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Article in Research in Nursing & Health · December 2014
DOI: 10.1002/nur.21633

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Biofeedback Relaxation for Pain Associated With Continuous Passive Motion in Taiwanese Patients After Total Knee Arthroplasty

Tsae-Jyy Wang, Ching-Fen Chang, Meei-Fang Lou, Man-Kuan Ao, Chiung-Chen Liu, Shu-Yuan Liang, Shu-Fang Vivienne Wu, Heng-Hsing Tung

Abstract: Effective pain management is crucial for patient recovery after total knee arthroplasty (TKA). Biofeedback therapy, which encourages relaxation and helps alleviate various conditions associated with stress, may help to decrease postoperative pain in patients undergoing TKA. A quasi-experimental design was used to investigate the efficacy of a biofeedback relaxation intervention in reducing pain associated with postoperative continuous passive motion (CPM) therapy. Sixty-six patients admitted to a general hospital in Taiwan for TKA were recruited and randomly assigned to the intervention or control group. The intervention group received biofeedback training twice daily for 5 days, concurrent with CPM therapy, whereas the control group did not receive the biofeedback intervention. Pain was measured using a numeric rating scale before and after each CPM therapy session on postoperative days 1 through 5. The CPM-elicited pain score was calculated by subtracting the pre-CPM pain score from the post-CPM pain score. Results of repeated-measures analysis of variance showed intervention group reported significantly less pain caused by CPM than did the control group ($F = 29.70, p < 0.001$). The study results provide preliminary support for biofeedback relaxation, a non-invasive and non-pharmacological intervention, as a complementary treatment option for pain management in this population. © 2014 Wiley Periodicals, Inc.

Keywords: osteoarthritis; total knee replacement; postoperative pain; biofeedback; progressive muscle relaxation training; continuous passive motion

Research in Nursing & Health, 2015, 38, 39–50
Accepted 4 November 2014
DOI: 10.1002/nur.21633
Published online 30 December 2014 in Wiley Online Library (wileyonlinelibrary.com).
Total knee arthroplasty (TKA) is most commonly performed for knee osteoarthritis when nonsurgical treatments are no longer helpful (Ibrahim, Bloch, Esler, Abrams, & Harper, 2010; Otten, van Roernumd, & Picavet, 2010; Tien et al., 2009). The primary goal of TKA is to allow continued motion of the knee (Zhang et al., 2008); the damaged knee joint surface is replaced with metal and plastic material to relieve pain and improve knee function (American Academy of Orthopaedic Surgeons, 2010; Hohler, 2008). With proper rehabilitation, a successful outcome is achieved in the majority of patients (Hohler, 2008; Nilsdotter, Toksvig-Larsen, & Roos, 2009).

With an overweight and aging population and advances in arthroplasty surgery, the number of TKAs performed has been escalating over the years and is projected to continue increasing in the near future (Otten et al., 2010). The incidence of TKA nearly doubled from 2000 to 2010 in 15 member countries of the Organization for Economic Cooperation and Development (OECD; 2013). In 2010, there were 719,000 TKAs in the United States alone (CDC/National Center for Health Statistics, 2014). In Taiwan, the rate of TKA increased from 39.1/100,000 in 2000 to 86.6/100,000 in 2010, an increase of 122% (National Health Insurance Administration, 2012; Tien et al., 2009). In 2010, about 20,000 TKA procedures were done in Taiwan (National Health Insurance Administration, 2012).

In Taiwan, patients who undergo TKA typically receive continuous passive motion (CPM) treatment. Postoperative pain is often intensified during CPM. The increased pain can hinder patients’ recovery and prevent them from following the prescribed CPM therapy regimens. Biofeedback therapy, a biopsychosocial approach to symptom management, may aid conventional pain control and decrease the need for analgesics in TKA patients receiving CPM. Biofeedback therapy enhances the patient’s self-understanding of body signals, applying principles of self-regulation to alleviate discomfort (Durand, & Barlow, 2009; Shaffer, & Moss, 2006). Using biofeedback to facilitate muscle relaxation has been found effective for decreasing cancer pain (Tsai, Chen, Lai, Lee, & Lin, 2007) and acute postoperative pelvic pain (Cheema, Lebovits, & Dubois, 2008). However, no evidence was found on the effect of biofeedback on postoperative pain relief after TKA. Therefore, the purpose of this study was to test the efficacy of a biofeedback relaxation intervention in reducing pain associated with CPM therapy in TKA patients. The hypothesis was that patients who received biofeedback relaxation intervention would report less pain associated with CPM therapy than patients who did not receive the intervention.

**Pain Management During CPM Therapy**

CPM has been used since the early 1980s to facilitate rehabilitation after TKA (Harvey, Brosseau, & Herbert, 2010). With the patient in a supine position, the foot on the affected leg is fixed in a track on which the foot slides toward and away from the body, maintaining a constant passive range of motion (ROM) on the postoperative joint. CPM may reduce blood and edema (fluid buildup) in and around the joint, which can lead to joint stiffness and the development of joint fibrosis and contractures (Viswanathan & Kidd, 2010). Some researchers found short-term reduction of postoperative CPM on soft-tissue swelling and increase in knee ROM in patients with a TKA (Bennett, Brearley, Hart, Bailey, 2005; Lenssen et al., 2008), but others reported no beneficial effects of CPM (Bruun-Olsen, Heiberg, & Mengshoel, 2009; Denis et al., 2006; Harvey et al., 2010). Due to the inconsistent findings, CPM is not part of standard postoperative management of TKA patients in some countries (Congdon, 2012; Rudisile, 2011), but prescribing postoperative CPM therapy is still a common practice and is covered by universal health insurance in Taiwan.

Significant pain can be associated with postoperative CPM therapy. Effective postoperative pain relief is crucial for patients’ recovery and has been associated with a smoother postoperative course and an earlier hospital discharge (Bader et al., 2010; Polomano, Punwoody, Krenzischeh, & Rathmell, 2008). In Taiwan, postoperative pain after TKA is routinely managed with a combination of analgesics, including acetaminophen, COX-2 selective or non-selective nonsteroidal anti-inflammatory drugs, and opioids. These analgesics are typically administered on an around-the-clock schedule or with patient-controlled analgesia pumps. The pain management for patients undergoing TKA in Taiwan is consistent with the guidelines for perioperative acute pain management of the American Society of Anesthesiologists (Apfelbaum, Ashburn, Conns, Gan, & Nickinovich, 2012), with the exception that local anesthetics are not commonly used during or after TKA surgery in Taiwan.

**Taiwanese Pain Beliefs**

Pain is a multifaceted experience shaped by individual cultural context (Narayan, 2010). In Taiwan, there is a strong cultural value on self-conduct. To be a good patient, an individual may suppress his/her emotions and expressions when responding to pain and avoid making demands on health care providers (Tung & Li, 2014). As a result, patients may underreport their pain and not want to trouble the nurses for pain medications (Chen, Miaskowski, Dodd, & Pantilat, 2008).

Patients influenced by Taiwanese folk beliefs may consider pain to be a result of their bad conduct in a previous life. Therefore, they may refuse to take prescribed pain medications, in order to accept their fates (Chen et al., 2008). Concern about side effects or addiction of analgesics is also prevalent among Taiwanese patients (Lai et al., 2002; Yin, Tse, & Wong, 2012). They may seek culture-based therapies or traditional Chinese medicine (e.g., herbal medications, acupressure, or acupuncture) instead...
of taking prescribed medications for pain (Chen, Kung, Chen, & Hwang, 2006; Chen et al., 2007). From the traditional Chinese medicine perspective, pain is considered as a result of disharmony in interaction between functional entities and the outside world, and the purpose of treatments is to regain the balance between them (Chen et al., 2008).

Biofeedback as Facilitator of Progressive Muscle Relaxation for Pain Relief

Biofeedback may be seen as assisting in regaining this balance. Biofeedback is a monitoring tool with which individuals can be coached to regulate bodily processes that usually occur involuntarily, including heart rate, blood pressure, muscle tension, and skin temperature. By increasing awareness of one's own bodily functions and understanding the power of the mind to influence them, an individual can have more control over his health (Durand & Barlow, 2009; Shaffer & Moss, 2006).

Biofeedback monitoring is performed using several devices and physiological endpoints, including electromyography, thermal biofeedback, neurofeedback or electroencephalography, electrodermal activity, and heart rate variability (Yucha & Montgomery, 2008). In a biofeedback session, electrodes are attached to the patient's skin. These electrodes transmit signals to a monitor that displays sounds, images, or light-flashes representing skin temperature, breathing rate, heart rate, blood pressure, muscle tension, or sweating. By observing the display, individuals train themselves to recognize the sensations associated with body functions and are guided by a biofeedback therapist to control these functions, using relaxation methods and mental exercises, including progressive muscle relaxation, deep breathing, guided imagery, and mindfulness meditation (Yucha & Montgomery).

Among these, progressive muscle relaxation has been predominantly used for reducing overall body tension and anxiety (Craske & Barlow, 2006; Yucha & Montgomery, 2008). Progressive muscle relaxation has both physical and mental aspects. Physically, it involves tensing and relaxing muscle groups of the legs, abdomen, chest, arms, and face. Mentally, it addresses the contrasting emotions associated with muscle tension and relaxation. During progressive muscle relaxation, an individual repetitively practices tensing and relaxing major muscle groups and focuses on the associated contrasting sensations (National Center for Complementary and Alternative Medicine, 2013). With the assistance of a biofeedback machine, one can reduce the tension carried in the body and feel less stress and anxiety (Yucha & Montgomery).

Biofeedback encourages relaxation and may alleviate some conditions associated with stress, such as migraine headaches, high blood pressure, chronic pain, and urinary incontinence (Nestoriuc, Martin, Rief, & Andrasik, 2008; Yucha & Montgomery, 2008). Biofeedback is reported to be safe and has no known negative side effects (Yucha & Montgomery). Using biofeedback to facilitate muscle relaxation may help to decrease the pain and anxiety associated with postoperative CPM in TKA patients, therefore facilitating the implementation of CPM rehabilitation.

Method

Design

This study used a quasi-experimental design with repeated measures. A convenience sample of 66 patients undergoing primary total knee replacement were recruited and randomly assigned to the intervention or control groups. Institutional Review Board approval was obtained from the Cheng Hsin General Hospital (IRB No. 98A-21–1).

Sample

The desired sample size was estimated using G-Power (3rd ed) (Faul, Erdfelder, Buchner, & Lang, 2009) for six repeated measures, with a significance level of 0.05, a medium effect size (f = 0.25), correlations of 0.5, and a power of 80%. A sample size of 30 per group was required to test the efficacy of the biofeedback relaxation intervention for reducing pain associated with CPM therapy in TKA patients.

Patients with osteoarthritis admitted for TKA were recruited from orthopedic wards of a 1000-bed general hospital in Taipei, Taiwan. The study was approved by the research ethics committee of the medical center. Potential participants were referred by their surgeons and then contacted and screened by the researcher to determine their eligibility. Patients who met the following inclusion criteria were solicited: 25 years of age or older, diagnosed with knee osteoarthritis, admitted to the hospital for a primary TKA, and able to communicate in Mandarin or Taiwanese dialect. Patients with cognitive problems and those experiencing complications from TKA were excluded from the study.

Seventy-three patients were screened for eligibility; four did not meet the eligibility criteria and were excluded. Two of these volunteers had cognitive problems, one spoke a language other than a Mandarin or Taiwanese dialect, and one was deaf. The 69 potentially eligible patients were approached; three refused to participate, and 66 were recruited and randomized to groups. All 66 participants, with 33 in each group, completed the study (Fig. 1). Informed consent was obtained from all participants.

Usual Care

The typical length of stay for TKA in Taiwan is 5–7 days. All participants were prescribed the standard of care for the study hospital of two 30-minute daily sessions of CPM therapy, beginning the first postoperative day until the discharge day. During the therapy, the patient’s postoperative
limb was placed on the CPM machine with a setting of “mini-
mal” speed, and with the knee ROM set to move between 0°
of extension and 35° of flexion. The ROM was increased 5–
10° each day according to the patient’s tolerance.

Both groups received standard postoperative care
from the hospital. The routine oral and injectable pain med-
ications were acetaminophen, celecoxib, pethidine, or
tramadol.

Biofeedback Intervention

The study intervention consisted of a 30-minute biofeed-
back-assisted progressive muscle relaxation training
session during the CPM sessions twice daily for 5 days. The
intervention group received 30 minutes of individual training
on biofeedback-assisted progressive muscle relaxation skills
on the day before the scheduled TKA surgery. This training
included orientation to biofeedback and instructions for pro-
gressive muscle relaxation skills. Then in each CPM treat-
ment session, the patients practiced progressive muscle
relaxation while observing how the computerized images
changed to indicate successful muscle tension and muscle
relaxation. An interventionist guided the patient through the
biofeedback intervention in each session.

A Wireless Monitoring and Biofeedback Nexus-10
biofeedback machine (Gunjan Human Karigar, India) was
utilized in the progressive muscle relaxation training. The
Nexus-10 is a 10-channel physiological monitoring and
feedback platform with a Bluetooth wireless transmission
system. Two surface electrodes were placed over the
quadiceps to record the surface electromyogram and to
monitor muscle tension. Two auxiliary sensors were placed
on the patient’s chest and fingertip to measure respiratory
rate, heart rate, and skin temperature, which have been
associated with relaxation responses (Benson & Klipper,
2000). The readings of these physical parameters were
transmitted to a notebook computer for data analysis and
represented in an audiovisual image displayed on the com-
puter screen to provide feedback to the patient.

The patients began practicing progressive muscle
relaxation by tensing all the muscles in their face, inhaling,
and counting to five. Patients were then instructed to
exhale, relax completely, and feel the tension drip out of
their facial muscles. They repeated the procedure continu-
ing down the body to the following muscle groups: neck
and shoulders, chest, abdomen, arms, hands, buttocks,
legs, and feet. During each intervention session, the inter-
ventionist gave a brief review of these skills and made sure
that every patient accurately executed the biofeedback-
assisted progressive muscle relaxation.

Data Collection and Instruments

The data were collected during 2010. At baseline, each
participant completed a demographics questionnaire. A
research nurse also collected data on disease variables,
including diagnosis, surgical procedures, CPM, and analge-
sic prescriptions, from the patients’ charts.
Data on pain intensity were collected before and after each CPM therapy from postoperative days one through five in both groups. The participants were asked to indicate the current level of knee pain on an 11-point numerical rating scale (NRS) on which 0 = no pain, and 10 = worst possible pain (McCaffrey & Beebe, 1993; National Institutes of Health, 2003). The NRS is commonly used in healthcare and has been found to be a reliable and valid pain intensity measure (Hjermstad et al., 2011).

A horizontal format of NRS was used (McCaffrey & Beebe, 1993; National Institutes of Health, 2003) using Chinese word descriptors and end points. The NRS was translated and back-translated until the meaning between the English and Chinese was in concordance. The word translations in Chinese were validated by five Taiwanese health professionals, and the content validity index was 0.933. Li, Liu, and Herr (2007) used this NRS to assess pain intensity in 173 Chinese postoperative adults and found high intraclass correlation coefficients (0.673–0.822) across current, worst, least, and average pain on 7 postoperative days ($p < 0.001$). The NRS was found to have concurrent validity with a visual analog scale, verbal descriptor scale, and faces pain scale-revised as evidenced by significant Spearman correlations among the four scales, ranged from 0.74 to 0.95 for ratings of current pain, 0.80 to 0.99 for worst pain, 0.71 to 0.97 for least pain, and 0.72 to 0.95 for average pain on 7 postoperative days. Zhou, Petpichetchian, and Kitrungrote (2011) reported a test–retest reliability ($N = 200$) of 0.80–0.99 in different age groups assessed over a 3-day interval. In the current study, the test–retest reliability of the NRS was 0.69 ($p < 0.01$), assessed at an 8-hour interval before sessions of CPM therapy on the morning and afternoon of the first postoperative day.

**Data Analysis**

The data were analyzed using the Statistical Package for Social Sciences 18.0 (SPSS, Inc., Chicago, IL). Descriptive statistics were used to describe participants’ demographics,

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Intervention (n = 33)</th>
<th>Control (n = 33)</th>
<th>$t^a$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Mean: 73.5, SD: 9.5</td>
<td>Mean: 71.7, SD: 6.5</td>
<td>0.9</td>
<td>0.378</td>
</tr>
<tr>
<td>Years since diagnosis with knee OA</td>
<td>Mean: 3.3, SD: 3.6</td>
<td>Mean: 4.3, SD: 4.8</td>
<td>488.5</td>
<td>0.465</td>
</tr>
<tr>
<td>BMI (Kg/m$^2$)</td>
<td>Mean: 27.4, SD: 4.5</td>
<td>Mean: 27.8, SD: 4.6</td>
<td>519.0</td>
<td>0.744</td>
</tr>
<tr>
<td>Gender</td>
<td>n: 12, %: 36.4</td>
<td>n: 11, %: 33.3</td>
<td>0.07</td>
<td>0.796</td>
</tr>
<tr>
<td>Marital status</td>
<td>n: 33, %: 100.0</td>
<td>n: 32, %: 97.0</td>
<td>1.02</td>
<td>1.000</td>
</tr>
<tr>
<td>Employment status</td>
<td>n: 0, %: 0.0</td>
<td>n: 1, %: 3.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Duration of CPM therapy</td>
<td>n: 32, %: 97.0</td>
<td>n: 32, %: 97.0</td>
<td>0.00</td>
<td>1.000</td>
</tr>
<tr>
<td>Length of CPM sessions</td>
<td>n: 32, %: 97.0</td>
<td>n: 30, %: 90.9</td>
<td>1.07</td>
<td>0.307</td>
</tr>
</tbody>
</table>

Note: OA, osteoarthritis; BMI, body mass index; CPM, continuous passive motion; $t$ (or $\chi^2$), value of independent t-tests (or Chi-square tests); SD, standard deviation.

$^a$Mann–Whiney U-test.

$^b$Fisher’s exact test.

*Research in Nursing & Health*
### Table 2. Intravenous Patient-Controlled Analgesia and Standing Analgesics Used by Group (N = 66)

<table>
<thead>
<tr>
<th>Day</th>
<th>Analgesic</th>
<th>Intervention (n=33)</th>
<th>Control (n=33)</th>
<th>$\chi^2$</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery</td>
<td>PCA with pethidine</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>15</td>
<td>45.5</td>
<td>16</td>
<td>48.5</td>
</tr>
<tr>
<td></td>
<td>Standing analgesics</td>
<td>26</td>
<td>78.8</td>
<td>19</td>
<td>57.6</td>
</tr>
<tr>
<td></td>
<td>Acetaminophen or COX-2</td>
<td>26</td>
<td>78.8</td>
<td>19</td>
<td>57.6</td>
</tr>
<tr>
<td></td>
<td>+ pethidine or tramadol</td>
<td>7</td>
<td>21.2</td>
<td>14</td>
<td>42.4</td>
</tr>
<tr>
<td>Postop 1</td>
<td>PCA with pethidine</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>18</td>
<td>54.5</td>
<td>18</td>
<td>54.5</td>
</tr>
<tr>
<td></td>
<td>Standing analgesics</td>
<td>18</td>
<td>54.5</td>
<td>18</td>
<td>54.5</td>
</tr>
<tr>
<td></td>
<td>Acetaminophen or COX-2</td>
<td>26</td>
<td>78.8</td>
<td>19</td>
<td>57.6</td>
</tr>
<tr>
<td></td>
<td>+ pethidine or tramadol</td>
<td>7</td>
<td>21.2</td>
<td>14</td>
<td>42.4</td>
</tr>
<tr>
<td>Postop 2</td>
<td>PCA with pethidine</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>19</td>
<td>57.6</td>
<td>18</td>
<td>54.5</td>
</tr>
<tr>
<td></td>
<td>Standing analgesics</td>
<td>26</td>
<td>78.8</td>
<td>21</td>
<td>63.6</td>
</tr>
<tr>
<td></td>
<td>Acetaminophen or COX-2</td>
<td>26</td>
<td>78.8</td>
<td>21</td>
<td>63.6</td>
</tr>
<tr>
<td></td>
<td>+ pethidine or tramadol</td>
<td>7</td>
<td>21.2</td>
<td>12</td>
<td>36.4</td>
</tr>
<tr>
<td>Postop 3</td>
<td>PCA with pethidine</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>20</td>
<td>60.6</td>
<td>20</td>
<td>60.6</td>
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<tr>
<td></td>
<td>Standing analgesics</td>
<td>20</td>
<td>60.6</td>
<td>20</td>
<td>60.6</td>
</tr>
<tr>
<td></td>
<td>Acetaminophen or COX-2</td>
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<td>78.8</td>
<td>21</td>
<td>63.6</td>
</tr>
<tr>
<td></td>
<td>+ pethidine or tramadol</td>
<td>7</td>
<td>21.2</td>
<td>12</td>
<td>36.4</td>
</tr>
<tr>
<td>Postop 4</td>
<td>PCA with pethidine</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>31</td>
<td>96.9</td>
<td>33</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Standing analgesics</td>
<td>31</td>
<td>96.9</td>
<td>33</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Acetaminophen or COX-2</td>
<td>26</td>
<td>81.3</td>
<td>21</td>
<td>63.6</td>
</tr>
<tr>
<td></td>
<td>+ pethidine or tramadol</td>
<td>6</td>
<td>18.8</td>
<td>12</td>
<td>36.4</td>
</tr>
<tr>
<td>Postop 5</td>
<td>PCA with pethidine</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>30</td>
<td>96.8</td>
<td>32</td>
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<tr>
<td></td>
<td>Standing analgesics</td>
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<td>96.8</td>
<td>32</td>
<td>100.0</td>
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<tr>
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<td>77.4</td>
<td>21</td>
<td>63.6</td>
</tr>
<tr>
<td></td>
<td>+ pethidine or tramadol</td>
<td>7</td>
<td>22.6</td>
<td>12</td>
<td>36.4</td>
</tr>
</tbody>
</table>

Note: $\chi^2$, Chi-square; PCA, intravenous patient-controlled analgesia; COX-2, COX-2 inhibitor; +, acetaminophen or COX-2 in addition to pethidine intravenous injection or tramadol oral.
*aFisher’s exact test.

### Table 3. Frequency of As-Needed Analgesics Used by Group after Total Knee Arthroplasty

<table>
<thead>
<tr>
<th>Day</th>
<th>Frequency</th>
<th>Intervention (n = 33)</th>
<th>Control (n = 33)</th>
<th>$\chi^2$</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day of surgery</td>
<td>0</td>
<td>23</td>
<td>69.7</td>
<td>26</td>
<td>78.8</td>
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<tr>
<td></td>
<td>1</td>
<td>8</td>
<td>24.2</td>
<td>5</td>
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<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>6.1</td>
<td>2</td>
<td>6.1</td>
</tr>
<tr>
<td>Postop day 1</td>
<td>0</td>
<td>30</td>
<td>90.9</td>
<td>30</td>
<td>90.9</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>6.1</td>
<td>2</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>3.0</td>
<td>1</td>
<td>3.0</td>
</tr>
<tr>
<td>Postop day 2</td>
<td>0</td>
<td>31</td>
<td>93.9</td>
<td>33</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>0</td>
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<td>2</td>
<td>1</td>
<td>3.0</td>
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<td>Postop day 3</td>
<td>0</td>
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<td>100.0</td>
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<tr>
<td>Postop day 4</td>
<td>0</td>
<td>30</td>
<td>96.8</td>
<td>31</td>
<td>96.9</td>
</tr>
<tr>
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<td>1</td>
<td>1</td>
<td>3.2</td>
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</tr>
<tr>
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<td>2</td>
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<td>1</td>
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<td>Postop day 5</td>
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<td>28</td>
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<tr>
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<td>2</td>
<td>7.1</td>
<td>3</td>
<td>9.7</td>
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<td>0</td>
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</tr>
</tbody>
</table>

Note: $\chi^2$, Chi-square. The “as-needed” analgesic prescribed was either pethidine injection or tramadol oral.
*aFisher’s exact test.
disease characteristics, and pain intensity. Chi-square tests or Fisher’s exact tests and independent samples t-tests were used to examine group differences in baseline values.

Repeated-measures analysis of variance (RM-ANOVA) was used to compare between-group differences in changes in CPM-associated pain intensity over time. The CPM-elicited pain score was calculated by subtracting the pre-CPM pain score from the post-CPM pain score. Age, gender, education level, and body mass index (BMI) were added to the model as covariates.

Results

Participants’ Characteristics and Baseline Equivalence

The characteristics of the intervention and control groups are presented in Table 1. There were no differences between groups on baseline variables. In the sample as a whole, there were 43 females and 23 males. The mean age was 72.6 years (SD = 8.2; range: 41–85). The majority were married (n = 65), unemployed (n = 64), and had completed elementary school education (n = 27). The duration since knee OA diagnosis ranged from 3 months to 20 years, with an average of 3.8 years (SD = 4.2). The average BMI was 27.6 kg/m² (SD = 4.5; range 19.1–39.4).

All 66 participants were prescribed 30 minutes of CPM twice a day for 5 days. Among them, 60 completed all 5 days of CPM, three (two in the intervention group and one in the control group) completed 4 days, and three (two in the intervention group and one in the control group) completed 3 days, all due to discharge from the hospital prior to the fifth postoperative day.

Four of the 66 participants discontinued the CPM before the prescribed full 30-minute session. One in the intervention group and three in the control group had to pause or terminate the 30-minute session due to pain. All of these patients were able to continue on CPM again as soon as their

Table 4. Pain Intensity before and After Continuous Passive Motion (CPM) Therapy and CPM-Elicited Pain Intensity in Patients After Total Knee Arthroplasty (N = 66)

<table>
<thead>
<tr>
<th>Day</th>
<th>CPM Time</th>
<th>Pain Intensity</th>
<th>Intervention</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>One</td>
<td>Morning</td>
<td>Pre-CPM</td>
<td>5.39</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-CPM</td>
<td>5.90</td>
<td>1.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CPM-elicited</td>
<td>0.52</td>
<td>1.58</td>
</tr>
<tr>
<td></td>
<td>Afternoon</td>
<td>Pre-CPM</td>
<td>4.93</td>
<td>1.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-CPM</td>
<td>5.54</td>
<td>1.97</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CPM-elicited</td>
<td>0.61</td>
<td>1.12</td>
</tr>
<tr>
<td>Two</td>
<td>Morning</td>
<td>Pre-CPM</td>
<td>5.21</td>
<td>1.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-CPM</td>
<td>5.06</td>
<td>1.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CPM-elicited</td>
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<td>1.39</td>
</tr>
<tr>
<td></td>
<td>Afternoon</td>
<td>Pre-CPM</td>
<td>5.06</td>
<td>1.43</td>
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<tr>
<td></td>
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<td>Post-CPM</td>
<td>5.06</td>
<td>1.73</td>
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<td></td>
<td></td>
<td>CPM-elicited</td>
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<td>1.30</td>
</tr>
<tr>
<td>Three</td>
<td>Morning</td>
<td>Pre-CPM</td>
<td>4.58</td>
<td>1.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-CPM</td>
<td>4.21</td>
<td>2.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CPM-elicited</td>
<td>−0.36</td>
<td>1.39</td>
</tr>
<tr>
<td></td>
<td>Afternoon</td>
<td>Pre-CPM</td>
<td>4.36</td>
<td>1.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-CPM</td>
<td>4.03</td>
<td>2.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CPM-elicited</td>
<td>−0.33</td>
<td>1.02</td>
</tr>
<tr>
<td>Four</td>
<td>Morning</td>
<td>Pre-CPM</td>
<td>4.15</td>
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<td>Post-CPM</td>
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<td>CPM-elicited</td>
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<td></td>
<td>Afternoon</td>
<td>Pre-CPM</td>
<td>4.32</td>
<td>1.64</td>
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<tr>
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<td>Post-CPM</td>
<td>3.71</td>
<td>1.79</td>
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<td>CPM-elicited</td>
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<td>1.02</td>
</tr>
<tr>
<td>Five</td>
<td>Morning</td>
<td>Pre-CPM</td>
<td>3.87</td>
<td>1.59</td>
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<tr>
<td></td>
<td></td>
<td>Post-CPM</td>
<td>3.58</td>
<td>1.75</td>
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<td>CPM-elicited</td>
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<td>1.01</td>
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<tr>
<td></td>
<td>Afternoon</td>
<td>Pre-CPM</td>
<td>3.86</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-CPM</td>
<td>3.36</td>
<td>1.47</td>
</tr>
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<td></td>
<td></td>
<td>CPM-elicited</td>
<td>−0.50</td>
<td>1.07</td>
</tr>
</tbody>
</table>

Note: F = 29.70, p < .001, for group effect on CPM-elicited pain intensity over time in repeated measures analysis of variance with one between-group factor. CPM-elicited pain intensity = post-CPM pain score minus pre-CPM pain score. A negative value indicates score was lower after CPM. SD, standard deviation.
pain subsided. The time range during which patients stopped or paused a session was 10–15 minutes into the session. There was no between-group difference in the duration and length of CPM carried out by the participants (Table 1).

Most participants were prescribed acetaminophen (Paramol\textsuperscript{1}), celecoxib (Celebrex\textsuperscript{2}), pethidine (Demerol\textsuperscript{3}), or tramadol (Tramal\textsuperscript{4}) for postoperative pain. The type and frequency of use of analgesics over the 6 days (day of surgery through postoperative day 5) were no different in the two groups (Tables 2 and 3).

**Intervention Adherence**

Among the 33 participants randomized to the intervention group, 29 completed the 5 days of biofeedback-assisted progressive muscle relaxation training. Of the four that did not complete the training, two participated in the intervention for 4 days, and the other two participated for 3 days; participation was discontinued because the patients were discharged from the hospital prior to the fifth postoperative day.

**Effect of Biofeedback on Postoperative Pain During CPM Therapy**

Pain intensity measured before CPM therapy was no different in the two groups on any of the 5 study days (Table 4). The levels of postoperative pain associated with CPM therapy gradually decreased over time in both groups (Fig. 2). However, pain intensity after CPM therapy was higher in the control group than in the intervention group on postoperative days one, four, and five (Table 4), and the pain intensity was intensified by CPM therapy (CPM-elicited pain) in the control group but not in the intervention group on the final four study days (Fig. 2).

Results of RM-ANOVA showed a significant group effect on CPM-elicited pain ($f$ = 24.17, $p < 0.001$). No covariates were statistically significant, and the reduced model without the covariates also showed a significant group effect ($f$ = 29.70, $p < 0.001$), supporting the study hypothesis that patients who received the biofeedback relaxation intervention would report less pain than would patients in the control group following CPM therapy.

There was a significant effect of time on CPM-elicited pain ($f$ = 22.36, $p < 0.001$, based on Greenhouse–Geisser correction); tests of within-subjects contrasts showed a significant linear term ($f$ = 48.94, $p < 0.001$). Both groups exhibited a gradual decrease in the difference between pre-treatment and post-treatment pain scores over time (Fig. 3), but the intervention group reported substantially lower pain levels.

![FIGURE 2. Changes in pain intensity measured before and after continuous passive motion therapy over time. The data are shown as the mean and 95% confidence interval (error bars). Note. CPM, continuous passive motion.](image-url)
less CPM-elicited pain than did the control group did on all 5 study days.

Discussion

Patients who underwent TKA experienced significant postoperative wound pain, which gradually decreased over time. The pain intensity was significantly intensified by the CPM therapy in the control group, but not in the intervention group for the final 4 study days. The beneficial effect of the intervention was observed on the first postoperative day and continued thereafter. The between-group differences were consistent across study days. These findings support the efficacy of biofeedback relaxation intervention for alleviating postoperative pain associated with CPM therapy in TKA patients.

Some patients from a traditional Chinese medicine perspective may believe that western pain medication is too strong and maybe reluctant to take the full dose of the prescribed pain medications or request an as needed based pain medication. Biofeedback can be an alternative choice for pain management in this group of patients, because it is a natural fit within the Taiwanese culture with an acceptance of the unity of mind-body-spirit (Lin, Peper, & Weng, 2007).

Patients were able to learn biofeedback-machine assisted progressive muscle relaxation skills with a 30-minute preoperational individual training session and a brief review prior to each biofeedback relaxation session. The intervention was received favorably among the participants in the intervention group, and they were willing and able to practice the progressive muscle relaxation skills during each CPM session. Participants in both groups adhered to the prescribed CPM therapy. All participants completed the twice-daily CPM therapy for 5 days, except those who were discharged from the hospital before the final study day. Although the patients in the control group experienced worse pain during the CPM therapy than those in the intervention group, there was no between-group difference in CPM adherence. This finding suggests that wound pain is not the only factor affecting participants’ adherence to CPM therapy. Other factors such as motivation and perceived CPM effectiveness may contribute to CPM adherence.

The study had several limitations. First, the participants were recruited from orthopedic wards of a medical

FIGURE 3. Changes in CPM-elicited pain intensity scores over time. The data are shown as the mean and 95% confidence intervals (error bars). Note. CPM, continuous passive motion.
center and may vary from those admitted to other clinical settings. Therefore, these results may not be generalizable beyond this sample population. Second, only the short-term effects of a 5-day biofeedback relaxation intervention associated with CPM therapy were tested in this study; the long-term outcomes and potential side effects remain to be determined. Third, due to ethical considerations, a placebo control group was not included; therefore, the potential of a placebo effect cannot be excluded, and the intervention effect may be overestimated. Last, issues of individual difference in participants were not taken into account in this study design. Previous studies showed that individuals may respond to biofeedback-assisted relaxation training differently due to differences in individuals’ cognitive capacity for absorption and imaginative involvement on the level of the relaxation achieved during biofeedback (Menzie, Taylor, & Bourguignon, 2008). Additional research is needed to explore individual differences in responding to the study intervention.

This is the first study to investigate the effects of biofeedback relaxation intervention for reducing pain associated with CPM therapy in TKA patients. Other studies have examined the effects of CPM, but none included biofeedback as a modality for pain management. These results provide preliminary support for the effects of biofeedback relaxation intervention for postoperative pain relief. However, additional randomized, controlled trials with longitudinal designs, larger sample sizes, and blinded outcome assessments are required to better define the role of biofeedback relaxation intervention in the treatment protocol for postoperative pain control in TKA patients. Future work with an appropriate design to determine who is most likely to benefit from this intervention is also an important next step.

Conclusion

The results of the current study showed that biofeedback relaxation intervention was safe and effective for controlling postoperative pain during the CPM therapy. Patients who practiced biofeedback-assisted progressive muscle relaxation showed less pain elicited by CPM therapy compared to those in the control group. No adverse reactions to the intervention were observed. Although more studies are required to define the role of biofeedback relaxation intervention in managing postoperative pain, it is a non-invasive and inexpensive intervention that can be considered as a complementary treatment option for postoperative pain control during CPM therapy.

References


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Acknowledgements

The authors thank all the participants.