Cognitive Strategies and Pain Tolerance in Subjects With Muscle Soreness

Lorette J. Pen, A. Craig Fisher, Gary A. Sforzo, and Beth G. McManis

The effects of cognitive strategies on pain tolerance and performance in subjects with muscle soreness were investigated. Female \((n = 18)\) and male \((n = 12)\) subjects were matched for strength and then randomly assigned to dissociation, association, or control groups. Muscle soreness was induced in the quadriceps and hamstrings muscle groups by repeated eccentric contractions against heavy resistance, which resulted in significant decrements in peak torque (PT) and total work (TW). ANOVAs revealed no significant group differences \((p > .05)\) in muscle soreness, state anxiety, and estimated strength and endurance performance 48 hr following the soreness induction. Association strategy subjects increased their quadriceps strength performance following cognitive intervention, whereas strength performance in the dissociation and control groups was not affected. No significant treatment effects were observed for hamstrings strength or quadriceps and hamstrings endurance. Both dissociation and association groups perceived that using the strategies enhanced their performance. This illusory efficacy effect may have implications for performance enhancement, particularly in injury rehabilitation.

Each year, approximately 3 to 5 million injuries occur in the context of competitive athletics and recreational physical activities (12). Therefore, pain is an experience that nearly all athletes will eventually face and have to accommodate. Pain associated with injury, whether “real” or perceived, has a potential negative impact on both performance and rehabilitation outcomes because it demands immediate attention, disrupts ongoing thought and behavior, and causes athletes to terminate the activity that exacerbates their pain (16, 17). Pain can be so overwhelming and incapacitating that it disrupts all functional coping behavior. This creates a serious problem for athletes because they face a variety

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of problems that demand accommodation (e.g., poor performances, failures, and pain).

Athletes have varying capacities to deal with pain (10), either because of their degree of sensitivity to pain (referred to as pain threshold) or because of their ability to cope with pain and its many concomitant physical and mental manifestations (referred to as pain tolerance). Being able to manage pain effectively is one of the keys to successful performance in the sports arena (1) and in injury rehabilitation settings (8).

However, it would be wrong to infer that pain is always negative, because sometimes pain is a signal that something is not right. Pain is multidimensional, encompassing both physical and psychological dimensions with varying "messages." Some pain should legitimately signal the cessation of physical activity, whereas other pain may be more of a test of one's coping abilities and tolerance to continue the activity.

Current research practices (e.g., scrutiny of subjects' rights to ensure ethical treatment) make it difficult to conduct research on pain, especially if pain is going to be inflicted on subjects. Additionally, contemporary pain-induction protocols (e.g., cold immersion, hot pressor, ischemia), even when they are approved for human research, do not inflict the kind of pain athletes typically experience. What is needed is an acceptable and relevant pain-induction protocol that can be used to test the effectiveness of cognitive coping strategies that athletes might employ to enhance pain tolerance. Researchers would then be able to advise practitioners as to how to teach their athletes pain-coping skills, when appropriate, to help them reach performance goals.

It is suggested that cognitive strategies (e.g., distraction) may enhance an athlete's pain tolerance because they potentially affect the mental component of pain (e.g., perceived intensity), thereby improving the athlete's coping capacities (10). Cognitive interventions generally involve helping people gain control over their thoughts about pain. Strategies based on this approach may help injured athletes refocus attention away from pain (i.e., dissociation) or focus attention on particular aspects of pain (i.e., association) to more accurately appraise its severity and control its typically pervasive nature (28).

Dissociation strategies include internal distractors (e.g., visualizing a pleasant scene, concentrating on breathing) and external distractors (e.g., listening to music). These interventions emphasize distraction from feelings of distress associated with pain (24), with the expectation that reduced focus on the negative stimuli will allow one to direct more attention to the demands of one's particular task. Association involves either focusing on the painful sensations to localize the pain and restrict its usual global nature (i.e., "flooding") (27) or reappraising the pain into positive terms (13), almost akin to a "badge of courage." Association strategies encourage individuals to constantly monitor their internal states and maintain their focus on and subsequent control over particular aspects of pain (e.g., location, intensity, meaning) (24).

The effectiveness of dissociation and association strategies in ameliorating athletes' pain is relatively unknown, although there is some indication that dissociation may work better than association for certain conditions (18, 19, 21, 27). Dissociation may be more helpful in preparing individuals to cope with pain prior to its onset, but it may not be as successful as association in dealing with the sudden impact of pain and its aftermath (25).
The purpose of this study was to assess the impact of cognitive strategies on pain tolerance and subsequent performance in subjects with exercise-induced muscle soreness and probable damage to related muscle fibers. Inducing muscle soreness seemed a reasonable and ethical means by which to examine the effects of cognitive intervention. It was hypothesized that the use of dissociation and association strategies would allow the subjects to cope better with their pain, thereby enhancing their performance.

Methods

Subjects

Twenty female and 14 male subjects, ranging in age from 18 to 22 years, initially volunteered to participate in this study. All read and signed an informed consent document that described the purpose, procedures, risks of participation, and right of voluntary discontinuance. Subjects had no history of knee or back problems, reported no medication usage, were moderately to highly active, and had not strength trained their lower body for at least 2 months prior to the beginning of this study.

Measures

**Strength and Endurance.** Muscle performance was measured on the Biodex System 2, an isokinetic muscle function dynamometer. Measurements were taken for eccentric contractions of the quadriceps and hamstrings and expressed as peak torque (PT) and total work (TW). Only eccentric muscle performance data were assessed because muscle fibers involved in these movements were most likely to be damaged during the subsequent soreness induction protocol (5).

**Muscle Soreness.** Subjects’ perceived rating of their muscle soreness (pain) was assessed by the Muscle Soreness Scale (MSS), using the following 7-point Likert-type response scale: 1 = no pain, 2 = vague pain, 3 = slight pain, 4 = more than slight pain, 5 = painful, 6 = very painful, and 7 = extremely painful. Each potential response was accompanied by a short descriptor (e.g., more than slight pain—soreness that hampers complex movement). The MSS is logically valid, but its psychometric properties will need to be assessed with further use.

**State Anxiety.** There was some concern that the exercise-induced muscle soreness might create heightened anxiety, which could possibly have confounding effects on performance. The shortened version (10 items) of the state portion of the State–Trait Anxiety Inventory (SAI) (23) assessed athletes’ feelings of apprehension. The 4-point Likert-type responses ranged from 1 = not at all to 4 = very much so.

**Perception of Performance.** Perceived performance scores (PPS) were assessed prior to (Pre-PPS) and following (Post-PPS) muscle testing to assess subjects’ performance expectations. The following response choices were offered for each perception of performance rating compared to the previous testing session: much weaker (<50%), somewhat weaker (75%), slightly weaker (90%), same (100%), slightly better (110%), somewhat better (125%), and much better (>150%). The PPS appears to be a logical construct, but future use will validate its effectiveness.
Cognitive Strategy Efficacy. A 10-item Strategy Evaluation Questionnaire (SEQ) assessed subjects' predisposition to distract (i.e., dissociate) or focus (i.e., associate) and also evaluated subjects' perceptions of the effectiveness of their assigned cognitive strategies. As a manipulation check, subjects were asked to indicate what percentage of time they utilized their particular strategy during the testing session and the accompanying thoughts they had during the testing session.

Procedures

Familiarization (Session 1). Upon entering the testing laboratory, each subject completed the SAI. The subject was seated on the Biodex for muscle performance testing with belts fastened securely across the chest and lap, over the dominant leg, and around the lower shin. An explanation of the testing was followed by two sets of 10 submaximal eccentric contractions performed unilaterally. This allowed the subject to become familiar with the movement speed (90°/s) and the effort required.

Baseline Assessment and Muscle Soreness Induction (Session 1). To ascertain baseline eccentric performance of the quadriceps and hamstrings muscle groups, the passive mode of the Biodex was selected and a speed of 90°/s was maintained for the following protocol: two sets of 10 maximal repetitions and two sets of 40 maximal repetitions, each set separated by a 3-min rest period. PT from the 10 repetitions provided the strength data, and TW from the 40 repetitions provided the endurance data.

Three minutes after baseline measurements were completed, a muscle soreness/damage protocol was undertaken. First, each subject performed an additional five sets of 10 maximal repetitions following baseline assessment. Within 15 min, each subject began performing leg squats on a Universal gym apparatus at a load of 80% of one maximum repetition. Squats were completed in sets of 10 repetitions with a 2-min rest between sets, and sets were executed until the subject became exhausted (i.e., subject could not complete a repetition).

Subject Assignment and Instructions. Using baseline measurements, subjects were matched in triads by averaging PT of the four sets of quadriceps and hamstrings data to reduce the possibility that the strongest and/or weakest subjects were assigned to the same treatment group. Matched subjects were then randomly assigned in subject-blind fashion to dissociation, association, and control groups. Following group assignment, subjects were requested not to exercise (e.g., stretch) or take any medication over the next 48 hr to allow muscle soreness to peak.

Postsoreness Testing (Session 2). Forty-eight hours following muscle soreness induction, subjects reported individually to the testing laboratory and completed the SAI, MSS, and Pre-PPS. Four subjects (2 males and 2 females) were eliminated from the study at this point because they reported no pain in either muscle group, a condition necessary for the subsequent testing.

Each subject reporting "adequate" soreness was seated in the Biodex and warmed up with two sets of 10 submaximal eccentric contractions, separated by a 1-min rest. The subject then completed two sets of 10 maximal repetitions and two sets of 40 maximal repetitions, with each set separated by 3 min. To minimize the possibility of further muscle damage, subjects were told to stop exercising if they experienced any sharp pain. Following muscle testing, each subject
completed the Post-PPS. Subjects again were reminded to keep their physical activity to a minimum and return to the laboratory in 3 hr.

**Experimental Manipulation (Session 3).** Upon entering the laboratory, subjects again completed the SAI, MSS, and Pre-PPS. Each subject then listened to a prerecorded message detailing his or her strategy (i.e., dissociation, association, or control) while reading the accompanying script. The same warm-up routine used in the second session was performed. Following the first warm-up set, the taped message was listened to and read a second time.

The dissociation group was asked to select and focus on a specific phrase (e.g., “Explode!”) and repeat it forcefully, either silently or out loud, with each subsequent repetition. Or, if they preferred, dissociation subjects could count the number of repetitions, exhaling on the exertion and inhaling between repetitions. Subjects were asked to focus all their attention on their preferred distractor and exert maximum effort with each exertion.

Members of the association group were requested to focus their attention on their pain and rate the intensity from 1 to 100. Association subjects also were asked to mentally frame the entire sore area to constrain its location, shrink the frame to encompass only the sorest part, and then transform this concentrated area into a bright light signifying power to motivate. Subjects were asked to focus on their pain and use it as power to increase their effort with each exertion. They were also told that they were among the very few who could work through their pain by focusing on it.

The prerecorded message the control group listened to merely reminded them to exert a maximal effort with each contraction.

The muscle testing protocol was then repeated, the only change being that the cognitive strategy was implemented for a third time between the second set of 10 repetitions and the first set of 40 repetitions, as a reinforcement of the treatment. Following muscle testing, each subject completed the Post-PPS and the SEQ. Subjects were then debriefed and given the opportunity to view their results and listen to the other groups’ tapes.

**Results**

**Internal Consistency of Strength Performance Data**

Intraclass correlation (R) coefficients of the two sets of 10 repetitions for the quadriceps and hamstrings muscle groups for PT over the three testing sessions ranged from .92 to .98, with a mean $R = .97$. Because the $R$ value exceeded the .95 reliability standard for isokinetic muscle function dynamometers (Biodex and Cybex) (3, 6, 14, 20), subsequent analyses of strength data used the mean of both sets of 10 repetitions.

$R$ values of both sets of 40 repetitions for the quadriceps and hamstrings muscle groups for TW over the three testing sessions ranged from .88 to .98, with a mean $R = .94$. Using the .95 standard, we decided to use only the data from the first set of 40 repetitions for subsequent analyses of muscular endurance data. It might be reasonably argued that fatigue gradually increased over the two sets of 40 repetitions, making the second set more atypical of our subjects’ endurance performance.
Soreness Induction Manipulation Check

Subjects reported mean MSS scores of 4.73 at the beginning of Session 2 and 4.87 at the beginning of Session 3 (1 = no pain; 7 = extreme pain). These values indicated that subjects described their collective sensations as painful. No significant differences in muscle soreness were reported among subjects in the dissociation, association, and control groups at the beginning of Session 2 (following the soreness induction), $F(2, 27) = 2.28, p > .05$, or prior to the administration of the cognitive interventions in Session 3, $F(2, 27) = 1.96, p > .05$. Therefore, any subsequent group differences in perceived or actual performance levels were not due to differential muscle soreness. Also, no between-session differences for Sessions 2 and 3 were found for any of the groups: dissociation, $t(9) = 1.81, p > .05$; association, $t(9) = 0.00, p > .05$; control group, $t(9) = 0.00, p > .05$.

Examination of the strength (PT) and endurance (TW) measures prior to and 48–51 hr following soreness induction revealed the magnitude of the performance decrements. ANOVAs of quadriceps and hamstrings performance data for the sets of 10 and 40 maximum repetitions by session (Table 1) reached statistical significance ($p < .05$), with $F$'s ranging from 30.09 to 81.51. Post hoc Tukey analyses located the differences between Session 1 and Sessions 2 and 3 in all cases. Previous studies have shown that strenuous exercise to which the subject is unaccustomed produces muscle damage and, therefore, soreness (2, 5, 22). Indirect evidence of damage includes the soreness and stiffness that appear 24–48 hr after exercise and the prolonged reduction in muscle performance that typically accompanies the soreness. The decrease in performance between Session 1 and Sessions 2 and 3 provided clear evidence that our soreness-induction protocol was effective and that the effects lasted throughout the experiment.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Means, Standard Deviations, and ANOVAs of Peak Torque and Total Work by Sessions</th>
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<tr>
<td></td>
<td>Peak torque (N · m)</td>
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<td>Quadriceps</td>
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<tr>
<td>Session 1</td>
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<td>Session 2</td>
<td>152.64</td>
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<td>Hamstrings</td>
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<td>Session 3</td>
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<td>(81.51*)*</td>
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*F ratio. *$p < .05$.
State Anxiety

Mean SAI scores across the three sessions (16.91, 15.83, and 13.90, respectively) indicated that subjects were not very apprehensive of the experimental protocol (SAI can range from 10 to 40). A-state was clearly not heightened in Sessions 2 and 3 from the baseline of Session 1. No significant A-state differences were found among dissociation, association, and control groups in either Session 2, \[ F(2, 27) = 1.94, p > .05, \] or Session 3, \[ F(2, 27) = 1.57, p > .05. \] Therefore, anxiety had negligible impact on strength and endurance performance.

Performance Expectations

Prior to muscle testing, subjects rated their expected performance in Session 2 to be “somewhat weaker (75%)” than in Session 1. In reality, their actual performance reached 65% of their baseline performance, less than they expected but still indicative of a reasonable degree of perceptual accuracy. In Session 3, prior to the cognitive intervention, subjects expected their performance to be just “slightly weaker (90%)” than in Session 2. Their actual performance following the cognitive intervention surpassed (104%) their Session 2 performance. Instead of the expected 10% performance decrease from the previous session, an overall 14% performance increment was realized. The groups did not differ significantly in their Pre-PPS expectations prior to the cognitive intervention in Session 3, \[ F(2, 27) = 1.03, p > .05 \] (see Figure 1). Therefore, any subsequent treatment effects were not confounded with differential expectations.
Following muscle testing in Session 2, subjects judged their performance to be "somewhat weaker (75%)" than their Session 1 performance. This paralleled their Pre-PPS expectations. The groups did not differ significantly in their Post-PPS expectations in Session 2, $F(2, 27) = 0.85, p > .05$, prior to the cognitive intervention. Again, subsequent treatment effects were not confounded by differential expectations.

Effects of Cognitive Strategies

**Strength Performance.** A 3 (Group) $\times$ 3 (Session) mixed-model ANOVA on quadriceps PT revealed a significant Group $\times$ Session interaction, $F(4, 54) = 2.83, p < .05$ (see Figure 2). The three within-group simple effects analyses were significant, and post hoc Tukey analyses revealed different results for the association group than for the dissociation and control groups. Following the cognitive intervention in Session 3, association group subjects improved their strength performance significantly from Session 2 (from $M = 162.23$ N·m to $M = 197.46$ N·m), unlike either the dissociation or control group subjects. For the association group, subjects’ mean strength recovered in Session 3 ($M = 197.15$ N·m) so that it was not dissimilar to Session 1 ($M = 215.56$ N·m), prior to the implementation of the muscle soreness induction. However, for subjects in the dissociation and control groups, strength performance remained significantly lower than it was in Session 1.

![Figure 2](image-url) — Quadriceps peak torque (PT) by sessions for experimental and control groups.
A 3 (Group) × 3 (Session) mixed-model ANOVA on hamstrings PT revealed a significant Group × Session interaction, $F(4, 54) = 2.82, p < .05$ (see Figure 3). The three within-group simple effects analyses were significant, but post hoc Tukey analyses revealed the same pattern for all three groups. Hamstrings strength performance did not improve from Sessions 2 to 3 for either cognitive intervention or control groups.

**Endurance Performance.** Mixed-model ANOVAs on TW revealed no significant Group × Session interactions for either quadriceps, $F(4, 54) = 1.89, p > .05$, or hamstrings, $F(4, 54) = 1.73, p > .05$. Group trends by session can be seen in Figures 4 and 5. Muscle endurance was not significantly influenced by the cognitive interventions.

**Performance Expectations.** Reexamination of Figure 1 reveals the Post-PPS judgments in Session 3. Following the cognitive intervention, both the dissociation and association groups offered more optimistic postperformance assessments than did the control group, $F(2, 27) = 5.24, p < .05$. The cognitive strategy groups perceived that their Session 3 performance was "slightly better (110%)" than in Session 2, whereas control group subjects judged their Session 3 performance to be similar to that in Session 2.

**Cognitive Strategy Efficacy Manipulation Check**

Both cognitive strategy groups indicated that their strategies were easy to use and effective and that they would use them in the future. Dissociation group
subjects reported that the mean percentage of time spent utilizing the strategy was 81.9%, whereas the reported mean utilization time for association group subjects was 80.5%. This does not suggest, however, that subjects’ attention on their cognitive strategies was unwavering; 30% of the subjects in the dissociation group and 50% of the subjects in the association group indicated they had lapses in concentration while using their strategies.

**Discussion**

This study examined the effectiveness of dissociation and association strategies on subjects’ pain tolerance and muscle performance. We hypothesized that these cognitive interventions would enhance subjects’ capacity to cope with experimentally induced muscle soreness, would increase pain tolerance, and thereby would promote greater muscular performance.

Although similar group-by-session trends were evident in Figures 2 and 3, only the association group revealed significant treatment effects for quadriceps strength. No treatment effects were seen for hamstrings strength. Association strategies reframe, restrict, or constrict the stimuli associated with a stressful event and tend to promote more successful coping with the event and its aftermath (25). Dissociation would seem to be less successful in this situation because the painful sensations (i.e., nagging soreness) were already present prior to muscle...
Figure 5 — Hamstrings total work (TW) by sessions for experimental and control groups.

testing. In previous studies where dissociation has been shown to be a successful coping strategy (e.g., 27), subjects were able to use the strategy before pain became intense.

The mixed results on quadriceps and hamstrings strength performance are perplexing until one considers task familiarity. The flexion action needed to produce PT on the Biodex is more unnatural than extension, causing an additional demand that might have contributed to the different results.

Endurance performance did not show any treatment effects for either the quadriceps or hamstrings. Of course, a set of 40 repetitions surpasses the task demands of two sets of 10 repetitions. Although distraction seems not to be a very successful coping strategy toward the end of a stressful event (25), any coping attempts will be more difficult when the physical and psychological demands increase. Such would seem to be the case with sets of 40 maximal repetitions. Girodo and Wood (11) reported that the effects in coping with pain are relatively short-lived perhaps because there is a ceiling effect on endurance time. Accordingly, even the association strategy was ineffective during the muscular endurance test that called for well over 1 min of sustained maximal effort.

Previous studies have found that cognitive strategies generally increase subjects’ capacity to tolerate pain and enhance a variety of performance measures (4, 9, 10, 18, 26). It has been customary, however, to induce a rather artificial type of pain, at least in comparison to the pain athletes experience. Specifically, most pain tolerance experiments induce pain with temperature (e.g., cold pressor,
ice immersion, radiant heat), electric shock, or pressure (e.g., inflated cuff). Subjects know in advance that they have control over the pain because they can discontinue their participation at any time, thereby terminating the painful stimuli.

However, our experimental induction procedure produced muscle soreness and pain that lasted for a prolonged time period, minimally throughout the duration of the experiment and perhaps as long as 7–10 days thereafter (5). Even had our subjects chosen to discontinue their involvement in the study, they would have still experienced all the symptoms of muscle soreness. Perhaps cognitive interventions are not as effective with intense and long-lasting pain as they are with artificially induced, short-term pain. At this point, we would like to recommend our muscle soreness induction protocol as a relevant strategy for research on pain management. Muscle soreness provides a more realistic representation of the inescapable pain experienced by injured athletes than previously used pain-induction techniques.

Our intervention strategies did not address the total dimensionality of the pain experience, even though it is recognized that pain is differentially perceived and accommodated. Our cognitive strategies offered subjects a particular focal point to use during painful muscle testing. Subjects in pain tolerance experiments as well as injured athletes typically experience the following: feelings of apprehension at the onset of the pain (affective component), thoughts such as “Why am I doing this?” or “This is going to hurt” (cognitive component), and an unwillingness or inability to offer a maximum effort (behavioral component). Clinical intervention, if it is to be maximally effective, will probably need to be as multidimensional as the pain experience itself.

It is possible that training to use cognitive strategies effectively may be required to increase one’s tolerance to pain. After all, cognitive skills, like all skills, need to be practiced especially if they are expected to assist individuals in dire circumstances (e.g., during protracted and painful injury rehabilitation). A self-control strategy must be validated by experience before it can represent a truly effective coping strategy (11). In some previous pain tolerance studies (10, 24, 26), subjects were trained to utilize their assigned cognitive strategies. On the other hand, our subjects used their strategies three times and only during the experiment. There was no practice and no indication prior to the final muscle testing session that they would be asked to utilize any potentially performance-enhancing strategy. Possibly, trained subjects would have been able to exercise more control over the debilitating effects of muscle soreness.

Notwithstanding the mixed effectiveness of the cognitive strategies to enhance performance, a majority of our subjects perceived that their strategies helped them increase their pain tolerance and performance. The adequacy of a cognitive process cannot be judged solely on the basis of its outcome, because numerous factors may undermine the end result (25). Unexpected soreness and pain, previous experience (e.g., successes and failures) dealing with soreness and pain, and temporary loss of control of one’s emotions (e.g., temporarily giving up) would likely impact on one’s decision to perform in adverse circumstances.

The dissociation and association strategies provided subjects with the confidence that they could succeed at the set task. This illusory efficacy has important implications, particularly for sport injury rehabilitation. In order for athletes to actively cope with their injuries and confront the task of rehabilitation with the
kind of intensity needed to return to normal function, a certain sense of optimism is necessary (25).

It has been argued elsewhere that self-efficacy is a powerful predictor of successful injury rehabilitation (7, 15). Injured athletes who believe they are capable of meeting the demands of a prescribed rehabilitation regimen (e.g., type, frequency, intensity, and duration) tend to adhere better to their rehabilitation treatment. A sense of efficacy, whether real or illusory, in the strategies one utilizes to maintain motivation in the face of adversity (e.g., devastating emotions, limited immediate progress, and long-term involvement) may be the prime predictor of rehabilitation adherence (15).

In summary, the effects of our cognitive intervention strategies on pain tolerance and muscle performance were mixed. The association strategy allowed subjects' diminished quadriceps strength to recover to baseline levels, unlike the dissociation strategy, which produced no such effect. Similar results were not seen for hamstrings strength. Perhaps not surprisingly, treatment effects were more pronounced with short bouts of exercise than with prolonged endurance bouts, in which no cognitive strategy influence was observed. Subjects in both treatment groups exhibited enhanced self-confidence in their capability to execute the required tasks. Self-efficacy may be an important mediating variable in assisting athletes to cope with pain and perform in spite of it.

References