm extended for 3 seconds.

**DOMS Protocol**

A BodyCraft K1 Strength Training System (BodyCraft, Sunbury, OH) was used to complete the series of 4 exercises targeting different muscle groups: 1) the chest press (targeting the pectoralis major and the serratus anterior muscles), 2) the seated row (targeting the middle trapezius and the latissimus dorsi muscles), 3) the shoulder flexion (targeting the anterior deltoid), and 4) the shoulder abduction at horizontal (targeting the upper trapezius and the middle deltoid). In order to assist the participant in performing the eccentric contraction of the target muscle only, 2 trained spotters assisted in the positioning during the concentric phase of each cycle, as well as in the removal of the load after each repetition. Guidelines for safe exercise testing were followed in accordance with published standards by the Canadian Society for Exercise Physiology. Research suggests that eccentric contractions most effectively induce DOMS. As such, participants were guided through a series of 4 different exercises requiring eccentric contractions (muscle contraction while lengthening) from specific muscle groups of the upper extremity muscles. Participants were asked to perform a maximum of 10 sets for each exercise. Each set included 5 repetitions during which participants performed an eccentric contraction of the target muscle group. Each repetition lasted approximately 10 seconds while maintaining a constant velocity. The resistance was gradually increased for each subsequent set so that participants reached their volitional maximum. The relative intensity of the final set was 80% of the predicted 1 repetition max (ie, the amount of weight the person could lift only 1 time) for each participant. Participants were encouraged to complete as many of the 10 sets as they could. The exercise was terminated either when participants indicated that their maximum effort had been reached or when they could not complete the entire set. Two-minute rest breaks were taken in between sets to avoid muscle fatigue.

**Session 2**

In both the TENS and placebo conditions, electrodes were affixed to the upper trapezius muscle of the dominant arm. A Metron Multistimulator (Patterson Medical, Bolingbrook, IL) with 2 stimtrode 50 mm × 90 mm rectangular electrodes (Cefar Medical, Lund, Sweden) was used for all participants. In the TENS condition, the unit delivered 200 μs biphasic pulses (100-μs phase duration) at a pulse frequency of 100 Hz. Pulse amplitude was adjusted to the point where participants reported that the sensation of stimulation was “strong but comfortable.” This was done to counteract the accommodation effect that normally occurs with TENS.

In the placebo condition, participants observed the device being turned on; however, a dummy wire was used so that no electrical current was delivered to the muscle sites. Participants assigned to the placebo condition were told that the wavelength and frequency of the type of TENS unit they were receiving were such that they should not perceive any sensation.

After the TENS devices were applied, participants watched a 5-minute instructional video demonstrating the proper lifting technique in order to standardize the canister lifting task instructions. Participants then proceeded to complete the canister lifting and tolerance tasks (described below) while wearing the TENS device.

**Canister Lifting Task**

The canister lifting task consisted of lifting and replacing 18 canisters (4-L-size paint canisters) that were partially filled with sand. The canisters were arranged on a table in 3 rows of 6 columns (Fig 1). The canister weights were 2.9, 3.4, or 3.9 kg and were positioned such that each weight was represented twice in each location of a double latin square.

![Figure 1. Canister positions, weights, and lift sequence used in the canister-lifting task.](image-url)
The height of the table was adjusted so that the handle of the canisters in the first row (ie, the row closest to the participant) was at standing elbow height. The top of each canister was labeled with the letters A to R, and participants were instructed to lift each can in alphabetical order. After the completion of the lifts in the first column (A–C), participants moved to the second column (D–F) and performed the lifts again, followed by the third column (G–I) until all the lifts of the 6 columns were completed. For each lift, participants were instructed to vertically lift the canister off the table to a height of approximately 5 cm.

As shown in Fig 2, the canister locations required that the participant assume 3 functional anthropometric postural positions in order to complete the task. In the normal reach position, the participant stood erect with his or her elbow bent at 90 degrees (position 1); in the maximum reach position, the participant stood erect with his or her arm fully extended (position 2); in the extreme reach condition, the participant was forward flexed with his or her arm fully extended (position 3). The task was designed to implicate the musculature targeted by the DOMS protocol. In a previous study, it was estimated that mean net moments (ie, force \times distance corresponding to the weight and body segments) was approximately equivalent across columns, varying from 17.3 to 17.9 Nm at the shoulder and from 34.0 to 35.0 Nm at the back (L4-L5 joint). The corresponding mean percentage of strength varies from 40.3 to 41.5% at the shoulder and from 20.2 to 20.7% at the back.

Lift Tolerance Task

Following completion of the canister lifting task, participants were asked to lift a 3.9-kg canister with arm fully extended for as long as possible. Previous research has shown that lifting tolerance is significantly associated with measures of pain severity, fear of movement, and self-reported disability and is often included as part of functional evaluation assessments. In the present study, lift tolerance was used as an index of functional disability consequent to RISP. A question of interest was whether the relation between RISP and functional disability that had been shown in clinical samples could be replicated in a healthy sample.

Data Analytic Approach

The canister lifting task required participants to lift 18 canisters arranged in 6 columns of 3 canisters. Each weight was represented in each column, thereby equalizing columns in terms of total physical demands of the shoulder and back. The units of analyses used were mean pain ratings computed within column. The mean of 3 pain ratings within column was used as the unit of analysis to maximize reliability. An index of RISP was derived by subtracting mean pain ratings provided while lifting canisters in the first column from mean pain ratings provided while lifting canisters in the sixth column. Higher values on the index of RISP reflect greater increase in pain across successive lifts.

Average lift duration and average duration of interlift rest periods were also computed for the first and last columns of canister lifts. A work-rest ratio was computed as the mean ratio (by column) of lift duration to rest period for each canister lift. Higher scores on this measure reflect less time for muscle recovery (relative to the work duration) and, consequently, a higher likelihood of building up muscle fatigue through the canister lifting task. The work-rest ratio served as a means to control for the potential confound of energy expenditure in the interpretation of RISP scores.

Means and standard deviations were computed for demographic and dependent measures. Separate t-tests for independent samples were used to examine group differences on demographic and dependent measures. Changes in pain ratings across columns were initially analyzed as a 3-way mixed factorial with condition (TENS, placebo) and sex as between-groups factors and column (columns 1 through 6) as the within-group factor. Analyses revealed no main effect or interactions involving sex. As such, the findings are presented collapsed across sex. For the repeated measures analyses of variance (ANOVAs), in cases where sphericity was violated, the Greenhouse–Geisser corrected F is reported.

Results

Sample Characteristics

The DOMS procedure led to a significant increase from session 1 (baseline) pain ratings (mean = 1.3, SD = 1.2) to session 2 pain ratings (assessed before the canister lifting task) (mean = 4.2, SD = 1.3), \( t(55) = -16.2, P < .001 \). MARP, RISP, fear of pain (FPQ-SF), catastrophizing (PCS), and scores on height and weight for men and women are presented in Table 1. Further, t-tests for independent samples revealed that women obtained higher scores on measures of fear of pain (t[54] = 3.0, \( P < .01 \)). Women’s scores on catastrophizing were marginally higher than men’s (t[54] = 2.1, \( P = .06 \)). Women obtained MARP scores that were significantly higher than men’s (t[54] = 5.4, \( P < .001 \)), but no significant differences were found between men and women on the index of RISP.
Distribution of Scores on the Index of RISP

Fig 3 shows the distribution of scores on the index of RISP. The mean index of RISP for the entire sample was 1.2 with a range of –1.3 to 5.6. The distribution was mildly positively skewed (.81), with the majority of participants (60%) obtaining RISP scores between 0 and 2.0. Approximately 25% of the sample obtained RISP scores equal to or greater than 2; increases in pain severity of 2 points or more are considered clinically significant.14 For some participants, this represented more than an 80% increase in pain from the first column to the last column of canisters.

Correlations Among Measures

Correlations among the 2 pain indices (ie, MARP and RISP) and the psychological variables (PCS, FPQ-SF) are presented in Table 2. Consistent with previous research, correlational analyses revealed variance overlap among measures of pain catastrophizing and fear of pain.24,39,43 The FPQ-SF was significantly correlated with MARP. MARP, the PCS, and the FPQ-SF were not significantly correlated with the index of RISP.

Repetition-Induced Summation of Activity-Related Pain

The effects of TENS on RISP scores were analyzed using 2 approaches. First, a t-test for independent samples was used to test whether overall RISP scores significantly differed between TENS and placebo conditions. Results revealed that the mean RISP score in the TENS condition (mean = .77, SD = 1.1) was significantly lower than the mean RISP score in the placebo condition (mean = 1.6, SD = 1.4), t(54) = –2.4, P < .05. A second approach was used whereby mean differences between TENS and placebo conditions were analyzed over successive columns. A 2-way (condition × column) repeated measures ANOVA on RISP scores revealed a significant main effect for column (F[Greenhouse-Geisser][2.72, 147.1] = 22.0, P < .001), and a significant condition × column interaction (F[Greenhouse-Geisser][2.72, 147.1] = 3.3, P < .05). The main effect for condition was not significant (F[1, 54] = 2.16, P = .147). The results of this analysis are presented in Fig 4. Tests of simple effects revealed that participants in the TENS condition rated their pain as significantly lower than participants in the placebo condition only for the sixth column of canisters (t[51.6] = –2.32, P < .05).

Task-Related Influences on Pain Summation: Work/Rest Ratio

In the present study, the average canister lift was 4.5 seconds (SD = 1.5), and the average rest period...
between lifts was 3.3 seconds (SD = 1.4). A work-rest ratio was computed as the mean ratio (by column) of lift duration to rest period for each canister. A 2-way (condition × column) ANOVA was conducted in order to examine whether the work-rest ratio also showed a repetition-induced summation effect and varied according to condition. The analysis revealed no significant main effect of column \( F(3.2, 167.1) = 1.52, P = .206 \) or condition \( F(1, 52) = 1.58, P = .214 \). As shown in Fig 5, there was a trend for work-rest ratios to decrease over canister lifts. The lack of significant effect rules out the possibility that variations of work-rest ratios (ie, energy expenditure) were responsible for the observed RISP effects.

**Physical Tolerance Correlates and the Index of RISP**

In the present study, lift tolerance was used as an objective measure of functional disability. Results replicated previous findings in clinical pain samples where higher RISP scores have been associated with reduced physical tolerance.\(^{29,43}\) Pearson correlation revealed a significant negative association \( r = –.317, n = 56, P < .05 \) between the index of RISP and the measure of lift tolerance, indicating that as RISP scores increased, lift tolerance decreased.

To address the possibility that reductions in lift tolerance were the result of muscle fatigue as opposed to RISP, an overall work-rest ratio was computed by averaging the overall work-rest ratio for the canister lifting trials. The correlation between the overall work-rest ratio and the index of RISP was not significant, \( r = .19, n = 56, P = .16 \). The negative association between the index of RISP and the index of lift tolerance remained significant even when controlling for the work-rest ratio.

**Discussion**

In previous research, RISP has been demonstrated in a subset of individuals with chronic low back pain, whiplash, and fibromyalgia.\(^ {24,39,43} \) Within each pain population examined, approximately 15–30% show evidence of clinically significant increases in pain in response to repeated physical activity. The findings of this study extend previous research in showing that RISP can be demonstrated in healthy participants following experimentally induced musculoskeletal pain. Approximately 25% of the study sample experienced an increase in pain of 2 points or greater from the first to the sixth column of canisters.

The findings of the present study suggest that susceptibility to RISP exists prior to the onset of persistent pain conditions. As such, the presence of RISP in individuals with persistent pain is unlikely to be the result of experiencing persistent pain. Because the proportion of healthy individuals who show evidence of RISP is comparable to that observed in individuals with persistent pain, a convincing argument cannot be made that RISP increases the risk of developing persistent pain conditions. It is possible, however, that susceptibility to RISP might contribute to adverse recovery or rehabilitation outcomes following the onset of musculoskeletal pain.

In the absence of a painful condition, movement is not a noxious stimulus. As such, susceptibility to RISP in healthy (pain free) individuals may not be associated with any adverse consequences. However, following the onset of a painful musculoskeletal condition, susceptibility to RISP may become problematic. If susceptibility to RISP is associated with heightened pain during the performance of physical tasks, the aversiveness of the pain experience might lead to progressive avoidance of activity, ultimately culminating in more severe disability. Individuals who are susceptible to RISP might also be less likely to benefit from activity-based interventions for musculoskeletal pain conditions. Clinical research suggests that a significant proportion of individuals with musculoskeletal injuries do not benefit from activity-based interventions.\(^ {5,10,29} \) Unfortunately, there has been a tendency to ascribe the failure of activity-based interventions to client factors such as poor motivation or noncompliance.\(^ {17,33} \) It is possible that susceptibility to RISP might be at the root of many rehabilitation failures for musculoskeletal injury.

There is increasing recognition that persistent musculoskeletal pain represents a heterogeneous population of pain conditions.\(^ {7} \) It is possible that RISP may constitute an important marker for a specific subgroup of chronic pain patients who may be less likely to benefit from activity-based rehabilitation strategies. High levels of RISP may be indicative of a decreased pain threshold following exercise and, hence, impact rates of compliance to medically indicated treatments. Early identification of individuals with high levels of RISP as well as interventions that directly target RISP could emerge as important components in the development of more effective pain and rehabilitation management interventions. Future research might also reveal that RISP might be a useful biobehavioral marker of improvement in individuals who have sustained musculoskeletal injury.

![Figure 5. Work-rest ratio as a function of lift repetition and condition. The values represent the mean ratio (by column) of lift duration to rest period for each canister. Higher values represent greater work output.](image-url)
In previous research, pain-related psychological variables such as fear of movement or catastrophizing have been associated with RISP. It has been suggested that pain-related psychological variables might play a causal or antecedent role in augmenting RISP. In the present study, pain-related psychological variables were not associated with RISP. The discrepancy between the pattern of findings in clinical studies and the present experimental study raises the possibility that pain-related psychological variables such as catastrophic thinking or fear of movement might be the consequence of RISP as opposed to being the cause of RISP. Individuals who experience significant increases in pain as a result of repeated physical activity might be more likely to react with alarmist or catastrophic thoughts or develop fears of engaging in physical activity.

One objective of the present study was to examine the effectiveness of TENS for reducing RISP. Half the participants in this study completed the canister lifting task while receiving high-frequency, high-intensity TENS, which is the most commonly used mode of TENS. Analyses revealed that the mean RISP score was significantly lower in the TENS condition than in the placebo condition. Tests of simple effects in the repeated measures ANOVA revealed that a significant effect of TENS was observed only during the lifting of the last 3 canisters (ie, last column). This pattern of results suggests that TENS impacted specifically on the “rise” in pain across successive lifts as opposed to the intensity of pain experienced during the lifts themselves. In other words, TENS reduced summation of pain, not simply the intensity of pain.

Results from randomized placebo-controlled trials investigating the effectiveness of TENS for the relief of chronic musculoskeletal pain have been mixed. In the present study, TENS attenuated dynamic changes in pain as measured by the index of RISP but had no effect on the static measure of pain (ie, MARP). Indeed, accumulating evidence suggests that TENS has a more pronounced effect on movement-evoked pain and results in improved function. If the effectiveness of TENS for reducing RISP can be demonstrated in a clinical population, TENS might emerge as a useful tool for facilitating participation in activity-based interventions for individuals susceptible to RISP. TENS-related reductions in pain and increased physical tolerance might ultimately contribute to better recovery and rehabilitation outcomes for individuals susceptible to RISP.

The analgesic effects of TENS have been shown to be mediated by both peripheral and central mechanisms. Peripherally, $\beta_2$-adrenergic receptors partially contribute to TENS-mediated analgesia and work synergistically when activated with opioid receptors. The antihyperalgesic effects of TENS have also been shown to activate central inhibitory mechanisms that include spinal and supraspinal structures. For example, neuropharmacological studies have shown that TENS produces opioid-mediated analgesia through activation of descending inhibitory systems from the periaqueductal gray and the rostroventromedial medulla. TENS has also been shown to influence nociceptive processing in the periphery. For example, opioid and $\delta_2$-noradrenergic receptors at the site of TENS application have been implicated in the analgesic effects of TENS. It is possible that the mechanisms responsible for the analgesic effects of TENS might be related to the mechanisms underlying RISP.

Previous research has drawn comparisons between RISP and temporal summation of pain (TS). TS has been operationally defined as the increase in self-reported pain severity in response to repeated noxious stimulation. TS has been demonstrated primarily in response to thermal stimulation, electrical stimulation, or mechanical pressure. TS and RISP have been demonstrated in clinical populations as well as healthy participants; both TS and RISP have been correlated with pain-related psychological variables (eg, catastrophizing, fear) and have been associated with impaired physical performance.

Caution must be exercised in the interpretation of the present findings. Although the DOMS paradigm offers a number of advantages in terms of experimental control, experimental control is gained at the expense of ecological validity. The pain associated with DOMS is significantly less intense and threatening than pain associated with other medical illnesses or procedures, and experimentally induced pain is not associated with the same threat value as clinical pain. Although steps were taken to increase the credibility of the placebo manipulation, there was no direct assessment of the degree to which individuals believed they were receiving either a TENS or a placebo intervention. In the present study, separate sets of instructions were used for the active TENS and placebo conditions and may have influenced participants’ expectations of treatment outcome. Interpretation of the results of the present study proceeds from the assumption that the prevalence of RISP in the placebo condition represents the natural history of RISP. It is possible, however, that the prevalence of RISP in the general population is higher than that observed in the placebo condition because of the influence of expectancy, a factor known to affect responses to placebo interventions. Finally, selection biases associated with volunteer participation in a long and physically challenging research study may have also influenced the composition of the sample.

In spite of these limitations, the results of this study indicate that RISP can be demonstrated in healthy participants following experimental induction of pain, and that high-frequency TENS can attenuate the effect. Research on RISP might reveal that a certain proportion of individuals with musculoskeletal injuries are more likely to become disabled as a result of dysfunction of peripheral or central factors that contribute to activity-related hyperalgesia. Elucidating the mechanisms underlying RISP holds promise of providing the empirical foundation for the development of...
References


29. Pape E, Hagen KB, Brox JI, Natvig B, Schirmer H: Early multidisciplinary evaluation and advice was ineffective for future research will need to clarify the precise physiological and psychological mechanisms that influence RISP.


