Evidence for

Percutaneous Neuromodulation Therapy

for the Treatment of Spinal Pain

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Preface

This report summarizes the results of five clinical studies of percutaneous electrical stimulation for the treatment of lumbar (low back) and cervical (neck) pain. These studies were published between 1999 and 2001 in peer-reviewed journals, including JAMA and Anesthesia & Analgesia. They form a foundation of scientific knowledge about the treatment of spinal pain with percutaneous electrical stimulation and they also establish the rationale for applying this innovative technology in the form of percutaneous neuro-modulation therapy (PNT) to make treatment more accessible and consistent.

Introduction

The prevalence of pain in our society is staggering. The National Institutes of Health and the American Pain Foundation estimate that nearly 50 million Americans suffer from chronic pain[1,2]. Two of the most prevalent pain-related ailments are lumbar pain, which is commonly referred to as low back pain, and cervical or neck pain. Neck pain is a common problem in our society and, at any given time, affects approximately 10% of the general population[3]. In the United States, cervical pain alone accounts for more than a million physician visits a year and over 31,000 hospital stays from cervical spine injuries alone[4]. The incidence of low back pain and its health and social cost is even greater. Each year, approximately 15-20% of adults experience back pain[5,6] At any given time, an estimated 5 million of these people are either temporarily or chronically disabled by back problems.[5] Despite extensive research on both its prevention and treatment, low back pain continues to be the second-most common reason (after the common cold) for primary care visits in this country.[7,8]

Not only does spinal pain significantly impair quality of life for many patients, but it also has far-reaching economic and societal implications. The total annual costs—direct and indirect—of low back pain alone are estimated at $50 million—100 billion.[9-11] The debilitating effects of low back pain cause an estimated 150 million lost workdays each year.[9] While neck pain is more prevalent (and severe) among adults over the age of 45, low back pain is more often the cause of long-term disability among those under the age of 45,[12-14] and the second most common cause of absence from work among adults under the age of 55.[9] Neck pain occurs half as often as low back pain and is slightly more common in women.[14] In addition to neck pain being more common in women, it is also found that those involved in both mentally and physically stressful jobs are at greater risk for having neck pain.[3,14]

Acute spinal pain, commonly defined as lasting less than four weeks, usually resolves without medical intervention.[15] However, many patients experience recurrent episodes of acute pain.[15,16] These recurrences may trigger increased sensitization of the nerve fibers that transmit pain signals.[17-21] As a result, patients may progress to the more debilitating stages of subacute pain (commonly defined as lasting from one–six months) and chronic pain (commonly defined as lasting for more than six months). The clinical literature is replete with evidence that early intervention during acute and subacute episodes of spinal pain can help stem the more severe problem of chronic, unremitting pain.[22-24] When patients reach this stage, their pain often is accompanied by both depression and disability, which can be more intractable than the back pain itself.

Dr. Scott Fishman, in his book "The War on Pain," puts the problem this way:

> If you're in chronic pain, you can become conditioned to suffering, and this can cloud your entire life….this feeling of being damaged and debilitated can build on itself and get worse….Dysfunction begets dysfunction.[25]

The treatment of spinal pain presents unique challenges. It is not a discrete diagnosis, but rather a constellation of symptoms. The spine is a complex entity with a number of anatomic structures capable of generating pain. This complexity often makes it difficult to identify the primary cause of pain.[26-30] Even magnetic resonance imaging (MRI), which allows physicians to visualize the soft tissues within the spine, including the spinal nerve roots and the intervertebral discs, often fails to reveal the true source(s) of pain.[30-32] Without clear diagnoses to structure an effective and integrated treatment approach, physicians often rely on trial and error with a limited arsenal of existing therapies. Indeed, an article in The Wall Street Journal chronicled the story of a reporter who visited eight pain specialists and received eight different treatments for her low back pain, none of which provided meaningful relief.

Initial therapies for spinal pain currently include nonsteroidal anti-inflammatory drugs (NSAIDs), physical therapy, massage, chiropractic care, and transcutaneous electrical nerve stimulation (TENS). For patients who do not respond to these options, treatment progresses rapidly to invasive and expensive diagnostic tests and therapies, including MRI scanning, opioids (narcotics), injections, and surgical interventions. For the most intractable pain patients, there remain only highly invasive tools for managing pain, such as implantable opioid drug pumps and spinal cord stimulators.

Like low back pain, neck pain can have multiple and complex origins. Disorders of the cervical spine occur when discs in the neck wear out in the normal course of aging (degenerative disc disease) or are damaged by sudden movement (post-traumatic syndrome or whiplash), repetitive activity, or are symptoms of a disease process. For one type of neck injury alone, whiplash, data indicate that between 1988 and 1996, there were over 800,000 whiplash injuries due to motor vehicle accidents in the United States resulting in a total annual cost of $5.2 billion[34]. As for aging, it is estimated that about half of the population shows evidence of degenerative changes in the cervical spine by age fifty. As the U.S. population ages, the problem of cervical pain will continue to increase with a limited range of treatment options for a growing number of patients. For those who do not respond to early treatment, the path from conservative therapies to riskier and more invasive interventions can be short, in part due to the limited number of effective treatment alternatives.

What is lacking in the treatment continuum for spinal pain are therapies that:

- Significantly reduce pain and associated medication intake
- Facilitate rehabilitation and help restore function
- Are well-tolerated and non-addictive
- Pose a low risk of complications, such as gastrointenstinal ulcers, infection, or nerve injury
- Provide meaningful pain relief early enough in the pain cycle to help prevent the development of unremitting chronic pain and its accompanying depression and disability
- Are cost effective

Percutaneous Electrical Stimulation for Spinal Pain

Percutaneous electrical stimulation meets all of these criteria and, as discussed below, has been proven to be efficacious in the treatment of spinal pain. This procedure involves the delivery of electrical stimulation directly to the deep paraspinal tissues, where nerve pathways leading to the spinal column reside. Percutaneous electrical stimulation is believed to modulate these neural pathways by stimulating nerve fibers that lie in the deep tissues. Stimulating these deep-tissue nerve fibers allows the body to "unlearn" the pain response, bringing neural activity back into balance over time and returning it to a more normal state of signal processing. A percutaneous approach is critical in order to bypass the high electrical impedance of the skin, enabling the delivery of sufficient electrical current to elicit a pain modulation response. This explanation is supported by studies such as one demonstrating that in an animal model, electrical stimulation of peripheral nerves leads to inhibitory input to pain pathways at the level of the spinal cord[35]. Importantly, the cumulative effects of such stimulation may relate to neuroplasticity—the central nervous system's ability to adapt or "rewire" in response to stimuli or injury. As a result, the therapy may provide sufficient relief to prevent further progression to more persistent or chronic pain.

Results of Clinical Trials

In the five studies reviewed here, investigators at the Eugene McDermott Center for Pain Management at the University of Texas Southwestern Medical Center demonstrated that percutaneous electrical stimulation improved several outcome measures for spinal pain. In these studies the researchers examined the following:

- In patients with chronic neck pain, does the location of electrical stimulation affect analgesic response?
- How does percutaneous electrical stimulation compare with other treatment modalities, specifically TENS, lumbar flexion-extension exercises, and placebo?
- How does frequency of percutaneous electrical stimulation administration affect relief of low back pain?
- What is the dose-response of percutaneous electrical stimulation when given to provide relief of low back pain?
- How does placement of electrodes during administration of percutaneous electrical stimulation affect outcome in patients with acute low back pain?

These randomized, crossover studies compared the effectiveness of percutaneous electrical stimulation with conventional treatments and/or a sham treatment for chronic low back and neck pain. Enrolled patients had radiological evidence of degenerative disc disease and the clinical symptoms of spinal pain. Patients had experienced persistent pain, despite treatments with oral nonopioid analgesics, for at least three months prior to the studies without chance in character or severity. Each study comprised 60–75 patients, including both men and women representing a broad age range.

Percutaneous Electrical Stimulation Positively Affected Outcome Measures

In a study published in *JAMA,*[36] Ghoname et al. reported the results of a randomized, single-blinded, sham-controlled, crossover study of patients with low back pain. The investigators compared percutaneous electrical stimulation with three different control treatments: 1) TENS, 2) lumbar flexion-extension exercises, and 3) sham percutaneous stimulation. As with the other studies reviewed in this report, the 31 women and 29 men participating in this study were categorized as having nonspecific low back pain with associated degenerative disc disease.

As part of the crossover design, patients were randomly assigned to four treatment groups, each of which received the four treatment modalities in random sequences over a 15-week period. Treatment modalities were administered for 30 minutes, three times a week for three weeks, followed by a one-week washout period.

Percutaneous electrical stimulation was administered via fine-gauge electrodes placed 2–4 cm deep in the lower back. The electrical stimulation was applied at a frequency of 4 Hz, and the amplitude of the stimulation was adjusted to produce the maximum tolerable “tapping” sensation without muscle contraction. With sham stimulation, percutaneous electrodes were placed, but no electrical stimulation was administered. In order to avoid bias against possible placebo, patients were told that stimulation levels could be quite low during their treatments. Treatment with TENS consisted of four surface electrodes arrayed in a standard TENS pattern with electrical stimulation at a frequency of 4 Hz. Lumbar flexion-extension exercises were performed while the patient was sitting in a chair.

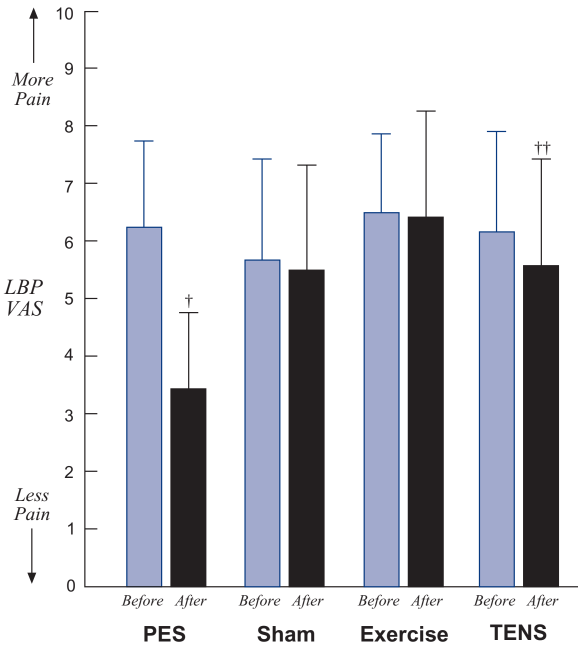
For the course of the study, patients were instructed not to change the type of any analgesic medication they were using. Patients made diary recordings of their oral analgesic use and any reactions they had to the applied treatments.

Outcomes

Patients’ responses to each of the treatment modalities were assessed with the Health Status Survey Short Form (SF-36), which patients filled out at the outset of the study and within 24 hours of completing the ninth and last treatment session for each modality. In addition, patients used a 10-cm visual analog scale (VAS) to rate their low back pain, physical activity, and quality of sleep during the 48 hours before each treatment session. The pain score also was reported immediately after completion of each treatment session.

Percutaneous electrical stimulation produced significantly reduced pain levels ($P<0.02$) and oral analgesic intake ($P<0.03$), as well as greater improvements in physical activity and sleep quality ($P<0.02$), than all of the other treatments tested in this trial.

Figure 1. Percutaneous electrical stimulation (PES) reduced pain better than other treatment modalities.



Mean visual analog scale (VAS) scores for low back pain (LBP) before treatment and 24 hours after the ninth treatment session with each of four modalities. Error bars show SD. PES, percutaneous electrical stimulation; TENS, transcutaneous electrical nerve stimulation. † Significantly different from value before treatment, P<0.03, and from sham stimulation, exercise therapy, and TENS, P<0.02. †† Significantly different from value before the first treatment, P<0.04.

Reduced pain

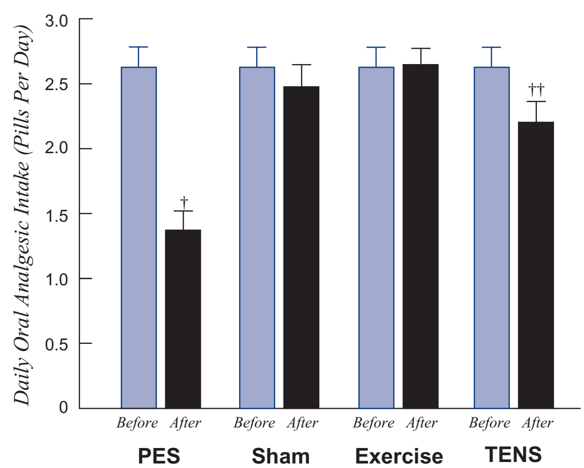
Over the 21-day treatment course, percutaneous electrical stimulation was associated with significantly greater reductions in pain (46% ± 18%, from 6.3 ± 1.5 to 3.4 ± 1.4 cm) than were TENS (11% ± 14%, from 6.2 ± 1.7 to 5.6 ± 1.9 cm), sham stimulation (no significant improvement in pain), and exercise (no significant improvement in pain) ($P<0.007$), as scored on the visual analog scale *(Figure 1)*.

Pain relief associated with percutaneous electrical stimulation was immediate and also demonstrated cumulative effects. The average acute decrease in pain after each individual treatment session, comparing the visual analog pain scores, was more than threefold greater with percutaneous electrical stimulation (82% ± 23%) compared with TENS (26% ± 19%). Sham stimulation and exercise achieved no significant reduction in pain scores. After 3–4 percutaneous electrical stimulation treatments, patients began reporting lasting pain relief, as evidenced by significant improvements in pretreatment pain, activity, and sleep scores ($P<0.03$).

Decreased intake of oral analgesics

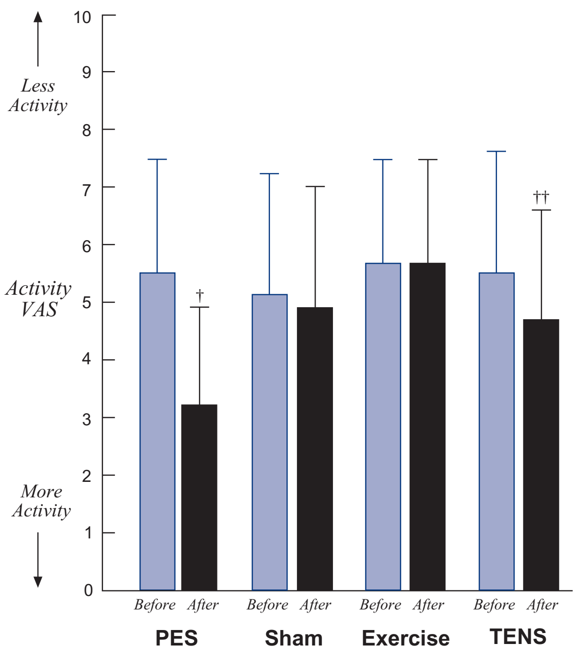
Beginning on the second day of treatment and for every subsequent day of the 21-day treatment period, percutaneous electrical stimulation was associated with a 50% reduction in intake of daily oral analgesics compared with pretreatment intake ($P<0.008$). TENS also reduced intake of oral analgesics, but to a much lesser degree and only on six days of the 21-day treatment course ($P<0.04$). Sham stimulation and exercise did not change patients' oral analgesic intake (*Figure 2*).

Figure 2. Percutaneous electrical stimulation (PES) reduced daily oral analgesic requirements.



Mean daily intake of oral analgesic medications before treatment and on the last day of the three-week treatment period with each of the four study modalities. Values are mean ± SEM. † Significantly different from prestudy value, P<0.008, and from sham stimulation, exercise therapy values, and transcutaneous electrical nerve stimulation (TENS), P<0.03. †† Significantly different from prestudy value, P<0.04.

Figure 3. Percutaneous electrical stimulation (PES) improved physical activity.



Average visual analog scale (VAS) scores for level of activity before treatment and 24 hours after the ninth treatment session with each of the four modalities. Error bars show SD. † Significantly different from value before treatment, P<0.03, and from sham stimulation, exercise therapy, and transcutaneous electrical nerve stimulation (TENS), P<0.02. †† Significantly different from value before the first treatment, P<0.04.

Increased physical activity

Compared with pretreatment scores, percutaneous electrical stimulation increased physical activity 42% ± 19% (from 5.5 ± 2.0 to 3.2 ± 1.7 cm, P<0.03). TENS improved physical activity 15% ± 16% (from 5.5 ± 2.1 to 4.7 ± 1.9 cm, P<0.04). Sham stimulation and exercise did not increase physical activity *(Figure 3)*.

Improved quality of sleep

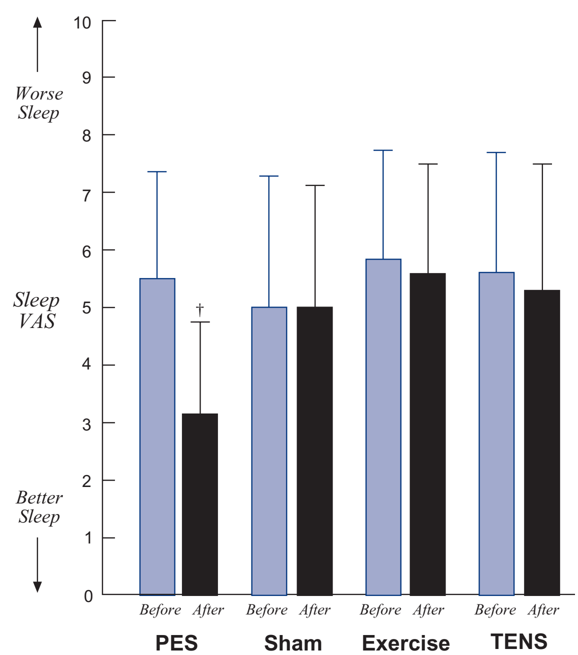
Percutaneous electrical stimulation improved quality of sleep from the pretreatment score by 44% ± 20% (5.5 ± 1.9 to 3.1 ± 1.6 cm, P<0.03). In comparison, no significant changes in quality-of-sleep scores were associated with TENS, sham stimulation, or exercise *(Figure 4)*.

Improved quality of life

Of the four treatment modalities, percutaneous electrical stimulation affected quality of life most positively, as assessed by the SF-36. As expected for patients with chronic low back pain, before treatment this patient population had significantly lower health-related physical and mental quality-of-life scores (28.4 ± 8.4 and 40.2 ± 5.0, respectively) than the general population, which has average scores of 50 for each category.

Physical and mental components of the SF-36 scores were significantly improved after treatment with percutaneous electrical stimulation (34.2 ± 7.4, P=0.003, and 42.8 ± 5.2, P=0.007, respectively). Both TENS and sham stimulation also were associated with statistically significant, although smaller, improvements. For TENS, the scores

Figure 4. Percutaneous electrical stimulation (PES) improved quality of sleep better than other treatment modalities.



Average visual analog scale (VAS) scores for quality of sleep before treatment and 24 hours after the ninth treatment session with each of the four modalities. Error bars show SD. † Significantly different from value before treatment, P<0.03, and from sham stimulation, exercise therapy, and transcutaneous electrical nerve stimulation (TENS), P<0.02.

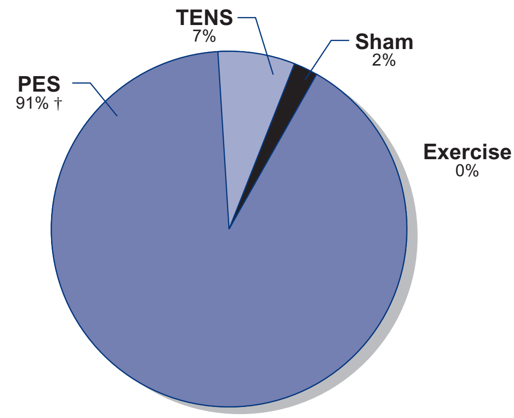
were 29.6 ± 8.4 for the physical component and 41.1 ± 5.5 for the mental component (P<0.02). For sham stimulation, the scores were 29.4 ± 8.6 for the physical component and 41.0 ± 5.4 for the mental component (P<0.02).

The preferred treatment

At the end of the study, patients compared the four treatment modalities. Fifty-five of the 60 patients (91%) identified percutaneous electrical stimulation as the preferred pain therapy, and 46 patients (76%) indicated that it most improved their sense of well-being. In addition, 31 of 38 patients (81%) who reported improvement in their level of physical activity indicated that it was most improved after treatment with percutaneous electrical stimulation. In comparison, four patients (7%) identified TENS as the preferred pain therapy, 10 patients (16%) identified it as most improving their sense of well-being, and five of 38 patients (13%) identified it as most improving their physical activity.

Percutaneous electrical stimulation scores differed significantly from the TENS scores, as well as from scores for sham stimulation and exercise. For example, one patient (2%) identified sham stimulation as the preferred pain therapy, seven patients (12%) identified it as improving their sense of well-being, and two of 38 patients (5%) indicated that it most improved their level of physical activity. For exercise, six patients (10%) felt it most improved their sense of well-being, but no patients selected it as the preferred pain therapy or the treatment that most improved their level of physical activity *(Figure 5)*.

Figure 5. Patients preferred percutaneous electrical stimulation (PES).



The overall evaluation of treatment modalities indicated that percutaneous electrical stimulation was the preferred therapy for 91% of the study patients. † Significantly different from transcutaneous electrical nerve stimulation (TENS), sham stimulation, and exercise therapy, P<0.02.

Treatment Variables and Their Impact on Outcomes

In three additional studies, these investigators examined key variables to optimize the effectiveness of percutaneous electrical stimulation for low back pain, including:

- Frequency modulation
- Duration of treatment
- Placement of electrodes

In all three studies, percutaneous electrical stimulation was associated with significant pain relief, decreased intake of oral analgesics, improved physical activity, and better quality of sleep compared with control treatments.

Stimulation frequency affects efficacy of percutaneous electrical stimulation

The investigators of this study, which was published in *Anesthesia & Analgesia,* designed a randomized, investigator-masked, crossover study to evaluate the effect of changes in frequency of percutaneous electrical stimulation on acute relief of low back pain.[7] Thirty men and 38 women with stable levels of chronic low back pain were treated with sham percutaneous stimulation, as well as with percutaneous electrical stimulation at 4 Hz, at 100 Hz, and at a frequency that alternated between 15 and 30 Hz every three seconds. Treatment sessions were randomized and were delivered for 30 minutes, three times per week for two weeks, with a one-week washout period between each type of treatment.

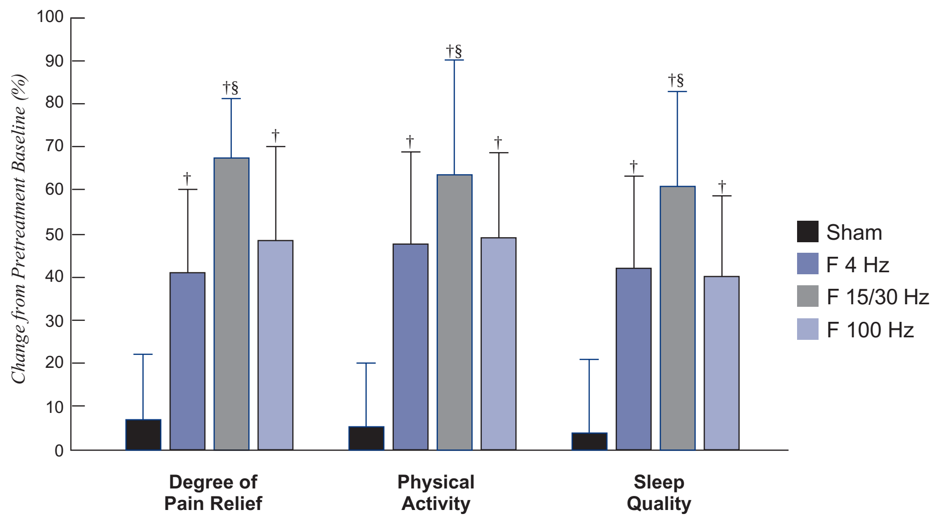
All three stimulation frequencies were associated with significant acute decreases in pain, as well as with decreased use of oral analgesics, improved physical activity, and improved quality of sleep after the two-week treatment period. Notably, variable frequencies proved to be more effective than single-frequency treatments ($P<0.05$). Sham stimulation did not improve outcomes compared with pretreatment *(Figure 6).*

Dose affects efficacy of percutaneous electrical stimulation

In a randomized, crossover study published in *Anesthesiology,* the investigators evaluated the effect of duration of percutaneous electrical stimulation on treatment-associated relief of low back pain.[37] Over the course of the study, 75 patients received two weeks of thrice-weekly percutaneous electrical stimulation with 0-, 15-, 30-, and 45-minute stimulation sessions. Patients were told that each session would last 60 minutes and include various periods of electrical stimulation. Assignment to treatment order was random, and the two-week treatments were separated by one-week washout periods.

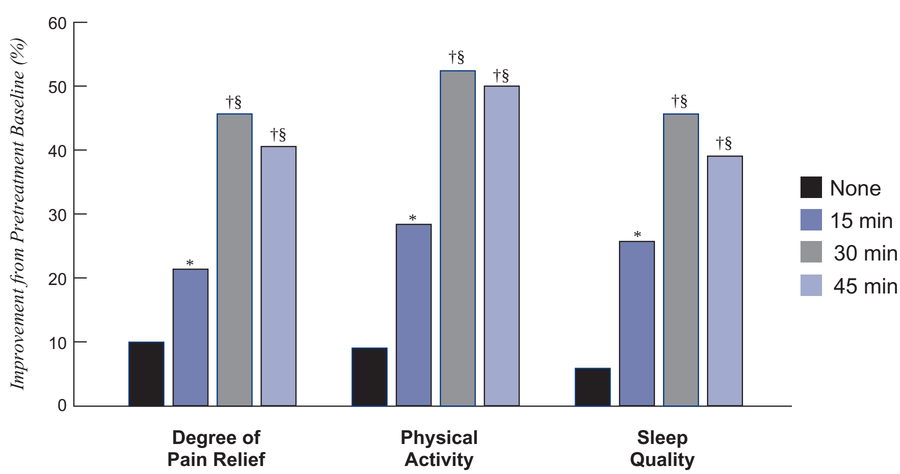
Duration of electrical stimulation affected quality of life, acute pain relief, level of physical activity, and quality of sleep *(Figure 7).* Stimulation for 15, 30, and 45 minutes improved SF-36 scores. Improvement was greater for the 30- and 45-minute stimulation periods than for the 15-minute stimulation

Figure 6. Frequency sensitivity: Alternating between frequencies better than single frequency.



Percent improvement from baseline (24 hours before the first treatment session with each modality) in pain relief, physical activity, and sleep quality at the end of each two-week treatment period. Data are mean ± SD. † P<0.05 compared with sham stimulation values. § P<0.05 compared with 4 Hz and 100 Hz values. Figure and legend reprinted with permission (Ghoname EA, Craig WF, White PF, et al. The effect of stimulus frequency on the analgesic response to percutaneous electrical nerve stimulation in patients with chronic low back pain. Anesth Analg. 1999;88:841–846).

Figure 7. Dose response: Percutaneous electrical stimulation (PES) with 30- and 45-minute durations superior to 15-minute duration.



*Comparison of the percentage improvements from the baseline (24 hours before and after the first treatment session with each method) in the degree of pain relief, physical activity, and sleep quality at the end of each two-week treatment period. Data are mean values ± SEM. Significant differences compared with no electrical therapy values are designated as follows: * P<0.05; † P<0.01. Significant differences compared with 15-minute values are designated by § P<0.05. Figure and caption reprinted with permission (Hamza MA, Ghoname EA, White PF, et al. Effect of the duration of electrical stimulation on the analgesic response in patients with low back pain. Anesthesiology. 1999;91:1622–1627).*

session ($P<0.01$), but there was no significant difference between these two longer durations.

Electrical stimulation for 15 minutes ($P<0.05$), 30 minutes ($P<0.01$), and 45 minutes ($P<0.01$) was associated with significant, immediate decreases in pain compared with sham stimulation. Twenty-four hours after the sixth (last) treatment of each of these three durations, pain, physical activity, and quality of sleep were significantly improved compared with 24 hours before the treatment (15 minutes, $P<0.05$; 30 and 45 minutes, $P<0.01$). Findings were similar for decreased use of oral analgesics. In all measured outcomes, 30- and 45-minute electrical stimulation sessions were more effective than 15-minute stimulation sessions, and all three durations of electrical stimulation were better than sham stimulation. No statistically significant difference was seen between 30- and 45-minute stimulation sessions.

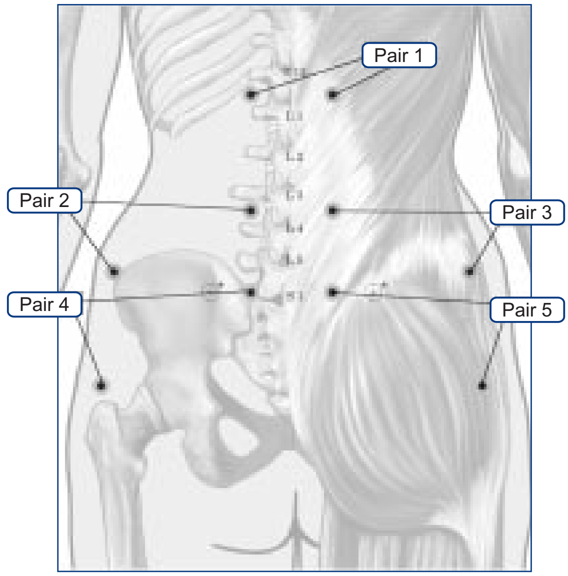
Anatomic location affects efficacy of percutaneous electrical stimulation in the treatment low back pain.

Investigators designed a randomized, single-blind, crossover study to determine whether the specific anatomic location of percutaneous electrodes (montage) affects acute relief of low back pain.[38] This study, published in Anesthesia & Analgesia, enrolled 31 men and 41 women ages 21–76 who had stable symptoms of low back pain for at least six months. Thirty-minute treatments were given three times a week for two consecutive weeks, with a one-week washout period between different montages. Patients were randomly assigned orders of montages.

Four montages were compared. The first had been used in prior studies.[8,36,37] In montages II–IV, electrical stimulation was applied at differing positions within the same dermatomes. All four montages were associated with significant improvements in SF-36 quality-of-life scores. However, improvement was greater with montages I and II than with III and IV (P<0.05).

All four montages also were associated with significant pain relief immediately after each treatment session, but the cumulative effect over the two-week treatment period was greater with montage II than with the other montages *(Figure 8)*. In addition, improvement in quality of sleep as measured on a visual analog scale was better with montage II than with the other montages (P<0.05), and increase in physical activity was better with montage II than with montages III and IV (P<0.05) *(Figure 9)*. Similarly, although all of the montages were associated with decreased use of oral analgesics, montages I and II were associated with greater decreases than montages III and IV (P<0.05).

Figure 8. Anatomic location of percutaneous electrodes (montage) for the treatment of low back pain.

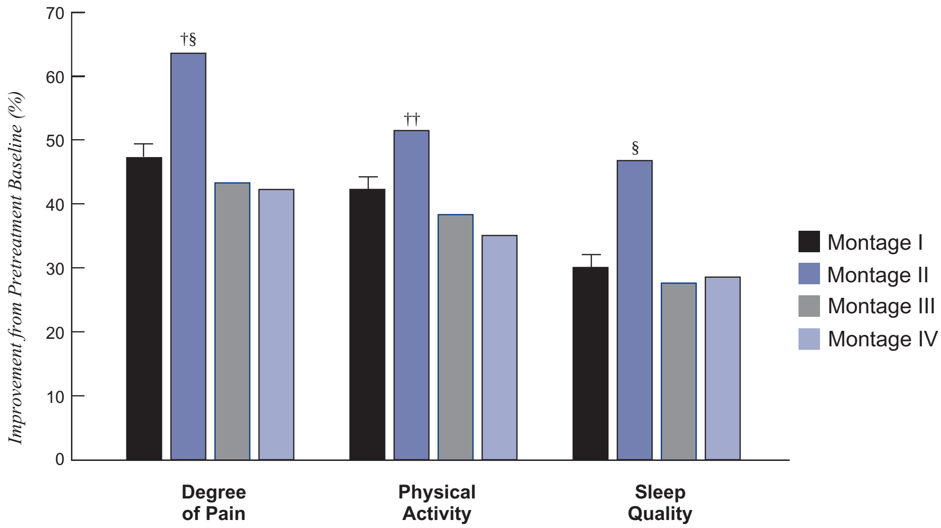


Four montages were compared in a randomized, crossover study of the effects of percutaneous electrical stimulation on low back pain. This figure illustrates the most-effective electrode positions and pairings (montage II).

Location of electrical stimulation affects efficacy of percutaneous electrical stimulation in the treatment of chronic neck pain.

In a study published in Anesthesia & Analgesia, White, et al. reported that percutaneous electrical stimulation delivered in the neck region produced significant improvements in pain control, physical

Figure 9. Anatomic location of percutaneous electrodes (montage) affected treatment outcomes.



Improvement in mean visual analog scale (VAS) scores for pain, level of activity, and quality of sleep 24 hours after the last treatment with each montage. Improvement is expressed as a percentage of the mean VAS score from the period 24 hours before the first treatment. † Significantly different from the 24-hour period before first treatment, P<0.01. †† Significantly different from montages III and IV, P<0.05. § Significantly different from montages I, III, and IV, P<0.05.

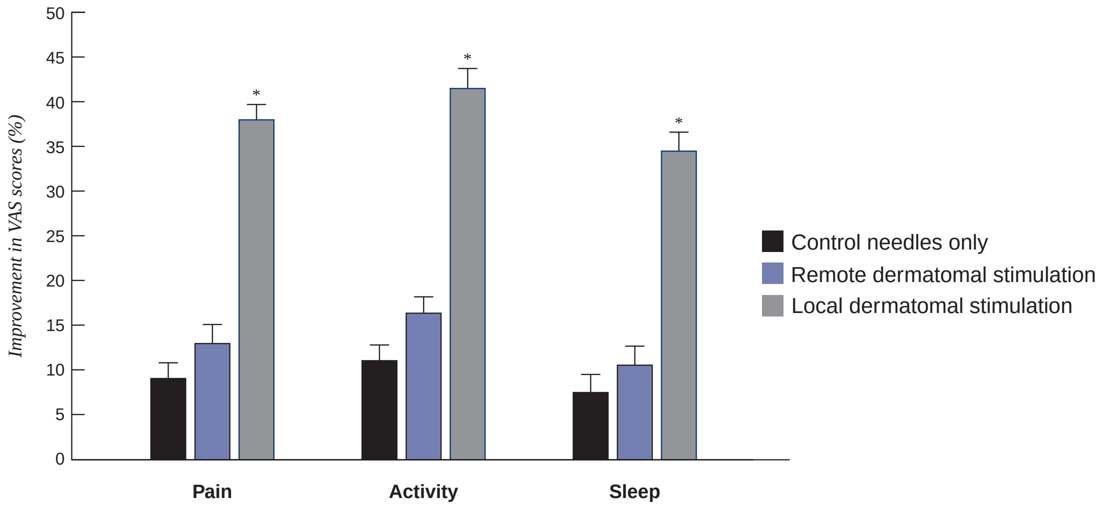
activity, and quality of sleep in patients with chronic neck pain[39]. The study showed that percutaneous electrical stimulation used at the location of the specific dermatomal levels corresponding to patients' neck pain resulted in notably greater improvements over either remote percutaneous electrical stimulation delivered in the lower back region or locally deployed electrodes (neck region) with no stimulation.

Researchers designed a randomized, investigator blinded, sham-controlled crossover study involving 68 patients with a mean age of 52 (± 23 years), all suffering from chronic non-radiating neck pain for at least three months before enrollment. The presence of cervical disk disease was confirmed in all study participants. All patients received the three treatment modalities during the 11-week study period.

As with the lumbar studies, percutaneous electrical stimulation was administered via fine-gauge electrodes placed 2–4 cm deep in the cervical region. Electrical stimulation was applied at an alternating frequency of 15 Hz and 30 Hz (15/30 Hz) and the amplitude of the stimulation was adjusted to produce a tolerable "tapping" sensation without muscle contraction. With sham stimulation, percutaneous electrodes were placed, but no electrical stimulation was administered. Percutaneous electrical stimulation was also administered remotely. This consisted of placing ten fine-gauge needle electrodes to a depth of 2–4 cm in the lower back region. The parameters of electrical stimulation were identical to the cervical stimulation therapy. Patients received each of the three treatments three times per week for three consecutive weeks with a one-week washout period between each modality.

Researchers used the Health Status Survey Short Form (SF-36) and a 10–cm visual analog scale (VAS) for evaluating pain, physical activity and quality of sleep. Patients completed the SF-36 and the visual analog scores before treatment began. The physical component summary (PCS) and the mental component summary (MCS) of the SF-36 were used to assess responses to all three therapies. Patients assessed their level of neck pain, physical activity and quality of sleep during the 24-hour

Figure 10. Comparison of the percentage improvements in pain, activity and sleep visual analog score (VAS) scores.



*Comparison of the percentage improvements in pain, activity and sleep visual analog score (VAS) scores between the baseline values 24 h before the first treatment session with each modality and the values 24 h after completion of each 3-wk treatment period. Data are mean values ± SEM. Symbols indicate significant differences compared with the control needles only and remote dermotomal stimulation values, *P < 0.05.*

period prior to the first treatment and 24 hours following the last treatment with each modality.

The visual analog scale was reassessed five to ten minutes after completing each treatment session to measure the acute analgesic response. Patients were also asked to record their daily intake of oral nonopioid analgesics in a diary. At baseline, the mean visual analog scale was 7.8 ± 2.5 cm and the mean duration of pain was 43 months (±19 months).

Significant pain reduction

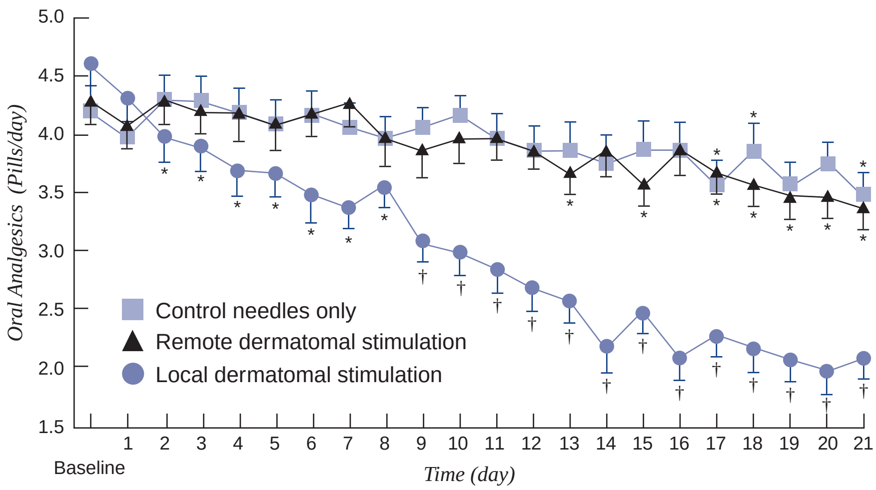
Local dermatomal stimulation in the neck produced significantly greater decreases in pain scores after each of the nine treatment sessions (P<0.01) than either electrodes only or remote dermatomal stimulation in the low back region. Compared to baseline, local dermatomal stimulation (neck) resulted in a 38% (± 17%) reduction in pain while patients treated with electrodes only had a 9% (± 16%) reduction and those treated remotely (lower spine) had a 13% reduction (±18%) in pain *(Figure 10).* Further, patients began to report more sustained pain relief with local, dermatomally applied percutaneous electrical stimulation after only two–three treatments.

Local percutaneous electrical stimulation (neck region) also demonstrated cumulative effects over the course of the nine-treatment protocol as evidenced by measurable decreases in the pre-treatment pain VAS scores at the last seven treatment sessions.

Increased physical activity

Patients who received percutaneous electrical stimulation locally (neck) reported a 41% increase (±21%) in physical activity while those treated locally without stimulation had an 11% increase (±17%) and those treated remotely (low back region) experienced an increase of 16% (±15%) compared to baseline values (P<0.05) (Figure 10).

Figure 11. Changes in daily oral intake of analgesic medications.



*Changes in the daily oral intake of non-opioid analgesic medications (pills per day) during the 3-wk treatment period with each of the three modalities. Data are mean values ± SEM. Symbols indicate significant changes from the values 24 h before the first treatment (baseline), *P < 0.005 and* †P < 0.01.

Improved quality of sleep

Patients treated locally with percutaneous electrical stimulation had a 34% (±18%) improvement in quality of sleep while those treated with electrodes only (no stimulation) experienced a 7% improvement (± 17%) and those treated remotely with percutaneous electrical stimulation had a 10% (±18%) improvement compared to baseline *(Figure 10).*

These findings are important because they suggest that percutaneous electrical stimulation may enhance a patient's ability to participate in therapeutic activities such as physical rehabilitation that can lead to functional improvement.

Decreased intake of oral analgesics

Local dermatomal stimulation produced a significantly greater decrease in the daily oral analgesic requirements than either of the other two treatment modalities (P<0.05). The need for oral analgesics decreased by an average of 37% (±18%) with percutaneous electrical stimulation administered locally (neck), 6% (±15%) with local sham stimulation, and 9% (±13%) with remote percutaneous stimulation (lower back region) *(Figure 11).*

Improvement statistically significant

The post-treatment SF-36 scores showed that all three modalities produced improvements over baseline scores, but the magnitude of the changes in the physical component summary (PCS) and the mental component summary (MCS) were significantly greater with local dermatomal stimulation,+7.9 for PCS and +3.6 for MCS compared to the group treated with electrodes only,+3.4 for PCS and +1.7 MCS; and those treated with remote percutaneous electrical stimulation, +3.7 for PCS and +1.9 for MCS (P<0.05).

Researchers concluded that use of local percutaneous electrical stimulation resulted in less severe body pain, fewer limitations in self-care, less psychological distress, lower levels of disability, and an enhanced ability to participate in rehabilitative therapies. The study provides further evidence that percutaneous electrical stimulation represents a safe and effective form of electroanalgesic therapy.

Discussion

Based on results from five separate clinical trials, investigators from the University of Texas have shown percutaneous electrical stimulation to be superior to other treatments studied for pain reduction and related outcomes among independent samples of lumbar and cervical pain patients. Prior to study enrollment, pain control in these patients consisted of at least three months of a steady regimen of nonopioid analgesics. For some patients, including 42% of those enrolled in one study,[37] these analgesics were necessary despite a history of previous back surgery.

In these studies, patients whose spinal pain was relieved by percutaneous electrical stimulation included men and women ranging in age from 21–76,[7,37,39] reflective of the broad age distribution and nearly equal gender distribution of patients affected by spinal pain. As anticipated with this minimally invasive, nonsurgical treatment, these studies reported no occurrences of significant treatment complications. This result contrasts with the known side-effect profiles of commonly used treatments for spinal pain. For example, NSAIDS, often considered a relatively benign treatment for pain, can cause gastrointestinal upset, bleeding, and damage to the liver or kidneys.[2] Opioid-based medications to treat spinal pain can cause nausea, constipation, sedation, and even delirium, especially among older patients, as well as the potential for increased dependence, tolerance, and addiction. Invasive treatments, such as surgical procedures and diagnostic/therapeutic injections, are often associated with significant complications, including headache, infection, nerve root injury, and a not-uncommon condition called "failed back surgery syndrome."[40]

Study design considerations

In the design of these studies, the investigators attempted to address challenges inherent in the clinical research of procedural therapies. For example, a possible placebo effect associated with the placement of electrodes was taken into account by the use of a sham treatment (electrode placement without electrical stimulation) as a control arm. However, this sham treatment could not be entirely blinded to patients, since they would note the absence of electrical stimulation. Therefore, investigators told patients that they would feel different degrees of stimulation during treatment sessions, without suggesting that efficacy might correspond with intensity or duration of stimulation. The fact that significant differences were seen between the 15-minute duration versus 30- and 45-minute durations of stimulation indeed suggests that the results of this therapy cannot be entirely associated with a placebo effect. Further, in one study the investigator was blinded to treatment, although patients were not,[38] and the random-order, crossover design of these studies with a washout period would be expected to offset the effect of previous treatments delivered to each patient.

Additional studies may be undertaken to identify subsets of patients who would benefit most from this treatment. Although these studies were conducted with chronic pain patients, clinical experience and the medical literature both confirm more pronounced benefits among patients with a subacute duration of pain. As discussed earlier, a therapy that is effective in treating spinal pain in its early stages has the potential to reduce the number of patients who progress to the chronic stage, where pain can become intractable and lead to long-term disability and depression.

Table 1. Five peer-reviewed studies of the effects of percutaneous electrical stimulation on nonacute spinal pain demonstrated that the therapy reduced pain, improved function, decreased analgesic intake, and improved sleep.

Study	Number of patients	Main conclusion
Ghoname et al. ***JAMA***[32]	60	Percutaneous electrical stimulation relieves pain and improves function better than sham stimulation, exercise therapy, and transcutaneous electrical nerve stimulation (TENS).
Ghoname et al. ***Anesthesia & Analgesia***[5]	68	Frequency (Hz) of electrical stimulation influences response to percutaneous electrical stimulation: Alternating frequency is more effective than constant frequency.
Hamza et al. ***Anesthesiology***[33]	75	Duration of stimulation influences response to percutaneous electrical stimulation: 30- and 45-minute durations are most effective.
White et al. ***Anesthesia & Analgesia***[34]	72	Placement of electrodes influences optimum response to percutaneous electrical stimulation.
White et al. ***Anesthesia & Analgesia***[39]	68	Local dermatomal stimulation (percutaneous electrical stimulation) relieves pain and improves function better than local sham stimulation (neck) and remote percutaneous stimulation (lower back), representing a safe and effective form of electroanalgesic therapy in patients with chronic cervical (neck) pain.

Five randomized, crossover studies were conducted at the McDermott Center for Pain Management at the University of Texas Southwestern Medical Center. The studies compared the effectiveness of percutaneous electrical stimulation with conventional treatments and/or with sham stimulation for lumbar and cervical pain and evaluated optimization of therapy based on variations in the delivery of the therapy.

Summary

These five randomized, crossover studies of percutaneous electrical stimulation provide compelling clinical evidence that this minimally invasive, low risk therapy can safely and positively affect outcomes for patients with a wide variety of acute and chronic spinal pain syndromes. As compared with other commonly used treatments, it significantly:

- Reduced pain
- Decreased the use of oral analgesics
- Increased levels of physical activity
- Improved quality of sleep

Furthermore, the therapy was utilized without any significant treatment complications or side effects and was the treatment of choice for most patients.

The investigators found that, although pain relief was achieved at all frequencies and anatomic locations used in these studies, the relative effectiveness of percutaneous stimulation is influenced by:

- Variations in the frequency (Hz) of the electricity used for stimulation
- Duration of each treatment session
- Anatomic location of the stimulating electrodes

Thus, the investigators have established a foundation for evidence-based percutaneous electrical stimulation treatment protocols.

In order for percutaneous electrical stimulation to have a widespread impact on spinal pain, it is essential that physicians be able to deliver this therapy in a consistent, reliable, and cost-effective manner, and within the constraints of a space- and time-limited outpatient practice. Percutaneous neuromodulation therapy, or PNT, achieves this objective with a system that is designed to be practical for delivering percutaneous electrical stimulation in a variety of clinical settings.

The PNT System and procedure for spinal pain have been optimized based on the research done at the University of Texas. Sharps-safe filament electrodes are temporarily inserted (3–cm for lumbar; 2–cm for cervical) in specific, predetermined locations along the spine (representative of montage II in previously discussed study, *Figure 8*). Percutaneous electrical stimulation then is delivered for 30 minutes within specific alternating frequency parameters (Figure 12).

As the standardized form of percutaneous electrical stimulation, PNT provides physicians with a therapy that is currently missing from the spinal pain treatment continuum—one that can be utilized safely and cost-effectively after noninvasive therapies and medications have failed to resolve acute pain, but ideally before patients develop chronic pain and its associated depression and disability. Treatment options for the chronic spinal pain patient include surgery, repeated epidural or other spinal injections, a spinal cord stimulation trial, chronic oral or pump-delivered opioids, and interdisciplinary pain management programs. The void in treatment options for chronic cervical pain patients is particularly notable, with a significant lack of alternatives between first-line therapies and risker, more interventional options such as a cervical neurotomy or discectomy. Most of these options to treat spinal pain are invasive and expensive, often running into the tens of thousands of dollars, and overall offer only mixed efficacy. PNT shows promise as a precursor, adjunct, or alternative to these more invasive and expensive therapies.

Figure 12. Percutaneous neuromodulation therapy (PNT) for low back pain.

Percutaneous neuromodulation therapy involves the delivery of electrical stimulation to the deep tissues near the spine through five pairs of fine-gauge, sharps-safe filament electrodes temporarily inserted to a depth of 3 centimeters. The electrodes enable the delivery of electrical stimulation directly to the deep tissues in order to reach the nerve pathways that lead to the dorsal horn of the spinal column, where pain signals are processed and transmitted to the brain.

In summary, PNT has the potential to provide spinal pain patients with a therapy that reduces pain and subsequently helps to facilitate rehabilitation and restore function. As such, PNT represents an important standard of care in the treatment of one of our society's most pervasive, debilitating, and costly healthcare problems.

References

1. *Fast Facts About Pain.* Baltimore, Md: American Pain Foundation; 2001.

2. *National Pain Survey.* Rochester, NY: Louis Harris & Associates; 1999.

3. Gore, DR. The Epidemiology of Neck Pain. Medscape. 1998.

4. Patient page, Neck Injuries. *JAMA*. 2001; 286.

5. Andersson GBJ. The epidemiology of spinal disorders. In: Frymoyer JW, Ducker TB, eds. *The Adult Spine: Principles and Practice.* New York, NY: Raven Press, Ltd.; 1991:107–146.

6. Agency for Health Care Policy and Research. *Acute Low Back Problems in Adults: Clinical Practice Guideline.* Rockville, Md: U.S. Department of Health and Human Services; 1994. AHCPR Publication No. 95–0642.

7. Ghoname EA, Craig WF, White PF, et al. The effect of stimulus frequency on the analgesic response to percutaneous electrical nerve stimulation in patients with chronic low back pain. *Anesth Analg.* 1999;88:841–846.

8. Cypress BK. Characteristics of physician visits for back symptoms: A national perspective. *Am J Public Health.* 1983;73:389–395.

9. Guo H, Tanaka S, Halperin WE, Cameron LL. Back pain prevalence in US industry and estimates of lost workdays. *Am J Public Health.* 1999;89:1029–1035.

10. Frymoyer JW, Cats-Baril WL. An overview of the incidences and costs of low back pain. *Orthop Clin North Am.* 1991;22:263–271.

11. Frymoyer JW, Pope MH, Clements JH, et al. Risk factors in low-back pain. *J Bone Joint Surg Br.* 1983;65–A:213–218.

12. Lawrence RC, Helmick CG, Arnett FC, et al. Estimates of the prevalence of arthritis and selected musculoskeletal disorders in the United States. *Arthritis Rheum.* 1998;41:778–799.

13. Cunningham LS, Kelsey JL. Epidemiology of musculoskeletal impairments and associated disability. *Am J Public Health.* 1984;74:574–579.

14. Hooper, DC. Occupational Neck Pain. *chiroweb.com*; 2002.

15. Biewen PC. A structured approach to low back pain: Thorough evaluation is the key to effective treatment. *Postgrad Med.* 1999;106:102–114.

16. Cherkin DC. Primary care research on low back pain: The state of the science. *Spine.* 1998;23:1998–2002.

17. Sotgiu ML, Biella G. Spinal neuron sensitization facilitates contralateral input in rats with peripheral mononeuropathy. *Neurosci Lett.* 1998;241:127–130.

18. Ren K, Dubner R. Central nervous system plasticity and persistent pain. *J Orofac Pain.* 1999;13:155–163.

19. Millan MJ. The induction of pain: An integrated review. *Prog Neurobiol.* 1999;57:1–164.

20. Johansen MK, Graven-Nielsen T. Generalised muscular hyperalgesia in chronic whiplash syndrome. *Pain.* 1999;83:229–234.

21. Gharibo CG. Spinal injections in diagnosis and treatment of low back pain. Pain.com. 1999.

22. Cooper JE, Tate RB, Yassi A, Khokhar J. Effect of an early intervention program on the relationship between subjective pain and disability measures in nurses with low back injury. *Spine.* 1996;21:2329–2336.

23. Loisel P, Abenhaim L. A population-based, randomized clinical trial on back pain management. *Spine.* 1997;22:2911–2918.

24. Hagen EM, Eriksen HR, Ursin H. Does early intervention with a light mobilization program reduce long-term sick leave for low back pain? *Spine.* 2000;25:1973–1976.

25. Fishman S, Berger L. *The War on Pain: How Breakthroughs in the New Field of Pain Medicine Are Turning the Tide Against Suffering.* 1st ed. New York, NY: Harper Collins; 2001.

26. Schwarzer AC, Aprill CN, Derby R, Fortin J, Kine G, Bogduk N. The relative contributions of the disc and zygapophyseal joint in chronic low back pain. *Spine.* 1994;19:801–806.

27. Schwarzer AC, Wang S, O'Driscoll D, Harrington T, Bogduk N, Laurent R. The ability of computed tomography to identify a painful zygapophysial joint in patients with chronic low back pain. *Spine.* 1995;20:907–912.

28. Schwarzer AC, Aprill CN, Derby R, Fortin J, Kine G, Bogduk N. Clinical features of patients with pain stemming from the lumbar zygapophysial joints: Is the lumbar facet syndrome a clinical entity? *Spine.* 1994;19:1132–1137.

29. Slipman CW, Sterenfeld EB, Chou LH, Herzog R, Vresilovic E. The predictive value of provocative sacroiliac joint stress maneuvers in the diagnosis of sacroiliac joint syndrome. *Arch Phys Med Rehabil.* 1998;79:288–292.

30. Beattie PF, Meyers SP, Stratford P, Millard RW, Hollenberg GM. Associations between patient report of symptoms and anatomic impairment visible on lumbar magnetic resonance imaging. *Spine.* 2000;25:819–828.

31. Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects: A prospective investigation. *J Bone Joint Surg Br.* 1990;72–A:403–408.

32. Jensen MC, Brant-Zawadzki MN, Obuchowski N, Modic MT, Malkasian D, Ross JS. Magnetic resonance imaging of the lumbar spine in people without back pain. *N Engl J Med.* 1994;331:69–73.

33. Gubernick L. Health: Have I got a cure for you! *The Wall Street Journal,* October 6, 2000:W1.

34. National Highway Traffic Safety Administration, Federal Motor Vehicle Safety Standards; Head Restrainers, 49 CFR, Part 571, NHTSA. 2000; 8750.

35. Hanai F. Effect of electrical stimulation of peripheral nerves on neuropathic pain. *Spine.* 2000;25:1886–1892.

36. Ghoname EA, Craig WF, White PF, et al. Percutaneous electrical nerve stimulation for low back pain: A randomized crossover study. *JAMA.* 1999;281:818–823.

37. Hamza MA, Ghoname EA, White PF, et al. Effect of the duration of electrical stimulation on the analgesic response in patients with low back pain. *Anesthesiology.* 1999;91:1622–1627.

38. White PF, Ghoname EA, Ahmed HE, Hamza MA, Craig WF, Vakharia AS. The effect of montage on the analgesic response to percutaneous neuromodulation therapy. *Anesth Analg*. 2001;92:483–487.

39. White PF, et al. Percutaneous Neuromodulation Therapy: Does the location of electrical stimulation effect the acute analgesic response? *Anesth Analg*. 2000;91:949–954.

40. Bell GK, Kidd D, North RB. Cost-effectiveness analysis of spinal cord stimulation in treatment of failed back surgery syndrome. *J Pain Symptom Manage.* 1997;13:286–295.

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