



9-2005

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Drury, Daniel G., et al. (2005) Changes in Pain Perception in Women During and Following an Exhaustive Incremental Cycling Exercise. *Journal of Sports Science and Medicine* 4:215-222.

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Abstract

Exercise has been found to alter pain sensitivity with a hypoalgesic response (i.e., diminished sensitivity to pain) typically reported during and/or following high intensity exercise. Most of this research, however, has involved the testing of men. Thus, the purpose of the following investigation was to examine changes in pain perception in women during and following exercise. Seventeen healthy female subjects (age 20.47 ± 0.87 ; VO₂ peak 36.77 ± 4.95) volunteered to undergo pain assessment prior to, during, and after a graded exhaustive VO₂ peak cycling challenge. Heart Rate (HR) and Oxygen Uptake (VO₂) were monitored along with electro-diagnostic assessments of Pain Threshold (PT) and Pain Tolerance (PTOL) at: 1) baseline (B), 2) during exercise (i.e., 120 Watts), 3) at exhaustive intensity (VO₂ peak), and 4) 10 minutes into recovery (R). Data were analyzed using repeated measures ANOVA to determine differences across trials. Significant differences in PT and PTOL were found across trials (PT, $p = 0.0043$; PTOL $p = 0.0001$). Post hoc analyses revealed that PT were significantly elevated at VO₂ peak in comparison to B ($p = 0.007$), 120 Watts ($p = 0.0178$) and R ($p = 0.0072$). PTOL were found to be significantly elevated at 120 Watts ($p = 0.0247$), VO₂ peak ($p < 0.001$), and R ($p = 0.0001$) in comparison to B. In addition, PTOL were found to be significantly elevated at VO₂ peak in comparison to 120 Watts ($p = 0.0045$). It is concluded that exercise-induced hypoalgesia occurs in women during and following exercise, with the hypoalgesic response being most pronounced following exhaustive exercise.

Keywords

Nociception, cycling, hypoalgesia, pain tolerance threshold

Disciplines

Other Medicine and Health Sciences | Sports Sciences

Authors

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Research article

CHANGES IN PAIN PERCEPTION IN WOMEN DURING AND FOLLOWING AN EXHAUSTIVE INCREMENTAL CYCLING EXERCISE

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Received: 07 February 2005 / Accepted: 03 May 2005 / Published (online): 01 September 2005

ABSTRACT

Exercise has been found to alter pain sensitivity with a hypoalgesic response (i.e., diminished sensitivity to pain) typically reported during and/or following high intensity exercise. Most of this research, however, has involved the testing of men. Thus, the purpose of the following investigation was to examine changes in pain perception in women during and following exercise. Seventeen healthy female subjects (age 20.47 ± 0.87 ; VO_2 peak 36.77 ± 4.95) volunteered to undergo pain assessment prior to, during, and after a graded exhaustive VO_2 peak cycling challenge. Heart Rate (HR) and Oxygen Uptake (VO_2) were monitored along with electro-diagnostic assessments of Pain Threshold (PT) and Pain Tolerance (PTOL) at: 1) baseline (B), 2) during exercise (i.e., 120 Watts), 3) at exhaustive intensity (VO_2 peak), and 4) 10 minutes into recovery (R). Data were analyzed using repeated measures ANOVA to determine differences across trials. Significant differences in PT and PTOL were found across trials (PT, $p = 0.0043$; PTOL $p = 0.0001$). Post hoc analyses revealed that PT were significantly elevated at VO_2 peak in comparison to B ($p = 0.007$), 120 Watts ($p = 0.0178$) and R ($p = 0.0072$). PTOL were found to be significantly elevated at 120 Watts ($p = 0.0247$), VO_2 peak ($p < 0.001$), and R ($p = 0.0001$) in comparison to B. In addition, PTOL were found to be significantly elevated at VO_2 peak in comparison to 120 Watts ($p = 0.0045$). It is concluded that exercise-induced hypoalgesia occurs in women during and following exercise, with the hypoalgesic response being most pronounced following exhaustive exercise.

KEY WORDS: Nociception, cycling, hypoalgesia, pain tolerance threshold.

INTRODUCTION

Exercise Induced Hypoalgesia (EIH) is characterized by a temporary alteration in pain perception associated with exercise (Cook et al., 2000; Cook and Koltyn, 2000; Koltyn, 2000). Typically, investigators have found a hypoalgesic response (i.e., diminished pain sensitivity) to occur either

during and/or following exercise (Cook and Koltyn, 2000; Koltyn, 2002; O'Connor and Cook, 1999). Different aspects of pain have been examined in these studies with the majority of studies reporting increases in pain thresholds (i.e., point at which a noxious stimulus first becomes painful) during and/or following exercise (Droste et al., 1991; Kempainen et al., 1985; 1990; 1998; Pertovaara et

al., 1984). A few investigators have reported decreases in pain ratings (i.e., ratings of pain intensity) during and/or following exercise (Gurevich et al., 1994; Koltyn et al., 1996; 1998; 2001), but less is known regarding changes in pain tolerance (i.e., point at which an individual is not willing to endure further noxious stimulation) during and following exercise.

A number of different exercise protocols have been used in the studies that have been conducted in this area. Some investigators have used exercise protocols involving incremental increases in workloads (Droste et al., 1988; Kemppainen et al., 1985; 1990; 1998; Pertovaara et al., 1984) while other investigators have prescribed a specific workload to participants for the exercise session (Guieu et al., 1992; Gurevich et al., 1994). In addition, several investigators have used an exercise protocol in which participants self-selected the exercise intensity (Fuller and Robinson, 1993; Janal et al., 1984; Sternberg et al., 2001). Inconsistent results have been found for studies that let participants self-select the exercise intensity. More consistent EIH responses have been found for studies that used a protocol involving exercise prescribed at a percentage of maximal oxygen uptake (e.g., 60-75%). In addition, exercise protocols involving incremental increases in workloads to exhaustion have consistently revealed EIH to occur at the higher workloads, with the exception of an increase in pain thresholds at a lower workload (e.g., 100 W) in a study by Kemppainen et al. (1990).

Most of this research, however, has involved the testing of men so it is currently unclear whether these results can be generalized to women. The general pain literature suggests that men and women differ in pain perception (Craft, 2003), but very little research has been conducted examining EIH in women (Koltyn et al., 2001; Sternberg et al. 2001). Further research is needed in this area. Therefore, the primary purpose of the following investigation was to examine changes in pain perception among women during and following exercise.

METHODS

Seventeen division III varsity female athletes (7 Basketball, 5 Soccer, 3 Volleyball, 1 Softball, 1 Field Hockey) were recruited to participate in this investigation. All of the women were screened using a healthy history questionnaire and reported being in good health and free from injury. In addition, all of the women indicated that they had not taken any prescription or over the counter medications in the past 48 hours. Prior to data collection, each woman completed a document of informed consent and

received a comprehensive verbal description of all the procedures along with an opportunity to ask questions. The research protocol and all associated documents were reviewed and approved by the Gettysburg College Institutional Review Board for the ethical treatment of human subjects.

Data collection began with anthropometric measurements of height, weight and body composition. Height and weight were measured using a balance beam scale (Detecto, Webb City, MO) and were recorded in centimeters and kilograms respectively. Body composition was estimated using Lange skin-fold calipers (Beta Technology Corp., Cambridge, MD) and a three-site formula (triceps, thigh and supraillium) previously described by Jackson and Pollock (1985). To avoid the hormonal variations associated with the menstrual cycle, we only tested our subjects between the 5th and 14th day after the onset of their last menses. A heart rate monitor (Polar US, Lake Success, NY) with conduction gel was adjusted, fitted and then strapped around the subject. The seat post of the stationary cycle (Monark, Sweden) was then adjusted so that each woman had a 5 degree bend at the knee during the bottom phase of the pedal stroke.

Once the woman was sitting comfortably on the cycle ergometer, she was then fitted with a neoprene face-mask that held the breath by breath neumotac apparatus which was connected to the metabolic cart (Medgraphics, St. Paul, MN). Sampling was reported in 30 sec intervals throughout the duration of the test and a time-down report of oxygen uptake and heart rate was printed after each test. A standard mercury sphygmomanometer was used to monitor blood pressure and a telemetry sensor from the metabolic cart was attached to the cycle to detect signals from the heart rate monitor.

The subject was then prepped for a neuroselective electrodiagnostic sensory nerve evaluation using a Neurometer® (Neurotron, Baltimore, MD) to assess pain perception. This machine has been used widely since 1986 for the assessment of nociceptive nerve function in a variety of populations (Katims, 1998; Raj et al., 2001). The device delivers an atraumatic electrical stimulus to a set of gold-plated electrodes (Raj et al., 2001). The stimulus created is delivered directly to the nerve fiber bypassing the nerves end-organs and it is not influenced by skin thickness, subcutaneous fat or temperature (Katims, 1998). The reliability and validity of this machine has been described elsewhere (Katims, 1998). For this investigation, we chose the median nerve of the right index finger as the site for assessment. The index finger was chosen because it was away from the active tissue of the

legs. In so doing, we have attempted to minimize the potential for simultaneous afferent impulses being received at the spinal cord, thus limiting the potential influence for gate-control differences. An example of the electrodiagnostic pain assessment site can be found in Figure 1.

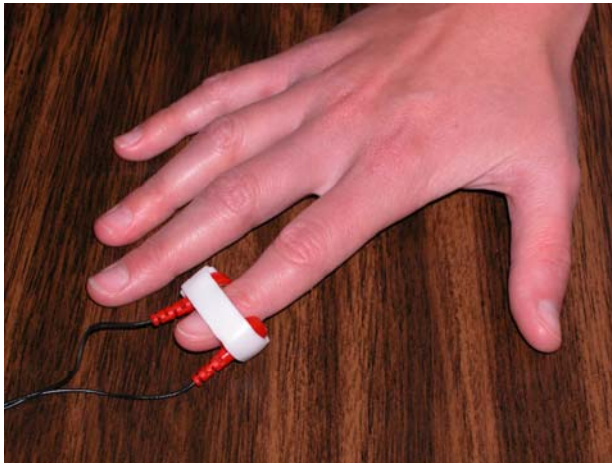


Figure 1. Electrodiagnostic pain set-up.

The protocol used in this study for inducing a quantifiable controlled pain stimulus incorporated a sinusoidal continuous electrical stimulus at 5 Hz which typically stimulates the small diameter unmyelinated nociceptive 'C' fibers associated with 'slow-pain' (Katims, 1998). The stimulus increased in intensity every second by 10 mA until the woman could no longer tolerate the pain. Therefore, the duration of the pain stimulus was determined by the time it took to reach pain tolerance, which was typically less than 1 minute.

Two separate pain perception variables were measured during each pain assessment. Pain Threshold (PT) was recorded when the tingling current first became painful. A verbal command of 'Pain' was used by the subject to indicate when PT was achieved. Pain Tolerance (PTOL) was recorded by the assessment device when the subject could no longer tolerate the painful current and the test was stopped. A verbal command of 'Stop' was used to tell the researcher to terminate the test.

After the initial prepping procedures, a familiarization pain test was given to allow the subject to experience the unique electrical transcutaneous pain stimulus. This initial test also allowed the subject to become comfortable with the verbal commands associated with indicating each type of pain. Familiarization testing has been used extensively when inducing electrical transcutaneous pain (Katims, 1998). During the pain testing procedure the subjects rested their hands on the handle bars of the cycle ergometer. In between pain assessments the women were allowed to grasp the handlebars with both hands. A ten-minute rest period was given after the familiarization pain test.

Data collection began after 10 minutes of quiet rest by obtaining baseline measures of PT, PTOL, relative oxygen consumption, heart rate and blood pressure. The metabolic cart collected data continuously until the end of the protocol. Once the baseline data was recorded, the subject was asked to warm-up by pedaling the cycle ergometer at 60 rpm's at a resistance of 30 Watts for 4 minutes. After the fourth minute the resistance was increased by 30 Watts every minute until the subject reached 120 Watts. After a full minute of pedaling at this resistance, a second set of cardiovascular and pain assessments were obtained while the subject continued to pedal in order to examine changes in pain perception during exercise. A resistance of 120 Watts was chosen in an effort to provide a 'moderately difficult' cardiovascular challenge that has been previously demonstrated in active females (Lee and Nieman, 1990).

After the assessment at 120 Watts, the resistance was increased again by 30 Watts every minute until the subject could no longer maintain 60 rpm's or they verbally indicated volitional failure (VO_2 peak). Ratings of Perceived Exertion (RPE) scores (1-10) (Pollock et al., 1998) were obtained every minute throughout the exercise protocol to help the investigators anticipate the achievement of VO_2 peak. Immediately after the VO_2 peak was achieved, another set of cardiovascular and pain measures were taken while the subject continued to pedal at 60 RPM's with little resistance (30 Watts). After the final exercise assessments were recorded, the subject was asked to sit on the cycle without pedaling for a ten-minute recovery period, which concluded with a final set of cardiovascular and pain assessments.

Data analyses

The PT and PTOL data were individually normalized by dividing the raw scores for each subject by their own respective baseline scores taken prior to exercise. This method of normalizing electrical pain stimulus data has been used by others studying EIH (Droste, 1992; Kemppainen et al., 1990; Kosek and Ekholm, 1995). The data were then analyzed using repeated measures ANOVA to determine differences. When differences were indicated, a *Fisher Protected Least Significant Difference* post hoc analysis was used to determine differences among the variables. An a priori p-value of 0.05 was considered statistically significant. Post hoc power analysis for the main effects was performed for PT and PTOL and revealed a power of 0.82 for PT and 0.99 for PTOL, respectively, given 4 measurements with a sample size of 17 subjects and an alpha of 0.05.

Table 1. Means (\pm SD) for the cardiovascular data at rest, 120 Watts, VO₂ peak, and recovery.

Workload	Variables	Means (\pm SD)
<i>Rest</i>	Heart Rate (bpm)	73 (10)
	Systolic Blood Pressure (mmHg)	112 (11)
	Diastolic Pressure (mmHg)	75 (9)
<i>120Watts</i>	VO ₂ (ml·kg ⁻¹ ·min ⁻¹)	27.33 (3.66)
	Heart Rate (bpm)	152 (12)
	Systolic Blood Pressure (mmHg)	150 (13)
<i>VO₂ peak</i>	Diastolic Pressure (mmHg)	68 (33)
	VO ₂ (ml·kg ⁻¹ ·min ⁻¹)	36.77 (4.95)
	Heart Rate (bpm)	179 (10)
<i>Recovery</i>	Systolic Blood Pressure (mmHg)	156 (17)
	Diastolic Pressure (mmHg)	59 (24)
	Heart Rate (bpm)	95 (10)
	Systolic Blood Pressure (mmHg)	116 (14)
	Diastolic Pressure (mmHg)	72 (9)

RESULTS

Reliability of pain responses

Data from the familiarization pain test were compared to baseline data to examine whether alterations in pain perception occurred as a result of pre-test exposure to the noxious electrical stimulus. Because these two tests were conducted under the same conditions in an effort to establish a valid baseline score, the normalization process was not used in this analysis. When the Raw PT pain scores from the familiarization test (198 ± 73) were compared to Raw baseline scores (207 ± 90) with a repeated measures ANOVA there were no significant differences between the trials for PT ($p = 0.732$). When the Raw PTOL pain scores from the familiarization test (428 ± 221) were compared to Raw baseline scores (431 ± 261) with a repeated measures ANOVA there were no significant differences between the trials for PTOL ($p = 0.963$). Intra-class correlations between the familiarization and baseline scores were significant for both PT ($r = 0.737$; $p = 0.001$) and PTOL ($r = 0.963$; $p = 0.001$). Thus, it appeared that pre-test exposure to the noxious electrical stimulus did not significantly influence the subsequent pain perception assessment.

Descriptive data

The mean age of the subjects was 20.5 ± 0.9 years, height 1.69 ± 0.08 m, weight 67.4 ± 9.0 kg, body fat % 29.8 ± 2.0 . Descriptive data for the cardiovascular

measurements of heart rate, oxygen uptake, systolic pressure and diastolic pressure can be found in Table 1.

Pain threshold

Significant differences in pain thresholds were detected across trials ($F_{1,14} = 5.077$; $p = 0.0043$). Post hoc analysis revealed PT scores were significantly higher at VO₂ peak in comparison to baseline (Table 2). The VO₂ peak scores were also significantly higher than both the 120 Watts scores ($p = 0.0178$) and the recovery scores ($p = 0.0072$). No significant differences were found between baseline and 120 Watts ($p = 0.2577$), baseline and recovery ($p = 0.498$) and 120 Watts and recovery ($p = 0.6727$). Of the 17 subjects tested none of the subjects had a higher PT score at 120 Watts versus VO₂ peak and only 3 subjects had a higher score during recovery. The results for pain thresholds are illustrated in Figure 2. In addition, a correlation analysis was performed to examine the association between Systolic Blood Pressure (SBP) and PT. Results indicated there was not a significant correlation between SBP and PT ($r = 0.03$).

Pain tolerance

Significant differences in pain tolerance were detected across trials ($F_{1,14} = 9.387$; $p < 0.0001$). Post hoc analysis revealed that PTOL scores were significantly higher at 120 Watts ($p = 0.0247$), VO₂ peak ($p < 0.001$), and recovery ($p = 0.0001$) in comparison to baseline. PTOL scores were also

Table 2. Means (\pm SD) for pain threshold and pain tolerance scores.

	Baseline (1)	120Watts (2)	VO ₂ peak (3)	Recovery (4)
<i>Pain Threshold</i>	100 (0) ³	109.6 (27.1) ³	124.7 (25.5) ^{1,2,4}	105.1 (21.8) ³
<i>Pain Tolerance</i>	100 (0) ^{2,3,4}	116.3 (16.0) ^{1,3}	133.6 (19.4) ^{1,2}	127.2 (29.3) ¹

Superscripts indicate $p < 0.05$ among the workloads.

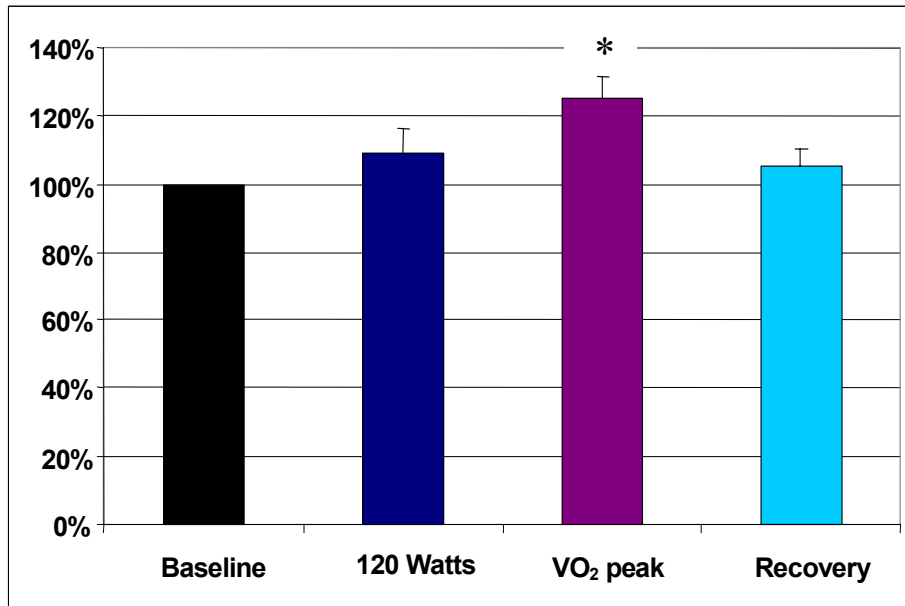


Figure 2. Normalized pain threshold scores and Standard Errors for Baseline, 120 Watts, VO₂ peak and Recovery (scores are expressed as a % of Baseline). * $p < 0.05$ compared with Baseline, 120 Watts and Recovery.

found to be significantly higher at VO₂ peak in comparison to 120 Watts ($p = 0.0045$). Of the 17 subjects tested only 1 subject (5.8%) had a higher score at 120 Watts versus VO₂ peak. Although approaching statistical significance, no difference was found between 120 Watts and recovery scores ($p = 0.0679$). In addition, a correlation analysis was performed to examine the association between Systolic Blood Pressure (SBP) and PTOL. Results indicated there was not a significant correlation between SBP and PT ($r = 0.30$). Finally, no significant differences were found between VO₂

peak scores and recovery scores ($p = 0.3098$). The results for pain tolerances are illustrated in Figure 3.

DISCUSSION

The primary purpose of this investigation was to examine changes in pain perception in women during and following exercise. Results from this study indicated that EIH occurred in women during and following exercise, with the hypoalgesic response being most pronounced during exhaustive exercise. These results are in agreement with results

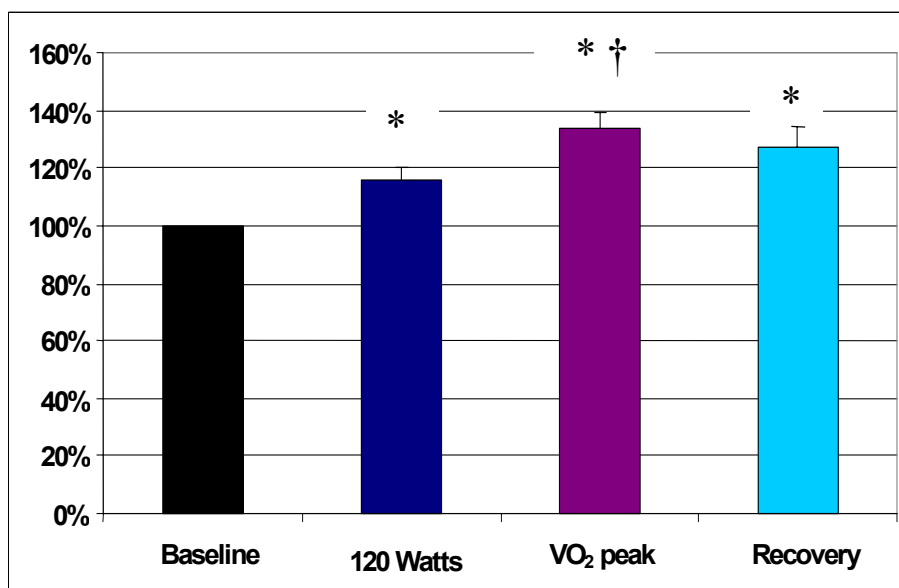


Figure 3. Normalized pain tolerance scores and Standard Errors for Baseline, 120 Watts, VO₂ peak and Recovery (scores are expressed as a % of Baseline). * $p < 0.05$ compared with Baseline, † $p < 0.05$ compared with 120 Watts.

from other investigations in which men were tested using protocols involving incremental increases in workloads (Droste et al., 1991; Kemppainen et al., 1985; 1990; 1998; Pertovaara et al., 1984). In addition, the results from this study add to the small literature on EIH in women (Sternberg et al., 2001; Koltyn et al., 2001). Specifically, results from the present study indicated that pain thresholds and pain tolerances were significantly elevated at VO_2 peak. In addition, pain tolerances were found to be elevated during exercise (120 Watts), as well as 10 minutes following exercise.

The mechanisms responsible for EIH are poorly understood. Several researchers have hypothesized that proprioceptive and muscle afferents may be responsible for 'overloading' the nociceptive circuitry causing hypoalgesia (Hoffman et al., 2004; O'Connor and Cook, 1999). This hypothesis is related to the gate-control theory wherein the nervous system may prioritize the large diameter, fast-propagating fibers that are responsible for tactile and proprioceptive afferent input over the smaller unmyelinated nociceptors (Porth, 2004). One of the unique aspects of the current investigation is that small unmyelinated nociceptors were stimulated by providing a painful stimulus at a frequency of 5 hz which has been shown to be specific to 'C' pain fibers (Katims, 1998; O'Connor and Cook, 1999). The fact that pain differences emerged while using an inactive testing site, provides further evidence that central mechanisms may play a role in EIH.

Another possibility that has received some attention in the literature is that alterations in blood pressure (BP) associated with exercise may be related to alterations in pain perception. It has been reported that there is an interaction between pain modulatory and cardiovascular systems (Randich and Maixner, 1984). Examination of BP in the present study indicated that SBP was the highest when pain thresholds and pain tolerances were the highest, however, correlations between SBP and pain threshold and SBP and pain tolerance were not found to be significant. It is unclear why there was not a significant association between BP and pain perception in this study, but sample size may have been limited to detect significant associations between BP and pain perception. The sample size was determined based on the primary purpose of this study, which was to examine EIH in women, however, this sample size may have been too small to detect significant associations between BP and pain perception. Further research is needed to clarify the relationship between BP and pain perception in women.

CONCLUSIONS

Results from this study indicated that exercise can temporarily reduce pain in women but this finding can only be generalized to the sample that was tested in this study (i.e., female athletes with average aerobic capacity). It is currently unclear whether these results generalize to athletes with a higher aerobic capacity or to non-athletes. Also, since the women tested in this study were healthy individuals with no reported chronic pain, it is unclear whether these results generalize to women experiencing various chronic pain conditions (e.g., arthritis, fibromyalgia, low back pain). It is conceivable that high intensity exercise may exacerbate an already existing painful condition, thus, further research is warranted to examine the impact of exercise on pain in women with existing chronic pain.

ACKNOWLEDGEMENTS

This project was funded by a Presidential Research Fellowship from Gettysburg College. We would like to thank the Provost's Office at Gettysburg College for their ongoing support. We would also like to thank Mr. David Petrie for his help during the data collection process.

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Degree

PhD

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Exercise Induced Hypoalgesia

KEY POINTS

- Exercise-induced hypoalgesia (i.e., elevated PT and PTOL) was found to occur in women during and following exercise, with the hypoalgesic response being most pronounced during exhaustive exercise.

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