Published in final edited form as:

Eur J Pain. 2013 August ; 17(7): 1005–1011. doi:10.1002/j.1532-2149.2012.00264.x.

TEMPORAL SUMMATION OF HEAT PAIN MODULATED BY ISOMETRIC EXERCISE

Kelli F. Koltyn, Matthew T. Knauf, and Angelique G. Brellenthin

Department of Kinesiology, University of Wisconsin-Madison, USA

Abstract

BACKGROUND—Little is known about the effects of isometric exercise on temporal summation of heat pain. Thus, the purposes of study 1 and study 2 were to examine the influence of exhaustive and non-exhaustive isometric exercise on temporal summation of heat pain in men and women.

METHODS—Forty-four men and 44 women (mean age = 20 yrs) completed an informed consent document and a packet of questionnaires. Ten heat pulses were applied to the thenar eminence of the dominant hand using a standardized temporal summation protocol. Participants rated the intensity of the heat pulses using a 0-100 pain rating scale before and following isometric exercise consisting of squeezing a hand dynamometer at 40% of MVC to exhaustion (exhaustive exercise, study 1) and at 25% MVC for 3 minutes (non-exhaustive exercise, study 2). Muscle pain and perceived exertion (RPE) were rated every 30 seconds during exercise using validated rating scales. The data were analyzed with repeated measures ANOVA.

RESULTS—The results indicated there were no sex differences ($p > 0.05$) in time to exhaustion (study 1), muscle pain or perceived exertion (studies 1 & 2). There was a significant reduction ($p < 0.05$) in temporal summation ratings following isometric exercise for men and women in both study 1 and study 2.

CONCLUSION—It is concluded that exhaustive and non-exhaustive isometric exercise significantly reduced temporal summation of heat pain in men and women.

INTRODUCTION

There have been a number of studies conducted examining whether exercise alters pain perception, and several review articles have been published summarizing this research (O'Connor and Cook, 1999; Cook and Koltyn, 2000; Koltyn, 2000; 2002). Investigators have typically reported an attenuation of pain during and following single episodes of exercise in healthy young adults, and this phenomenon has been referred to as exercise-induced analgesia (Koltyn, 2000; 2002; Cook and Koltyn, 2000). Various modes of exercise have been used including aerobic exercise (e.g., cycling, running), resistance exercise (e.g., weight lifting), and isometric exercise (e.g., static muscular contractions). Exercise-induced analgesia has generally been characterized by elevations in pain thresholds and pain tolerances, as well as reductions in pain ratings during and following exercise.

Correspondence: Kelli F. Koltyn, Ph.D., 2000 Observatory Drive, University of Wisconsin-Madison, Madison, WI 53706-1121, Koltyn@education.wisc.edu, Telephone: (608) 262-4234, Fax: (608) 262-1656.

****Note:** All authors participated in the conduct of this research. In addition, all of the authors discussed the results and provided comments on the manuscript.

Conflicts of interest: None of the authors have any conflicts of interest

Less is known regarding the effect of exercise on temporal summation of second pain which is a dynamic psychophysical measure thought to reflect the degree of central nervous system excitability to noxious stimulation, a phenomenon referred to as central sensitization. Temporal summation is considered to be the result of C-fiber evoked responses of dorsal horn neurons (i.e., wind-up)(Staud et al., 2007) and is characterized by an increase in subjective pain ratings during application of repetitive noxious stimulation. Enhanced temporal summation is thought to be an important marker of central nervous system sensitization in the context of both chronic and acute pain (Edwards et al., 2006). However, very little research has been conducted examining the influence of exercise on temporal summation of pain. In one of the few studies conducted in this area with healthy adults, Vierck et al (2001) reported that temporal summation of thermal stimuli was reduced in a small sample of men and women following 15 minutes of aerobic exercise. Reducing temporal summation is potentially important because central sensitization is hypothesized to be involved in the progression of acute to chronic pain conditions. Subsequently, interventions which inhibit central sensitization may be helpful in the prevention of chronic musculoskeletal pain (Bishop et al., 2011). Additional research is needed examining the influence of exercise on temporal summation of pain in men and women.

Currently, it is unclear whether men and women differ in the effects of exercise on pain responses. This is in contrast to a much larger literature in the general pain area indicating that women report more clinical pain, have a higher incidence of musculoskeletal pain, and show heightened sensitivity to experimentally-induced pain compared to men (Unruh, 1996; Riley et al., 1998; Wijnhoven et al., 2006; Greenspan et al., 2007; Fillingim et al., 2009). There are, however, only a limited number of studies examining whether men and women differ in exercise-induced analgesia, and results from this small database are equivocal (Koltyn et al., 2001; Sternberg et al., 2001; Bement et al, 2008; Umdea et al., 2010). Therefore, the primary purpose of this research was to examine the influence of isometric exercise on temporal summation of heat pain in men and women.

METHODS

Two studies were conducted to examine the influence of exhaustive and non-exhaustive isometric exercise on temporal summation ratings of heat pain. Study 1 was conducted first and involved exhaustive isometric exercise (i.e., 40% MVC to exhaustion). Study 2 consisted of recruiting another sample of healthy men and women and involved non-exhaustive isometric exercise (i.e., 25% MVC for 3 minutes). These intensities of exercise were chosen based on our previous research examining different intensities and durations of isometric exercise (Koltyn et al., 2001; Umeda et al., 2010).

1.1. Participants

Healthy men and women between the ages of 18 - 40 years were recruited for this study. The participants were asked to refrain from consuming caffeine and strenuous physical activity for 4 hrs prior to participation in the study. A power analysis was performed prior to this study to estimate an optimal sample size to detect group differences in pain perception with an $\alpha = 0.05$, a power = 0.80, and a medium effect size (Cohen, 1992). Results indicated that a minimum of 15 men and 15 women would be needed for this research. The participants completed an informed consent document which had been approved by the University Human Subjects Institutional Review Board.

1.2. Procedures

Initial procedures—Participants reported to the laboratory and signed an informed consent form. Participants performed two maximal voluntary contractions (MVC) consisting

of squeezing a hand dynamometer with the dominant hand as hard as possible for 5 seconds with a 2 minute recovery between the contractions. The average of the two contractions was used to calculate the relative intensity of exercise to be performed. Participants completed a packet of questionnaires, and then were familiarized with the temporal summation of heat pain protocol which involved administration of brief, repetitive, suprathreshold heat pulses to evoke C-fiber (Type IV) pain summation. A thermode was programmed to deliver pulses that rapidly rose from an adapting temperature to a peak temperature of 51 °C at a rate of 30 °C/second, remain at this level for 0.5 seconds, and then return to baseline at a rate of 30 °C/second. Ten heat pulses were delivered to the thenar eminence of the dominant hand using a Medoc Pathway Neurosensory Analyzer (CHEPS) according to the adjusted protocol by Staud et al. (2006). Briefly, the temperature of the thermode increased during the first four stimuli from 35° C (baseline) to 45° C (peak), 36° C to 47° C, 37° C to 48° C, 38° C to 49° C, while the baseline and peak temperatures of the 6 remaining pulses were 38° C and 51° C. During exposure to the thermal stimulus, participants rated late sensations of pain (i.e., approximately 1 sec after each pulse) using a 0 - 100 pain scale. Pilot testing using this protocol revealed that the first pulse was rated as non-painful (mean rating = 10) while the last pulse in a train of 10 pulses was rated as painful (mean rating = 40) and was significantly more painful than the fifth pulse indicating that this was a sufficient protocol to evoke temporal summation of heat pain. Also, previous pilot research employing a control condition in which participants rested quietly before a second exposure to the temporal summation protocol indicated that temporal summation did not change significantly following a second exposure to the protocol after sitting quietly (see Appendix 1 for a summary of data from this previous control condition). Participants in study 1 completed one session in which familiarization to the testing procedures was done at the beginning of the session with a recovery period between familiarization to the protocol and the pre-testing. For study 2, additional funding was received thus the familiarization session and the non-exhaustive exercise session were completed on separate days. In addition, the sample size was increased and women were tested during the follicular phase of their menstrual cycle in study 2.

Experimental testing—Temporal summation of heat pain testing using the protocol described above was completed before exercise in study 1 and study 2. The exercise stimulus in study 1 consisted of squeezing a hand dynamometer with the dominant hand at 40% MVC to exhaustion, while the exercise stimulus in study 2 consisted of squeezing the hand dynamometer with the dominant hand at 25% MVC for 3 minutes. A visual feedback system was used to help participants maintain their target force and participants were verbally encouraged during exercise to maintain their designated force of contraction. In addition, participants in study 1 were encouraged to maintain their contraction for as long as possible. The criteria used to determine exhaustion in study 1 was either when the participant stopped holding the dynamometer or dropped below 25% of the target force. Every 30 seconds during isometric exercise, participants rated their perceived exertion using Borg's 6 - 20 RPE scale (Borg, 1998) and muscle pain intensity using a 0 - 10 muscle pain intensity scale developed by Cook et al. (1997). Both of these scales have been shown to be valid in assessing perceived exertion during exercise (Borg, 1998) and exercise-induced muscle pain (Cook et al., 1997). Immediately following exercise, participants were post-tested using the same temporal summation protocol.

1.3. Statistical Analyses

Thermal pain ratings were assessed in men and women after each of the 10 heat pulses during exposure to the thermal stimulus, however, it was decided a priori that 3 ratings of interest (pulses 1, 5, and 10) were to be used in the data analysis, thus the data were analyzed with 2 (sex) × 2 (trials: pre- and post-isometric exercise) × 3 (pulses: 1, 5, and 10)

repeated measures ANOVA. Ratings of perceived exertion and muscle pain were assessed every 30 seconds during exercise. For study 2, the duration of isometric exercise was 3 minutes, thus, the data were analyzed with a 2 (sex) $\times$ 6 (every 30 sec) repeated measures ANOVA. For study 1, isometric exercise was completed to exhaustion, thus, the duration of exercise was not pre-determined. Some participants held the contraction for shorter durations while others for longer durations. The data were examined to determine the time point at which the majority of participants completed the contraction. The majority of participants completed the contraction to 120 sec with a minority of participants completing the contraction to 150 sec (women = 2 men = 7). Thus, the data were analyzed with a 2 (sex) $\times$ 4 (every 30 sec) repeated measures ANOVA.

RESULTS

2.1. Study 1

The participants in this study consisted of 15 men (mean age = 21.4 yrs; sd= 2.5) and 15 women (mean age = 19.5 yrs; sd = 1.4). All of the participants were healthy, and the majority of the participants were Caucasian (90%). There was a significant difference ($p < 0.05$) in MVCs between the men (mean = 28.9 kg, sd= 5) and the women (19.9 kg, sd=5). Results, indicated that men and women did not differ significantly ($p > 0.05$) in time to exhaustion (mean for men = 136.63 sec, sd = 32 sec and women = 121.37 sec, sd = 28 sec). Also, there were no significant differences ($p > 0.05$) between men and women in muscle pain or perceived exertion (RPE) during isometric exercise performed at 40% MVC to exhaustion. The data for muscle pain and RPE during exercise for the men and women are summarized in Table 1.

2.2. Temporal Summation of Pain

Results indicated there were significant main effects for sex ($p < 0.004$), trials ($p < 0.001$), and pulses ($p < 0.001$). In addition, the trials $\times$ pulses interaction ($p < 0.001$) was found to be significant. Post hoc analyses indicated that temporal summation of pain occurred in men and women before exercise (rating for pulse 10 was significantly higher than rating for pulse 5 which was significantly higher than rating for pulse 1). In addition, temporal summation of pain was found to be higher in the women in comparison to the men, but both men and women experienced large reductions in temporal summation following exercise (Cohen's d : women = 0.77; men = 1.42). The results for temporal summation of heat pain are summarized in Figure 1.

2.3. Study 2

The participants in this study consisted of 29 men (mean age = 21 yrs, sd= 3) and 29 women (mean age = 20.7 yrs, sd = 2.5). All of the participants were healthy with the racial and ethnic composition of the sample consisting of 33 Caucasian participants (57%), 10 African American participants (17%), 8 Asian American participants (14%), 6 Latino participants (10%), and 1 American Indian participant (2%). There was a significant difference in MVCs between the men (mean = 38.3 kg, sd=10) and the women (mean = 22.4 kg, sd=6.5). The results indicated that men and women did not differ significantly ($p > 0.05$) in muscle pain or RPE during isometric exercise performed at 25% MVC for 3 minutes, and these data are summarized in Table 2.

2.4. Temporal Summation of Pain

Results indicated there were significant main effects for trials ($p < 0.001$) and pulses ($p < 0.001$), but the sex main effect was not found to be significant ($p > 0.05$). In addition, the trials $\times$ pulse interaction was found to be significant ($p < 0.001$). Post hoc analyses indicated

that temporal summation of pain occurred in men and women before exercise (rating for pulse 10 was significantly higher than rating for pulse 5 which was significantly higher than rating for pulse 1). In addition, temporal summation of heat pain was found to be significantly lower following submaximal exercise and the magnitude of change was moderate (Cohen's d : men = 0.39 and women = 0.62. The results for temporal summation of heat pain following submaximal exercise are illustrated in Figure 2.

CONCLUSIONS

The primary objective of this research was to examine the influence of isometric exercise (i.e., static handgrip contractions) on temporal summation of heat pain in men and women. Results from this research indicated that exercise-induced analgesia (EIA) occurred following both exhaustive and non-exhaustive isometric exercise. These results are in agreement with other investigators who have also found EIA to occur in healthy individuals during or following isometric exercise (Kosek and Ekholm, 1995; Kosek et al., 1996; Persson et al., 2000; Koltyn et al., 2001; Kosek and Lundberg, 2003; Staud et al., 2005; Koltyn and Umeda, 2007; Ring et al., 2008; Bement et al., 2008; Umeda et al., 2010). The results from the present study extend these findings to temporal summation of heat pain which provides information regarding central pain processing mechanisms related to central sensitization. Numerous studies have suggested that central sensitization of pain is a specific neurophysiological mechanism associated with the development and maintenance of chronic pain (George et al., 2006). Thus, interventions which inhibit central sensitization may be useful in the prevention of chronic pain (Bishop et al., 2011). Results from the current study indicated that ratings of temporal summation of heat pain were significantly reduced following short duration (i.e., 2-3 minutes) isometric exercise. These results are the first results to show that temporal summation of heat pain was reduced following exhaustive and non-exhaustive static muscle contractions. Temporal summation is considered to be the result of C-fiber evoked responses of dorsal horn neurons (i.e., wind-up)(Staud et al., 2007). The findings from the current study indicating a reduction in temporal summation of heat pain following exercise suggests a potential spinal cord-mediated mechanism of isometric exercise. Other hypothesized mechanisms suggested to be responsible for EIA include afferent inhibition, activation of conditioned pain modulation (CPM), stress-induced analgesia, and activation of endogenous opioid or non-opioid systems (Kosek et al., 2003; Fuentes et al., 2011).

Temporal summation of heat pain was found to be significantly higher in women in comparison to men in study 1. These results are in agreement with three other studies of healthy adults who found ratings of temporal summation of heat pain to be higher in women in comparison to men (Price et al., 1977; Fillingim et al., 1998; Robinson et al., 2004). In contrast, there were no sex differences in temporal summation of heat pain in study 2 which is in agreement with one other study in which there were no significant differences between men and women in temporal summation of heat pain (Staud et al., 2003). It is unclear why the results for temporal summation for the men and women differed between study 1 and study 2. The same temporal summation protocol was used in both studies, however, menstrual cycle phase was controlled in one study but not the other study. Menstrual cycle phase was not controlled in study 1 and results indicated a significant sex difference in temporal summation. In contrast, women were tested during the follicular phase of their menstrual cycle in study 2 and men and women were not found to differ in temporal summation of heat pain in this study. Previous research has demonstrated that menstrual cycle phase may affect experimental pain (Fillingim et al., 2009), but the relative impact remains under debate (Sherman & LeResche, 2006).

To date, there has not been a systematic examination of whether men and women differ in the effects of exercise on temporal summation of heat pain. Results from this study indicated that men and women did not differ in the effects of exercise on temporal summation of heat pain, with both men and women reporting significant reductions in temporal summation following exercise. Isometric exercise performed to exhaustion (i.e., 40% of maximum to exhaustion) produced large decreases while non-exhaustive isometric exercise (i.e., 25% MVC for 3 minutes) produced moderate decreases in temporal summation of heat pain in men and women. Very little research has been conducted examining sex differences in exercise-induced analgesia (EIA) which is in contrast to a much larger literature in the general pain area focused on sex differences in pain perception. Considerable evidence indicates that men and women differ in pain perception (Unruh, 1996; Riley et al., 1998; Greenspan et al., 2007; Fillingim et al., 2009), but there are only a limited number of studies that have been conducted examining whether men and women differ in EIA. Currently, the results from this small database are equivocal with two studies indicating sex differences in EIA (Sternberg et al., 2001; Koltyn et al., 2001) while results from two other studies indicated no significant difference between men and women in EIA (Bement et al., 2006; Umeda et al., 2010). It is unclear why there are conflicting results but the exercise protocols differed across studies (e.g., mode and intensities of exercise). The results from the present study extend the knowledge in this area and indicate that temporal summation of pain which reflects the degree of central nervous system excitability to noxious stimulation was reduced in both men and women following isometric exercise.

In summary, the results from this study can only be generalized to healthy young men and women. It is unclear whether these results generalize to individuals with chronic pain. Exercise training is frequently used in the rehabilitation setting as part of a pain management program, and exercise training is regarded to be an efficacious treatment for chronic muscle pain (Fuentes et al., 2011). Limited research is available, however, examining changes in pain after an immediate (i.e., acute) bout of exercise in individuals with chronic pain. There are reports that individuals with chronic pain (e.g., fibromyalgia, temporomandibular disorders) may not experience an attenuation of pain during or following an acute bout of exercise (Kosek et al., 1996; Staud et al., 2005; Mohn et al., 2008). Thus, additional research is needed in this area. Expanding our understanding of changes in pain following acute exercise may shed some light on why adherence rates to exercise programs tend to be low in chronic pain patients. It is concluded that exhaustive and non-exhaustive isometric exercise significantly reduced temporal summation of heat pain in healthy men and women.

Acknowledgments

Funding Sources:

This research was supported by NIH grant R21AR057159, 1UL1RR025011 and the UW-Madison Graduate School.

Appendix 1

Summary of Data from a Previous Control Condition (i.e., pre and post quiet rest)

<u>Temporal Summation</u>		
	<u>Pre</u>	<u>Post</u>
<u>Pulse</u>	<u>Mean (sd)</u>	<u>Mean (sd)</u>
1	14.2 (3)	14.1 (5)

Temporal Summation		
	Pre	Post
Pulse	Mean (sd)	Mean (sd)
5	30.0 (9)	29.0 (8)
10	48.1 (12)	47.0 (15)

No significant difference between pre and post tests ($p > 0.05$)

Test-retest reliability: Intraclass correlation coefficient = 0.859 ($p < 0.001$)

References

- Bement MH, Dicapo J, Rasiarmos R, Hunter SK. Dose response of isometric contractions on pain perception in healthy adults. *Med Sci Sports Exerc.* 2008; 40:1880–1889. [PubMed: 18845975]
- Bishop MD, Beneciuk JM, George SZ. Immediate reduction in temporal sensory summation after thoracic spinal manipulation. *Spine J.* 2011; 11:440–446. [PubMed: 21463970]
- Borg, G. Borg's Perceived Exertion and Pain Scales. Human Kinetics; Champaign, IL: 1998.
- Cohen JA. Power Primer. *Psychol Bull.* 1992; 112:155–159. [PubMed: 19565683]
- Cook DB, O'Connor PJ, Eubanks SA, Smith JC, Lee M. Naturally occurring muscle pain during exercise: assessment and experimental evidence. *Med Sci Sports Exerc.* 1997; 29:999–1012. [PubMed: 9268956]
- Cook DB, Koltyn KF. Pain and exercise. *Int J Sport Psychol.* 2000; 31:256–277.
- Edwards R. Pain-related catastrophizing in healthy women is associated with greater temporal summation of and reduced habituation to thermal pain. *Clin J Pain.* 2006; 22:730–737. [PubMed: 16988570]
- Fillingim RB, Maixner W, Kincaid S, Silva S. Sex differences in temporal summation but not sensory-discriminative processing of thermal pain. *Pain.* 1998; 75:121–127. [PubMed: 9539681]
- Fillingim RB, King CD, Ribeiro-Dasilva MC, Rahim-Williams B, Riley JL. Sex, gender, and pain: a review of recent clinical and experimental findings. *J Pain.* 2009; 10:447–485. [PubMed: 19411059]
- Fuentes JP, Armijo-Olivo S, Magee DJ, Gross DP. Effects of exercise therapy on endogenous pain-relieving peptides in musculoskeletal pain; a systematic review. *Clin J Pain.* 2011; 27:365–374. [PubMed: 21430521]
- George SZ, Bishop MD, Bialosky JE, Zeppier G, Robinson ME. Immediate effects of spinal manipulation on thermal pain sensitivity: an experimental study. *BMC Musculoskeletal Disord.* 2006; 7:68. [PubMed: 16911795]
- Greenspan JD, Craft RM, LeResche L, Arendt-Nielsen L, Berkley KJ, Fillingim RB, Gold MS, Holdcroft A, Lautenbacher S, Mayer EA, Mogil JS, Murphey AZ, Traub RJ, Consensus Working Group of the Sex, Gender, and Pain SIG of the IASP. Studying Sex and Gender Differences in Pain and Analgesia: A consensus report. *Pain.* 2007; 132(Suppl 1):S26–S45. [PubMed: 17964077]
- Knauf MT, Koltyn KF. Exercise induced modulation of pain. *Med Sci Sports Exerc.* 2010; 42:S5.
- Koltyn KF. Analgesia following exercise: a review. *Sports Med.* 2000; 29:85–98. [PubMed: 10701712]
- Koltyn KF, Trine MR, Stegner AJ, Tobar DA. Effect of isometric exercise on pain perception and blood pressure in men and women. *Med Sci Sports Exerc.* 2001; 33:282–290. [PubMed: 11224819]
- Koltyn KF. Exercise-induced hypoalgesia and intensity of exercise. *Sports Med.* 2002; 32:477–487. [PubMed: 12076175]
- Koltyn KF, Umeda M. Contralateral attenuation of pain after short duration submaximal isometric exercise. *J Pain.* 2007; 8:887–892. [PubMed: 17681886]
- Kosek E, Ekholm J. Modulation of pressure pain thresholds during and following isometric contraction. *Pain.* 1995; 61:481–486. [PubMed: 7478692]

- Kosek E, Ekholm J, Hansson P. Modulation of pressure pain thresholds during and following isometric contraction in patients with fibromyalgia and in healthy controls. *Pain*. 1996; 64:415–423. [PubMed: 8783304]
- Kosek E, Lundberg L. Segmental and plurisegmental modulation of pressure pain thresholds during static muscle contractions in healthy individuals. *Eur J Pain*. 2003; 7:251–258. [PubMed: 12725848]
- Mohn C, Vassend O, Knardahl S. Experimental pain sensitivity in women with temporomandibular disorders and pain-free controls: the relationship to orofacial muscular contraction and cardiovascular responses. *Clin J Pain*. 2008; 24:343–352. [PubMed: 18427233]
- O'Connor PJ, Cook DB. Exercise and pain: the neurobiology, measurement, and laboratory study of pain in relation to exercise in humans. *Exerc Sport Sci Rev*. 1999; 27:119–166. [PubMed: 10791016]
- Persson AL, Hansson GA, Kalliomaki J, Moritz U, Sjolund BH. Pressure pain thresholds and electromyographically defined muscular fatigue induced by a muscular endurance test in normal women. *Clin J Pain*. 2000; 16:155–163. [PubMed: 10870728]
- Price DD, Hu JW, Dubner R, Gracely RH. Peripheral suppression of first pain and central summation of second pain evoked by noxious heat pulses. *Pain*. 1977; 3:57–68. [PubMed: 876667]
- Riley JL 3rd, Robinson ME, Wise EA, Myers CD, Fillingim RB. Sex differences in the perception of noxious experimental stimuli: a meta-analysis. *Pain*. 1998; 74:181–187. [PubMed: 9520232]
- Ring C, Edwards L, Kavussana M. Effects of isometric exercise on pain are mediated by blood pressure. *Biol Psychol*. 2008; 78:123–128. [PubMed: 18316153]
- Robinson ME, Wise EA, Gagnon C, Fillingim RB, Price DD. Influences of gender role and anxiety on sex differences in temporal summation of pain. *Journal of Pain*. 2004; 5:77–82. [PubMed: 15042515]
- Sherman JJ, LeResche L. Does experimental pain response vary across the menstrual cycle? A methodological review. *Am J Regul Integr Comp Physiol*. 2006; 291:R245–R256.
- Staud R, Robinson ME, Vierck CJ, Price DD. Diffuse noxious inhibitory controls (DNIC) attenuate temporal summation of second pain in normal males but not in normal females or fibromyalgia patients. *Pain*. 2003; 101:167–174. [PubMed: 12507711]
- Staud R, Robinson ME, Price DD. Isometric exercise has opposite effects on central pain mechanisms in fibromyalgia patients compared to normal controls. *Pain*. 2005; 118:176–184. [PubMed: 16154700]
- Staud R, Price DD, Fillingim RB. Advanced continuous-contact heat pulse design for efficient temporal summation of second pain (windup). *J Pain*. 2006; 7:575–582. [PubMed: 16885014]
- Staud R, Crass JG, Robinson ME, Peristen WM, Price DD. Brain activity related to temporal summation of C-fiber evoked pain. *Pain*. 2007; 129:130–142. [PubMed: 17156923]
- Sternberg WF, Bokar C, Kass L, Alboyadjian A, Gracely RH. Sex-Dependent Components of the Analgesia Produced by Athletic Competition. *J Pain*. 2001; 2:65–74. [PubMed: 14622787]
- Umeda M, Newcomb LW, Ellingson LD, Koltyn KF. Examination of the dose-response relationship between pain perception and blood pressure elevations induced by isometric exercise in men and women. *Biol Psychol*. 2010; 85:90–96. [PubMed: 20594949]
- Unruh AM. Gender variations in clinical pain experience. *Pain*. 1996; 65:123–167. [PubMed: 8826503]
- Vierck CJ, Staud R, Price DD, Cannon RL, Mauderli AP, Martin D. The effect of maximal exercise on temporal summation of second pain (windup) in patients with fibromyalgia syndrome. *J Pain*. 2001; 2:334–344. [PubMed: 14622813]
- Wijnhoven HAH, deVet HCW, Picavet SJ. Prevalence of musculoskeletal disorders is systematically higher in women than in men. *Clin J Pain*. 2006; 22:717–724. [PubMed: 16988568]

Bulleted statements

What's already known about this topic?

- Pain is typically reduced following exercise, a phenomenon referred to as exercise-induced analgesia.

What does this study add?

- Exhaustive and non-exhaustive isometric exercise significantly reduced temporal summation of heat pain in men and women.

Temporal Summation of Second Pain (Study 1)

Figure 1.

Means and standard errors for temporal summation ratings before and following exhaustive isometric exercise (i.e., 40% MVC to exhaustion) for the men and women

Figure 2. Means and standard errors for temporal summation ratings before and following non-exhaustive isometric exercise (i.e., 25% MVC for 3 minutes) for the men and women

Table 1
Means and Standard Deviations for Muscle Pain Intensity Ratings and RPE During Exhaustive Isometric Exercise (Study 1)

<u>Muscle Pain Intensity</u>				
Time	Men		Women	
30 sec	2.20	(1.36)	1.50	(1.32)
60 sec	3.76	(1.95)	3.43	(2.27)
90 sec	5.46	(2.61)	5.46	(2.42)
120 sec	6.20	(2.25)	6.50	(2.07)
<u>RPE</u>				
Time	Men		Women	
30 sec	11.86	(1.59)	12.53	(1.92)
60 sec	14.73	(1.33)	14.80	(1.74)
90 sec	16.93	(1.66)	17.00	(1.96)
120 sec	17.90	(1.19)	18.16	(1.83)

Table 2
Means and Standard Deviations for Muscle Pain Intensity Ratings and RPE During Non-Exhaustive Isometric Exercise (Study 2)

<u>Muscle Pain Intensity</u>				
Time	Men		Women	
30 sec	0.97	(1.19)	0.60	(0.82)
60 sec	1.66	(1.67)	1.24	(1.12)
90 sec	2.69	(2.27)	2.02	(1.54)
120 sec	3.72	(3.24)	2.67	(1.83)
150 sec	4.40	(3.89)	3.50	(2.22)
180 sec	4.93	(3.92)	4.14	(2.46)
<u>RPE</u>				
Time	Men		Women	
30 sec	9.90	(2.47)	10.10	(2.06)
60 sec	11.52	(2.32)	11.86	(2.00)
90 sec	13.10	(2.62)	13.66	(2.04)
120 sec	14.26	(2.72)	14.97	(2.26)
150 sec	15.38	(2.73)	16.21	(2.16)
180 sec	16.28	(2.86)	16.90	(2.19)