Does Aerobic Exercise Improve Pain Perception and Mood? A Review of the Evidence Related to Healthy and Chronic Pain Subjects

Martin D. Hoffman, MD, and Debi Rufi Hoffman, MA

Corresponding author
Martin D. Hoffman, MD
Department of Physical Medicine and Rehabilitation (117),
Sacramento VA Medical Center,
10535 Hospital Way, Mather, CA 95655, USA.
E-mail: martin.hoffman@va.gov

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Aerobic exercise can cause an acute improvement in mood as well as a reduction in the perception of pain from a painful stimulus. Regular exercise training also may offer some protection from depression, is clinically useful in treating certain psychiatric and chronic pain conditions, and may allow for an enhancement of the acute improvements in mood from a single exercise session. The utility of aerobic exercise training for improving mood disturbances and pain perception among patients with chronic pain requires further investigation.

Introduction

The adverse effects of inactivity have become well recognized. Inactive individuals have approximately twice the risk of developing heart disease compared with their active counterparts, and there are a host of other known health problems associated with inactivity, including diabetes, colon cancer, degenerative joint disease, and hypertension. Conversely, physical activity has been shown to reduce the risk of premature mortality, improve functional capacity, and help older individuals maintain independence [1]. As a result, the Centers for Disease Control and Prevention, and the American College of Sports Medicine, have recommended that adults engage in moderate-intensity physical activity for a total of 30 minutes per day, accumulated in durations of no less than 10 minutes each, on most (if not all) days of the week [2].

In addition to physical health benefits, regular exercise is now recognized to induce various psychological [3–6] and cognitive [7,8] benefits. Most people are familiar with the phrase "a healthy mind in a healthy body," translated from the Latin "mens sana in corpore sano." Attributed to a Roman satirist of the first and second century AD, it is evident that the connection between the mind and body, and the importance of both physical and mental health, is not a new concept. We now have scientific evidence to support such a connection.

A relationship between physical and mental health is considered in the conceptual model of the chronic pain process [9]. This model involves a cycle that includes physical changes resulting in altered pain levels (Fig. 1). This in turn causes psychological stress and tension, and emotional dysfunction. The cycle is then completed with emotional changes leading to a disruption in physical activity levels and further physical changes. In addition to operating in this direction, the cycle may work in the reverse direction as well.

The connection of activity level with mood and pain perception is considered in this article. Specifically, our current understanding of the acute and chronic effects of exercise on mood and pain perception is discussed. Given the involvement of these factors in the chronic pain process, an understanding of such effects has obvious important clinical implications in the treatment of various psychological and pain conditions. Furthermore, examining the acute effects of exercise on mood might reveal beneficial information regarding the development of interventions directed at exercise initiation and maintenance.

Acute Effects of Exercise on Mood

People often seek relief from negative moods in a variety of ways, such as self-medicating with alcohol and drugs, smoking cigarettes, or overeating. Others use healthier mechanisms, such as reaching out for social support, or engaging in meditation or exercise. This section explores the scientific support for an acute mood enhancement from exercise.

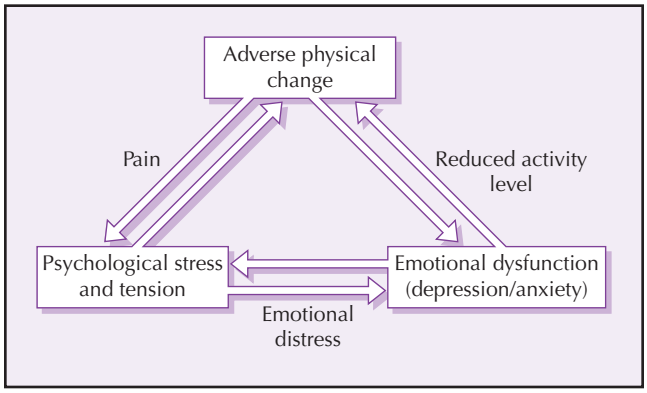

Figure 1. Chronic pain process model. (*Adapted from* Gatchel [9].)

In a review of 20 years of literature regarding the acute effects of exercise on mood, Yeung [10] concluded that there was strong support for the existence of acute mood benefits from a single bout of aerobic exercise. These acute positive effects of exercise on mood were thought to be generally evident regardless of gender or age of the subjects.

Limited work has been directed at examining how the acute mood effects from exercise might be influenced by exercise intensity or duration. It has been tentatively suggested that very high and very low intensities do not appear to be optimal in the improvement of mood [10]. Moderate-intensity exercise seems to be more consistent at inducing acute mood improvement [11,12]. Yet, there is some evidence that exercise intensity and duration may interact in such a way that short periods of exercise at higher intensities [13], as well as long periods of exercise at lower intensities [14], can offer mood benefits.

The duration of exercise-induced mood enhancement is another area that has not been fully examined. Some work has suggested that the effect may persist for 3 to 4 hours [15] or even as long as 24 hours [16].

There has been some evidence that the acute effect of exercise on mood might be affected by fitness level. For instance, Shepanski et al. [17] systematically compared acute mood changes after aerobic exercise of different intensities and durations between regular exercisers and nonexercisers. Subjects of varying ages and fitness levels were categorized as habitual exercisers or nonexercisers based upon exercise history. Habitual exercisers performed aerobic exercise more than 15 times each month for 30 minutes or more in the 6 months preceding the study. Nonexercisers had exercised less than five times per month in the preceding 6 months. On separate days, the Profile of Mood States was administered immediately before and 5 minutes after treadmill exercise for 10 minutes at 75% maximal oxygen uptake (VO_{2max}), 30 minutes at 50% VO_{2max}, 30 minutes at 75% VO_{2max}, and 30 minutes of rest. Total mood disturbance scores improved significantly after each exercise condition among the habitual exercisers, whereas there was no change among the nonexercisers.

At this point, we can say that aerobic exercise can have positive effects on mood when performed across a fairly wide intensity range, and that the effect seems to be most evident among regular exercisers. Indeed, if the mood enhancement from exercise is minimal for nonexercisers, this could account for some of the challenges this group faces when initiating and attempting to maintain an exercise program. Given that approximately 50% of those who initiate an exercise program drop out within 3 to 6 months [5], it might be useful for those in the early stages of an exercise program to recognize that they could have greater mood benefits from exercise if they persist with the program.

To our knowledge, there has been minimal exploration of whether aerobic exercise might offer an acute improvement in mood for patients with chronic pain. One study [18] found that sedentary, obese, older adults with knee osteoarthritis did not experience acute psychological benefits from a combined workout of walking and strengthening exercises. Yet, such a finding may be due to the patients being sedentary rather than having a chronic pain condition.

Acute Effects of Exercise on Pain Perception

It has been suggested that the acute mood enhancement associated with exercise may be linked to an exercise-induced analgesic effect. Although the evidence is not conclusive, the endogenous opioid system has been implicated in both phenomena.

Among healthy subjects, exercise has been found to result in an acute decrease in pain perception to a variety of stimuli, including ischemia [19], electrical stimulation of dental pulp, a tooth or a finger [20,21], pressure to a finger [22,23,24•,25], and holding a weight from a fingertip [26]. However, pain perception to cold pressor testing [19] has not been shown to be acutely affected by exercise, and our recent work has demonstrated that thermal (heat or cold) pain testing is not useful for examination of exercise-induced analgesia [27]. The use of heat and cold testing is likely confounded by the increase in body temperature and blood flow from exercise.

The duration and intensity of exercise have varied among the studies examining for exercise-induced analgesia. One study [26] reported a decrease in pain perception after a 1-mile run, but generally longer bouts of exercise have been investigated. Although the exercise intensity frequently has not been well quantified, there is some evidence that intensities of over 70% of maximal aerobic capacity are required and that pain threshold increases with increasing intensities above this level [20]. Our recent work [24•] demonstrated that an intensity of 50% of maximal aerobic capacity was inadequate to show statistically significant changes in pain perception, but exercise for 30 minutes at 75% of maximal aerobic capacity was sufficient to elicit exercise-induced analgesia to a pressure pain stimulus.

The duration of the exercise-induced analgesia also is not well quantified. Some studies have demonstrated

the effect to be present for at least 30 minutes [20,22], whereas another study showed the phenomenon to persist for as long as 50 minutes after exercise [21].

Although the evidence is not definitive, there is some support that distorted nociception can occur in chronic pain. It has been suggested that dysfunction of the endogenous opioid system may play a role and that this may contribute to the increased pain sensitivity often observed among severely disabled chronic pain patients [28•]. It also has been suggested that among less disabled chronic pain patients, the ongoing pain may serve as a primer producing upregulated opioid antinociceptive responses to acute pain [28•].

Little effort has been directed at examining the acute effects of exercise on pain perception among individuals with chronic pain. To our knowledge, only one study has been directed along these lines. Our recent work [23] has demonstrated that among a group of eight subjects with chronic low back pain causing minimal to moderate levels of disability, exercise-induced analgesia to pressure pain testing was evident for over 30 minutes after bicycle ergometry of 20 minutes at 70% of peak oxygen uptake (Fig. 2). The effect observed for the subjects with chronic low back pain was similar to that observed in healthy control subjects. Therefore, initial data suggest that chronic pain may not necessarily alter the presence of exercise-induced analgesia. However, the potential influences of fitness level and chronic pain on exercise-induced analgesia remain to be fully investigated.

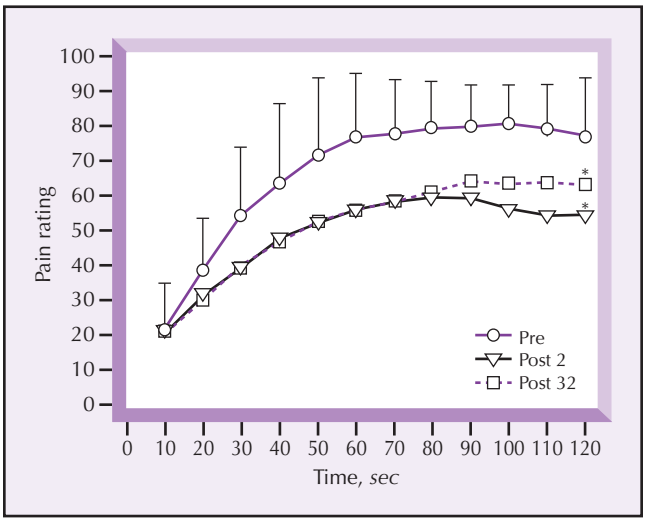

Figure 2. Demonstration of mean pain ratings on a 100-mm scale for chronic low back pain subjects before (Pre), and 2 (Post 2) and 32 (Post 32) minutes after cycle ergometry exercise. *Asterisk* indicates where pain ratings that were averaged over the last minute of the test were significantly different ($P < 0.05$) than for the pre-exercise test. *Brackets* represent 1 SD and are only displayed for the first trial for clarity. (*From* Hoffman et al. [23].)

Effects of Exercise Training on Mood

Aerobic exercise has been demonstrated to be effective in improving general mood and symptoms of depression and anxiety in both healthy individuals and psychiatric patients [3–6]. The most robust effects are evident for clinical populations, as might be anticipated, given that depression and anxiety scores for psychiatric populations have a baseline that allows for greater opportunity for improvement than those of mentally healthy individuals. In the treatment of depression, the research seems to suggest that exercise is as effective as psychotherapy and antidepressant medication [3]. For treatment of anxiety, exercise seems to be comparable to other anxiety-reducing interventions such as meditation, relaxation, and quiet rest [29]. Whether directed at treating depression or anxiety, the greatest improvements occur after several months of exercise training [6].

In addition to the acknowledged treatment effects of exercise on depression, there is some evidence that individuals who become or remain active or fit are less likely to suffer clinical depression [4]. In other words, regular exercise seems to offer a protective effect from depression.

In one study [30], the Profile of Mood States was used to compare runners to nonexercisers. Over the course of 3 weeks, the runners scored significantly lower on tension, fatigue, confusion, and total mood disturbance, and higher on vigor, compared to the group who remained sedentary. Of interest was the discovery that the runners who averaged 45 or more miles per week, although scoring lower on total mood disturbance than the sedentary group, scored higher on this measure than the low-mileage runners who ran 25 to 44 miles per week. Thus, it may be that the mood benefits increase up to a certain optimal level of exercise, beyond which the mood-enhancing effect may be reduced.

Given the potential implications from improved mood through aerobic exercise training, it is unfortunate that relatively little research has been directed at this issue in groups with chronic pain. Most of such work has been in patients with fibromyalgia syndrome (FMS), in which there have been mixed results. Mood improvements were associated with interventions focused on exercise training in some studies [31,32•,33] but not others [34,35]. In one study [36], FMS subjects in a supervised twice weekly, 20-week pool-based exercise program improved on depression and anxiety scores, whereas subjects who received a similarly structured land-based exercise program did not show improvements.

The findings also are mixed in other populations with chronic pain. In patients with rheumatoid arthritis and osteoarthritis, an antidepressant effect from aerobic exercise training was found in one study [37], but other studies either found only temporary [38] or nonsignificant trends of improvement [39,40]. Among two groups of patients who had recently undergone lumbar microdiscectomy, a 12-week aerobic exercise program compared with stretching and trunk strengthening resulted in no group difference in depression scores [41]. In addition, traumatic

spinal cord–injured subjects who underwent twice weekly arm crank ergometry for 15 to 30 minutes over a 9-month period showed significantly less stress and depression after training, compared with a control group [42].

Effects of Exercise Training on Pain Perception

Cross-sectional studies have suggested that pain perception is altered from regular exercise training. A study comparing 30 sedentary individuals and 30 regular exercisers showed that the exercisers had higher pain thresholds to a painful pressure stimulus [43]. Another study [44] demonstrated that regular runners had a higher threshold for noxious cold than did normally active controls, but there was no difference in ischemic pain threshold. Other studies have provided some evidence that pain tolerance (but not pain threshold) to ischemic, compression, and/or thermal stimuli is higher among athletes than nonathletes [45], and competitive compared with noncompetitive athletes [46]. These findings suggest that some type of adaptation in pain perception can occur as a result of systematic exposure to periods of intense but limited pain experiences, such as exercise. However, no study has longitudinally examined whether pain perception is altered through an exercise training program.

The possible role of physical activity in providing protection from the development of chronic pain syndromes has been postulated. Early evidence for such an effect was prompted by results of a sleep deprivation study [47]. Nonrunners deprived of stage 4 sleep were found to develop musculoskeletal symptoms and increases in muscle tenderness thresholds similar to what is seen with FMS, whereas these symptoms and findings did not develop in three habitual runners.

Examination of the benefits of aerobic exercise training for patients with chronic pain conditions has received limited formal testing. Some evidence has suggested that improvements in pain symptoms can occur through exercise training for individuals with FMS [31,32•,34,48,49], traumatic spinal cord injury [42], and chronic low back pain [50].

The issue of whether the perception of pain from a standardized painful stimulus is altered through a regular exercise training program among those with chronic pain has yet to be explored. In patients with FMS [34], pain threshold scores using a dolorimeter at five paired FMS tender points improved significantly among an aerobic exercise training group, compared with a flexibility training group. However, such pain testing involved only the measurement of pain threshold at FMS tender point sites. Pain testing at limb sites free of pain rather than at FMS tender points, and testing methods that provide information on both pain threshold and pain rating, have yet to be performed.

Conclusions

The evidence is clear that aerobic exercise represents a valuable strategy for self-regulation of mood in some individuals. Acute mood enhancement can be induced across a wide range of exercise intensities, and the effect can last for hours. Regular exercise training also seems to offer some protection from depression, is clinically useful in treating certain psychiatric conditions, and may allow for an enhancement of the acute improvements in mood from a single exercise session. However, the utility of aerobic exercise training in combating mood disturbances among patients with chronic pain requires further investigation.

The perception of a painful stimulus may be reduced for approximately 1 hour after aerobic exercise among healthy individuals. This exercise-induced analgesia also seems to be present in those with minimal to moderate disability from chronic low back pain, but it is unknown if the effect is present among those with greater disability from chronic pain. Regular aerobic exercise training has been demonstrated to be useful for managing the pain from several different chronic pain conditions. There is also some evidence that regular exercisers may have some adaptation in pain perception, but whether such an adaptation can occur in those with chronic pain has yet to be explored.

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- •• Of major importance

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