

## Experimentally induced pain perception is acutely reduced by aerobic exercise in people with chronic low back pain

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**Abstract**—This study examined whether subjects with chronic low back pain demonstrate exercise-induced analgesia to experimentally induced pressure pain. We employed a repeated measures design to study eight subjects with chronic low back pain (mean  $\pm$  standard deviation age = 40  $\pm$  10, duration of pain = 7  $\pm$  4 years). Pain ratings were measured immediately before and 2 minutes and 32 minutes after 25 minutes of cycle ergometry (5 minutes at 50% peak oxygen uptake, then 20 minutes at 70% peak oxygen uptake). We based the pain ratings on subject input on a visual analog scale at 10-second intervals during the 2-minute pressure pain stimulus to the non-dominant index finger. Compared with preexercise values, pain ratings were significantly ( $p < 0.05$ ) decreased after exercise at both 2 and 32 minutes postexercise. We conclude that pressure pain perception can be reduced for more than 30 minutes following aerobic exercise from leg cycling among people with chronic low back pain.

**Key words:** aerobic exercise, analgesia test, back pain, cycle ergometer, exercise analgesia, nociception test, pain, pain assessment, pain measurement, pain threshold, pain tolerance, physical activity, visual analog pain scale.

### INTRODUCTION

The results of several studies suggest that chronic pain may alter pain perception. However, it is not clear

whether the presence of chronic pain results in an increase or a decrease in the response to an experimentally induced painful stimulus. Of those studies of patients with chronic low back pain, all found the patients to have higher pain thresholds than control subjects to a heat stimulus [1–3]. In contrast, patients with fibromyalgia syndrome were found to have lower pain thresholds to heat than healthy subjects [4]. Furthermore, other studies among patients with fibromyalgia syndrome [4–11], myofascial pain syndrome [12–13], complex regional pain syndrome, and various other chronic pain syndromes [7,14–15] have found these groups to have lower

**Abbreviations:** ANOVA = analysis of variance, SD = standard deviation,  $\dot{V}O_2$  = oxygen uptake.

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pain thresholds or tolerance to a variety of painful stimuli when compared with control subjects. It is not clear if the divergent findings for patients with chronic low back pain compared with patients with other sources of chronic pain are due to variances among patient populations, types of experimental noxious stimuli, and/or experimental designs. Additional studies of patients with chronic low back pain are needed to further examine these differences.

Researchers have found evidence that aerobic exercise causes an acute analgesic effect in healthy subjects [16–17]. Our recent work has suggested that such reductions in pain perception can last for nearly 30 minutes after subjects have exercised at intensities of more than 50 percent of maximal oxygen uptake for more than 10 minutes [16]. However, no previous study has examined the acute effect of exercise on pain perception among subjects with chronic pain.

This study determined whether a single exercise bout would alter the perception of experimentally induced pressure pain in individuals with chronic low back pain. We hypothesized that pain perception after exercise would be decreased for individuals with chronic low back pain in a similar manner as has been previously demonstrated in normal healthy individuals. This study also compared pressure pain perception between normal healthy individuals and subjects with chronic low back pain. We hypothesized that we would find a lower baseline perception of pressure pain among the chronic low back pain subjects compared with healthy subjects.

## METHODS

### Subjects

Eight individuals (four male and four female) with chronic low back pain participated in the study. The **Table** displays selected characteristics of the subjects. Criteria for participation in the study included the presence of back pain for at least 1 year and clinical evidence that the etiology of the back pain was stable and non-neurological. Exclusion criteria included the use of narcotic analgesics, inability to walk without an assistive device, evidence of sacroiliac joint dysfunction as the primary etiology for symptoms, current involvement in a regular exercise or physical therapy program, major surgery within the past year, history of spondyloarthropathy, and presence of spinal infection, fracture, spondylolisthe-

sis, or malignancy. Individuals with known cardiac, pulmonary, or metabolic disorders; diseases affecting sensory nerves; musculoskeletal disorders preventing safe participation in exercise; and pregnancy were also excluded. In effect, the chronic low back pain subject group was composed primarily of individuals with muscular and/or degenerative disk etiologies of pain. Their mean  $\pm$  standard deviation (SD) Oswestry disability index score was  $23 \pm 16$  percent. The Oswestry disability index score was developed to represent a percentage of limitation in function compared with that of a healthy person [18]. Scores of 0 to 20 percent are considered “minimal disability,” 20 to 40 percent represent “moderate disability,” 40 to 60 percent represent “severe disability,” 60 to 80 percent indicate “back pain impinges on all aspects of these patients’ lives,” and scores of 80 to 100 percent indicate patients who “are either bed-bound or exaggerating their symptoms” [18].

Therefore, the present subjects had a minimal to moderate level of disability. Furthermore, the conditions responsible for their pain were chronic as demonstrated by their reported mean  $\pm$  SD duration of  $7 \pm 4$  years of low back pain.

A separate group of 10 subjects (7 male and 3 female, age =  $34 \pm 8$  [mean  $\pm$  SD]) also participated in the study. Each of these subjects was healthy and free of any chronic pain or metabolic disease and had not previously participated in pain testing studies. Selected characteristics of these subjects are also displayed in the **Table**.

We provided all subjects general information about the intent of the study, but did not discuss the hypothesized results prior to completion of their participation in the testing. The institutional review board approved the study procedures, and informed consent was obtained from each subject prior to participation. We provided a

**Table.**

Selected characteristics (mean  $\pm$  SD) of subjects.

Characteristic	Low Back Pain	Reproducibility
	Subjects	Subjects
Age (yr)	40 $\pm$ 10	34 $\pm$ 8
Height (cm)	172 $\pm$ 12	176 $\pm$ 12
Mass (kg)	83.0 $\pm$ 17.4	83.5 $\pm$ 18.7
Peak $\dot{V}O_2$ (mL/kg/min)	19.4 $\pm$ 5.1	—
Duration of Back Pain (yr)	7 $\pm$ 4	—
Oswestry Disability Index Score (%)	23 $\pm$ 16	—
$\dot{V}O_2$ = oxygen uptake      SD = standard deviation		

small stipend to the chronic low back pain subjects for participation in the studies.

### Experimental Design

The 10 healthy subjects visited the laboratory on two occasions separated by 3 to 9 days. Each visit was approximately the same time of day. On each visit, the subjects performed the pressure pain test three times with intervals of 28 minutes of rest separating each test. The first visit familiarized the subjects with the testing methods. We examined data from the second test day for reproducibility of the three trials and for comparison with the preexercise results from the chronic low back pain subjects.

The eight subjects with chronic low back pain visited the laboratory on two separate occasions, approximately the same time of day, separated by 2 to 9 days. On the first visit, all subjects underwent a pressure pain test, after which they completed the Oswestry low back pain disability questionnaire [18]. Approximately 30 minutes after the first pressure pain test, we performed a second pressure pain test. Each subject then performed a maximal exercise test (described in the Exercise Testing section). Following each subject's completion of the exercise test, we administered a third pressure pain test. As we did with the healthy subjects, we administered the pain tests on the first visit to the laboratory to familiarize the chronic low back pain subjects with the testing methods.

On the second visit to the laboratory, each chronic low back pain subject first performed a pressure pain test. After completion of the pressure pain test, the subject moved to the cycle ergometer and began cycling 1 minute after the pain test had ended. Cycling was initiated at the workload that generated 50 percent of peak oxygen uptake ( $\dot{V}O_2$ ). After subjects exercised 5 minutes at this workload, we increased the intensity to a level that generated 70 percent of peak  $\dot{V}O_2$ , and it was continued for 20 minutes. Immediately after completion of the cycling, the subjects repositioned themselves for a second pressure pain test that was initiated 2 minutes after cycling ended. Following this pain test, the subjects rested quietly until we administered a third pain test, 28 minutes after completion of the second pain test (32 minutes postexercise). Thus, the time between each of the three pain tests was 28 minutes, and the subjects performed 25 minutes of cycling between the first and second pain tests. Laboratory temperature was maintained at approximately 19 °C during all testing.

### Pressure Pain Testing

The pressure pain stimulator used to induce the painful stimulus is similar to that previously used by others [17,19–20] and is the same device used in our previous work [16]. The device consists of a Lucite edge measuring 6.00 mm × 0.25 mm, through which we applied a constant force of 9.8 N against the dorsal surface of the middle phalanx of the nondominant index finger, halfway between the distal and proximal interphalangeal joints.

Prior to each pain test, the subjects listened to a recorded message reviewing the procedures. Each pain stimulus lasted 2 minutes. At 10-second intervals, the subjects indicated the level of perceived pain by marking a 100 mm visual analog scale stretching from “no pain” to “worst possible pain.” During testing, subjects remained seated comfortably with their arms supported on a table. We have recently reported good reproducibility of these techniques with repeat testing at a 15-minute interval as well as across days [16].

### Exercise Testing

During the first visit to the laboratory, each chronic low back pain subject underwent a maximal exercise test on a cycle ergometer (Cateye Ergociser, model EC-1600, Osaka, Japan). The test involved a graded continuous protocol with 2-minute stages. The protocol began at 25 W, then increased to 50 W, and subsequently increased at 50 W increments. Exercise was continued until the subject was unable to continue to produce the desired workload.

We measured  $\dot{V}O_2$  continuously by open-circuit spirometry using a mask (Hans Rudolph, Inc., 7200 Wyandotte Street, Kansas City, Missouri 64114) and a system (Vacu-Med, Vista Mini CPX, 4538 Westinghouse Street, Ventura, California 93003) that is computer-integrated with electronic analyzers for measurement of oxygen and carbon dioxide concentrations in the expiratory gases, and a turbine flow meter for measurement of expiratory volumes. We calibrated the gas analyzers immediately before each test.

We used submaximal exercise intensities estimated to induce 50 and 70 percent of peak  $\dot{V}O_2$  during the second test day for the chronic low back pain subjects. We determined the desired workloads from plots of  $\dot{V}O_2$  versus workload data from the maximal exercise test. Since the ergometer provided a constant workload through adjustment of resistance dependent on pedaling frequency, subjects were allowed to assume a comfortable pedaling frequency during all exercise.

### Statistical Analysis

We converted each mark on the visual analog scale to a numeric value by measuring the distance in millimeters between the mark and the left side of the scale. Given that the pain ratings were relatively stable during the last minute of the pain test, we averaged these six data points to yield a single value for that trial.

We compared the chronic low back pain subjects' pain ratings, before and after exercise, across time using a one-way repeated measures analysis of variance (ANOVA). Pain ratings from the second day of tests on the healthy subjects participating in the reproducibility study were also compared across trials with a one-way ANOVA. Finally, subject characteristics and the pain ratings from the first trial of the second day of tests for the two subject groups were compared with unpaired two-tailed *t*-tests.

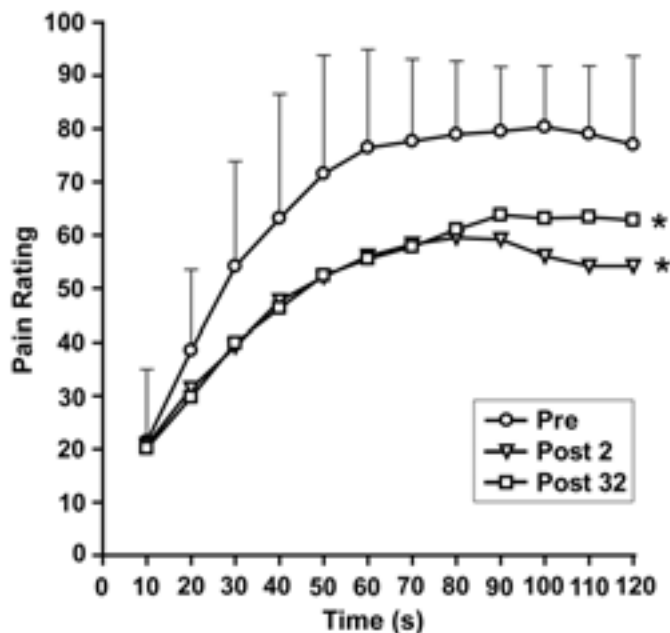
Significant *F*-values from the ANOVA tests were followed by a Newman-Keuls post hoc analysis. We set a probability value of 0.05 as the level of statistical significance.

### RESULTS

Among the chronic low back pain group, pain ratings at both 2 minutes and 32 minutes postexercise were lower ( $p < 0.05$ ) than preexercise values (**Figure 1**). The mean  $\pm$  SD preexercise value of 79 mm  $\pm$  12 mm was reduced to 57 mm  $\pm$  26 mm (28% reduction) and 62 mm  $\pm$  27 mm (22% reduction) at 2 and 32 minutes postexercise, respectively.

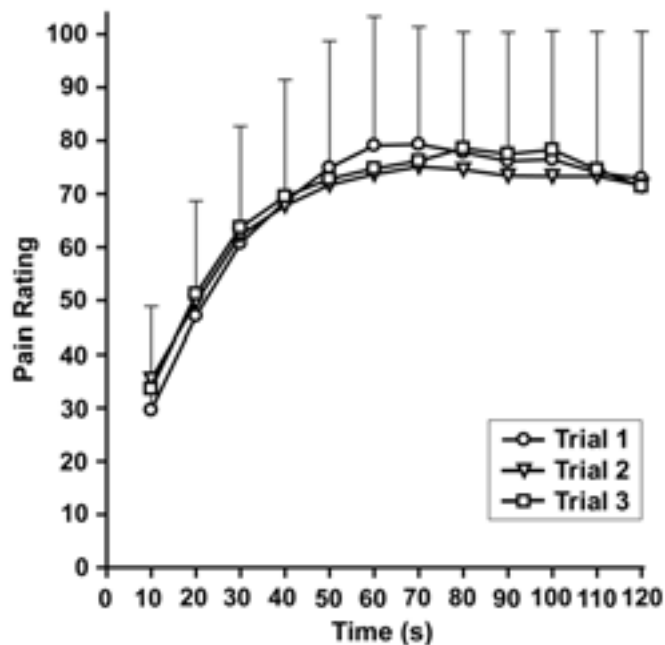
The reproducibility testing on the healthy subjects revealed no alterations in pain ratings across the three trials (**Figure 2**). Mean  $\pm$  SD pain ratings averaged over the last minute of each trial were 76 mm  $\pm$  24 mm, 74 mm  $\pm$  19 mm, and 76 mm  $\pm$  17 mm.

We found no statistical difference in age, height, and weight between the chronic low back pain group and the healthy subjects. Mean  $\pm$  SD pain ratings for the first trial of the second test day were no different between the two subject groups (79 mm  $\pm$  12 mm for the chronic low back pain subjects compared with 76 mm  $\pm$  24 mm for the healthy subjects).



**Figure 1.**

Mean pain ratings for chronic low back pain subjects before (pre) and 2 minutes (post 2) and 32 minutes (post 32) following exercise. \*Pain ratings averaged over last minute of test were significantly different ( $p < 0.05$ ) than preexercise test. Error bars represent 1 standard deviation and are only displayed for first trial for clarity.



**Figure 2.**

Results of reproducibility study. No differences were found in pain ratings across three tests, which were each separated by 28 minutes of rest. Error bars represent 1 standard deviation and are only displayed for first trial for clarity.

## DISCUSSION

The findings from this study support our hypothesis that pain ratings from an experimentally induced pressure pain stimulus may be reduced after aerobic exercise in people with minimal to moderate disability from chronic low back pain, just as we observed in healthy individuals [16]. We anticipated this finding, since we specifically used an exercise intensity and duration within the range used by previous studies that have demonstrated the presence of exercise-induced analgesia to a pressure pain stimulus [16–17].

The phenomenon of exercise-induced analgesia has potential clinical relevance for individuals with pain. This present study demonstrates that subjects perceived a painful local stimulus to be less painful after exercise. That the painful stimulus was distant from the exercising muscles suggests that the mechanism for the observed exercise-induced analgesia relates to a systemic process. Therefore, the perception of pain arising from the chronic pain source could also be favorably influenced, at least transiently, by exercise. Perhaps this phenomenon at least partially accounts for some of the improvements in disability and pain scores that have been demonstrated from exercise programs in patients with chronic low back pain [21–23].

We chose cycle ergometry as the exercise mode in this study because we felt that this form of exercise would be less likely to aggravate back pain than other modes of exercise, such as walking or running. It is unknown if an analgesic effect would be elicited from a form of exercise that is painful for the subject to perform.

We considered the chronic low back pain subjects examined in this study to have minimal to moderate levels of disability [18]. With a mean peak  $\dot{V}O_2$  level of 19.4 mL/kg/min, they were considered to have mild to moderate functional aerobic impairment [24]. The chronicity of their low back pain was evident from their reported mean duration of 7 years with the condition.

The reproducibility study performed on the healthy subjects demonstrates that the pressure pain testing itself does not evoke a significant stress-induced analgesic effect. In previous work, we have also demonstrated that the same pain-testing methods have good reproducibility for two tests separated by only 15 minutes, as well as for repeat tests across days [16]. Reproducibility of the pain test is important to allow us to attribute the reduction in pain ratings following exercise to the exercise stimulus. While we did not examine reproducibility in the chronic

low back pain subjects, we had no reason to suspect that the presence of back pain would affect reproducibility of the testing methods. Furthermore, the findings that the chronic low back pain subjects demonstrated a similar alteration in pain ratings for both postexercise pain tests as the healthy subjects in our previous work provides further support that they were not merely displaying a stress-induced analgesic effect from the pain tests [16].

Our findings also demonstrate that we found no difference in baseline pain ratings between healthy subjects and the chronic low back pain subjects. This finding is interesting and in contrast with our hypothesis. Based upon previous studies demonstrating that patients with chronic low back pain had higher pain thresholds to painful heat stimuli than control subjects [1–3], we hypothesized that we would find a lower baseline perception of pressure pain (i.e., lower pain ratings) among the chronic low back pain subjects compared with the control subjects.

To the best of our knowledge, this work is the first to examine the response of chronic low back pain subjects to a pressure pain stimulus. However, previous studies have examined the perception of a pressure pain stimulus among subjects with various etiologies of chronic pain other than low back pain. These studies found lower pain thresholds or tolerance to pressure pain among patients with fibromyalgia syndrome [6–11], myofascial pain syndrome [12–13], various regional chronic pain syndromes [7], and complex regional pain syndrome and various other chronic pain syndromes compared with control subjects [15]. Given these findings, one could speculate that patients with chronic pain may have a relatively different response from healthy subjects to a painful thermal stimulus compared with a painful pressure stimulus. Indeed, the work of Janal et al. provides some support for the notion that the perception of pain from different stimuli may not be closely linked [25]. They observed no correlation between measures of perception of heat, cold, ischemic, and electrically induced pain. However, the different populations studied may account for the suggested difference in response to a painful thermal stimulus compared with a painful pressure stimulus among individuals with chronic pain. Perhaps pain perception is affected differently in more generalized conditions, such as fibromyalgia syndrome, compared with more localized conditions. Clearly, more work is necessary so that researchers may understand and explain the responses of individuals with various etiologies of chronic pain to different types of painful stimuli.

We should point out that the absence of a difference in baseline pain ratings between the healthy subjects and the chronic low back pain subjects could also be related to the fact that our study population of chronic low back pain subjects had only minimal to moderate levels of disability. A more disabled group may have shown a difference in preexercise pressure pain perception compared with healthy subjects. Furthermore, we recognize that the study population was small and that a Type 2 error was possible. Gender, fitness level, ethnicity, and other subject characteristics may affect pain perception. The influence of such factors requires consideration when comparing baseline pain ratings among different groups.

## CONCLUSION

From this work, we conclude that exercise-induced analgesia to an experimentally induced pressure pain can be evident for more than 30 minutes after aerobic exercise from leg cycling in people with minimal to moderate levels of disability caused by chronic low back pain. Additionally, baseline pressure pain perception does not appear to differ between chronic low back pain and normal healthy subjects.

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