

**A COMPARISON OF PAIN REDUCTION METHODS IN KNEE
REPLACEMENT PATIENTS: USING COLD COMPRESSION
BEFORE OR BOTH BEFORE AND DURING EXERCISE
ON CONTINUOUS PASSIVE MOTION MACHINE**

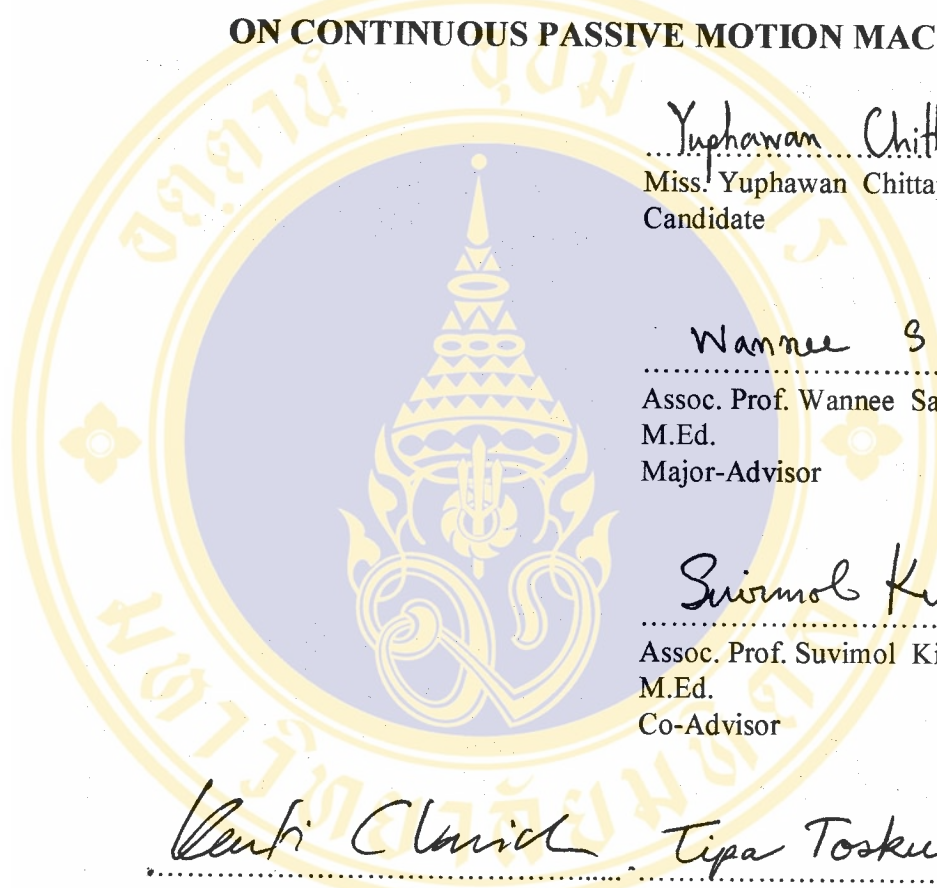


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Yuphawan Chittapiwat

A COMPARISON OF PAIN REDUCTION METHODS IN KNEE REPLACEMENT PATIENTS: USING COLD COMPRESSION BEFORE OR BOTH BEFORE AND DURING EXERCISE ON CONTINUOUS PASSIVE MOTION MACHINE.

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ABSTRACT

The purpose of this study was to compare the effectiveness of pain reduction between cold compression before passive exercise, and cold compression both before and during passive exercise by means of a continuous passive motion machine in total knee replacement patients. The thirty eligible total knee replacement patients from Siriraj Hospital were selected. A simple cross over design was used for this study. All participants received both methods of cold compression on the fourth postoperative day. One group of participants received cold compression only before exercise in the morning and cold compression both before and during exercise in the afternoon. For the other group the order of methods was reversed receiving cold compression both before and during exercise in the morning and only before exercise in the afternoon. Pain intensity was evaluated before, during, and after passive exercise by the vertical 0-10 Numeric Rating Scale. A comparison of pain scores between two groups of cold compression methods was analyzed by ANOVA for a simple cross over design.

The results revealed that the participants who received cold compression before and during passive exercise had statistically significant lower pain scores than those of the participants who received cold compression only before passive exercise ($p < .001$). Furthermore, the participants who received cold compression before and during passive exercise had the most satisfaction.

The investigator suggests that nurses should apply cold compression before and during passive exercise to reduce pain in total knee replacement patients using the continuous passive motion machine in the rehabilitation period. Furthermore, nurses should recommend cold compression to discharged total knee replacement patients and their caregivers for a self-care method of decreasing pain.

**KEY WORDS: COLD COMPRESSION / POST-OPERATIVE PAIN /
KNEE REPLACEMENT PATIENTS /
CONTINUOUS PASSIVE MOTION**

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เปรียบเทียบผลของการบรรเทาปวดระหว่างการประคบเย็นก่อนบริหารและการประคบเย็นทั้งก่อนและขณะบริหารด้วยเครื่องบริหารอย่างต่อเนื่องแบบพาสซีฟ ในผู้ป่วยหลังผ่าตัดใส่ข้อเข่าเทียม (A COMPARISON OF PAIN REDUCTION METHODS IN KNEE REPLACEMENT PATIENTS: USING COLD COMPRESSION BEFORE OR BOTH BEFORE AND DURING EXERCISE ON CONTINUOUS PASSIVE MOTION MACHINE)

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บทคัดย่อ

การศึกษานี้เป็นการวิจัยกึ่งทดลอง เพื่อเปรียบเทียบผลของการบรรเทาปวดระหว่างการประคบเย็นก่อนบริหารและการประคบเย็นทั้งก่อนและขณะบริหาร ด้วยเครื่องบริหารอย่างต่อเนื่องแบบพาสซีฟ ในผู้ป่วยหลังผ่าตัดใส่ข้อเข่าเทียม กลุ่มตัวอย่างเป็นผู้ป่วยหลังผ่าตัดใส่ข้อเข่าเทียม วันที่ 4 ในโรงพยาบาลศิริราช จำนวน 30 ราย รูปแบบการทดลองเป็นการทดลองแบบสลับ กลุ่มตัวอย่างทุกคนจะได้รับการประคบเย็นทั้งสองวิธีในวันเดียวกัน โดยจับสลากสุ่มวิธีการประคบเย็นให้กับกลุ่มตัวอย่างแต่ละคนว่าจะได้รับวิธีใดก่อน ประเมินความปวดของกลุ่มตัวอย่างโดยใช้ The vertical 0–10 Numeric Rating Scale ในเวลาต่าง ๆ ของการทดลอง ได้แก่ ก่อนเริ่มประคบเย็น ขณะบริหารและหลังบริหารข้อเข่า เปรียบเทียบคะแนนความปวด ระหว่างกลุ่มที่ได้รับการประคบเย็นก่อนบริหาร และกลุ่มที่ได้รับการประคบเย็นทั้งก่อนและขณะบริหาร โดยใช้สถิติ ANOVA แบบ cross over design

ผลการวิจัยพบว่า กลุ่มที่ได้รับการประคบเย็นทั้งก่อนและขณะบริหารมีความปวดน้อยกว่ากลุ่มที่ได้รับการประคบเย็นก่อนบริหารอย่างมีนัยสำคัญทางสถิติ ($p < .001$) และกลุ่มตัวอย่างทุกคนที่ได้รับการประคบเย็นทั้งก่อนและขณะบริหารมีความพึงพอใจมาก

ผู้วิจัยเสนอแนะให้นำวิธีการประคบเย็นทั้งก่อนและขณะบริหารไปใช้ในการลดความปวด ในผู้ป่วยหลังผ่าตัดใส่ข้อเข่าเทียม ขณะบริหารข้อเข่าด้วยเครื่องบริหารอย่างต่อเนื่องแบบพาสซีฟ เพราะทำได้สะดวก ไม่ต้องใช้เครื่องมือซับซ้อน และพยาบาลควรแนะนำการประคบเย็นแก่ผู้ป่วย และญาติเพื่อเป็นแนวทางในการนำไปปฏิบัติเพื่อลดความปวดในระยะฟื้นฟูสภาพข้อเข่าที่บ้าน

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CHAPTER I

INTRODUCTION

Background and significance of the study

Total knee replacement (TKR) is treatment for osteoarthritis of the knee when degeneration of the cartilage and tissue around the knee results in disability and chronic pain. The procedures of total knee replacement are implanting a proper knee prostheses for improvement in joint mechanics for mobility and stability. Furthermore, the patients have pain relief and improvement in their quality of life (Hawker, et al., 1998: 163–164). Currently, total joint replacement surgery is increasing, particularly in elderly people who have degenerative joints due to aging. In addition, the advancement of medical technology can make people have longevity, so the number of elderly people is increasing. Palmer (1999: 419) reported that more than 40 million Americans experience some form of arthritis. The prevalence of total knee replacement paid for by Medicare in the United States was 186,644 operations in 1998 (Mendenhall, 1999 cited by Healy, et al., 2000: 65). In Thailand, there were about 5.9 million elderly people who were 60 years old or more in 2002 (Statistical Forecasting Bureau of National Statistical Office, 2002). Although there are no national statistics available for total knee replacement in Thailand at the time of this study, Siriraj Hospital, the largest hospital in Thailand, has 455 documented cases for the year 2002 and the patients are aged from 40 to 96 years old (Medical Record of Orthopedics Department, Siriraj Hospital, 2002).

The patients who undergo total knee replacement operation suffer from postoperative pain or acute pain that is an unpleasant sensory and emotional experience (Turk & Okifuji, 2001: 17). This postoperative pain occurs due to tissue injury continuously releasing chemical substances (Coda & Bonica, 2001: 236-237). Results show patients have moderate to severe pain and may suffer unbearable pain during the first to the third postoperative days. For this reason, in this period, the

patients received strong opioids to control pain such as morphine and pethidine by the methods of muscular injection, or vascular injection which is PCA (Patient Control Analgesia), and epidural injection which is PCEA (Patient Control Epidural Analgesia) (Chinachoti, et al., 2002: 140).

Rehabilitation after the TKR surgery is extremely important and necessary because surgery around the joint will cause scar formation and decrease joint mobility. Furthermore, immobilization in the acute postoperative period may cause muscle atrophy and weakness leading to instability of the knee (Kubniratsaikul, P., 2000: 173-176). Therefore, if patients have a delay in rehabilitation they will have failure in treatment that can lead to a deterioration in physiological, psychological, and economic aspect. Generally, rehabilitation should begin as early as possible after TKR, commencing with changing position and quadriceps exercise on the second to the third postoperative days. Then on the 4th postoperative day, after the surgeon has removed the stabilizing slab and bandages there can be an increase in flexion and extension of the TKR joint. Nowadays, many surgeons like to use the continuous passive motion (CPM) machine to help patients increase a continuous range of motion of the operated knee joint. The benefits of the CPM after TKR include improvement in the range of motions, decreased deep vein thrombosis and time of rehabilitation of the knee (Lachiewicz, 2000: 145). However, the flexion and extension of the TKR joint usually leads to more pain from muscle contraction and spasm due to the stretch reflex (Puchanjanamorakot, C. & Sinpermsuksakul, A., 1997: 19). This muscle contraction and spasm creates blood vessel constriction that produces muscle containing less oxygen but with more metabolism for exercise. It creates an anaerobic metabolism, which increases lactic acid contributing to local acidosis. Lactic acid begins to stimulate free nerve endings in muscles and then creates muscle pain (Benjamin & Johnson, 2000: 119). Physiological pain that occurs from the surgical wound and exercise will have an effect on patients who avoid movement, in order to avoid pain. On the psychological side, pain causes fear and anxiety for patients, which increases muscle tension and spasm, causing more pain and so it becomes a vicious cycle (McCaffery & Beebe, 1989: 188).

The nurse, a member of the patient care team, who spends the most time with

the patient and is responsible for management of pain by assessment, prevention, and by applying implementation of nursing care to reduce pain. The most commonly used methods of pain management are pharmacological and nonpharmacological intervention. In the rehabilitation period after TKR, patients receive analgesic drugs by the methods of muscular injection or consumption that may also have side effects of the medicine and pain because of injection. Nonpharmacological interventions include distraction, relaxation, touch, massage, acupuncture, transcutaneous elective nervous stimulation (TENS), imaginary, hot therapy, and cold therapy (cryotherapy).

The local application of cold to reduce pain is well known and a widely used method in orthopedic surgery. The term cryotherapy is used to describe the application of cold modalities that have a temperature range between 0°C and 18.33°C (32°F and 65°F) (Starkey, 1999: 110). The local effects of cold application are decreased nerve conduction velocity of pain and decreased source of pain by producing vasoconstriction to limit blood loss, decreased cellular metabolic rate to restrict the area of inflammation and edema, and also decreased muscle contraction and spasm which occur from the stretch reflex. Cryotherapy is usually applied for 15 to 30 minutes per treatment (Anderson & Hall, 1995: 163). In foreign countries, many researchers have found that using cold modalities which produce continuous cold to the surgical wound of orthopedic patients for two to three days can reduce postoperative pain (Levy & Marmar, 1993; Ohkoshi, et al., 1999). However, these cold modalities are expensive and seldom used in hospitals in Thailand. The local application of cold in postoperative orthopedic patients in Thailand uses a reusable cold gel pack as it is inexpensive, easily purchased and convenient in application. The reusable cold gel pack has therapeutic effects for 20 minutes (Starkey, 1999: 132). In addition, many researchers have found that reusable cold gel packs have plenty of therapeutic effects. For instance, Hecht and colleagues (1983) found that cold compression with reusable cold gel packs for 20 minutes with patients who have undergone TKR on the 14th postoperative days before they performed exercise with the assistance of a physical therapist can reduce significantly edema from exercise. Moreover, Weston and colleagues (1994) found a significant reduction in local blood volume in traumatized ankle patients during cold gel pack application for 20 minutes. Furthermore, Enwemeka and colleagues (2002) found a significant temperature fall in

cutaneous and subcutaneous superficial tissue when using cold gel pack application for 20 minutes.

From the investigator's experience, it was found that nursing intervention for pain reduction in rehabilitation period of TKR patient, particularly during flexion and extension exercise with CPM machine, was to administer analgesic drugs and apply local cold compression with a cold gel pack. But in this nursing intervention, the nurse did not have an instrument to control temperature and confirm about the appropriate temperature for therapeutic effects of cold gel packs. Moreover, the suitable time to reduce pain with cold compression is not confirmed. Also, the methods of cold gel pack compression are various, such as cold compression before exercise, cold compression only during exercise, and cold compression after exercise. However, the investigator has interviewed patients who have obtained cold compression, and most of them reported that cold compression made them feel better and gave pain relief.

The investigator is an orthopedic nurse, and realizes the suffering from pain of patients undergoing TKR and exercise in the rehabilitation period. Therefore, the investigator became interested in the study of the effect of cold compression on pain reduction by controlling the methods and time of cold compression, in order to discover an effective nursing intervention that does not use expensive cold modalities. Two methods of cold compression to reduce pain were used to compare the results. The first method was cold compression for 20 minutes before passive exercise (method B). This method can reduce pain from surgical wound of TKR patient before exercise but the effectiveness of cold may be inadequate for reducing the new pain that occurs during exercise. The second method was cold compression both before and during passive exercise (method A). This method can reduce pain from surgical wound and exercise. After finishing cold compression for 20 minutes before exercise, the patients will receive another cold compression at the beginning until end of exercise to reduce the new pain that occurs during exercise. The investigator will control the temperature of cold gel packs to be between 0⁰ C and 18.33⁰ C for therapeutic effects through each method of cold compression. The investigator hopes the results will yield benefits for the nursing intervention of applying cold gel pack compression to reduce pain in patients undergoing TKR who have exercise with CPM machine.

Research question

What is the best method of cold compression to reduce pain between cold compression before passive exercise, and cold compression both before and during passive exercise by means of a continuous passive motion machine in total knee replacement patients?

Purpose of the study

To compare the effectiveness of pain reduction between cold compression before passive exercise, and cold compression both before and during passive exercise by means of a continuous passive motion machine in total knee replacement patient.

Conceptual framework

In this study, the conceptual framework is based on the physiology of pain, which has four processes such as transduction, transmission, perception, and modulation (McCaffery & Pasero, 1999: 17).

Passive exercise by using CPM machine in TKR patients causes pain by passing through the pain processes that can be explained as follow:

When the CPM machine produces flexion and extension of the TKR joint, it also stimulates sensory nerves of muscles around the knee joint which are situated in the muscle spindles. These nerves have primary endings and secondary endings. Then the impulse from muscle spindles is sent to the alpha motor and gamma motor neurons at the spinal cord. Next, the motor neurons return the impulse to the muscle to produce muscle contraction. The mechanism of this muscle contraction is known as stretch reflex. At the same time, the surgical wound is releasing chemical substances such as histamine and prostaglandin etc. that can stimulate pain receptors (nociceptors) and suppress the function of the Golgi tendon organ. The Golgi tendon organ has the function of adjusting muscle tension for suitable muscle contractions during a stretch reflex. For this reason, chemical substances cause a failure in controlling muscle contraction. Due to the increased pain and suppressing function of the Golgi tendon organ from chemical substances, it can cause hyperactivity of the stretch reflex that is known as muscle spasm. Muscle spasm creates blood vessel constriction that means muscles contain less oxygen. This condition causes an anaerobic metabolism during

exercise subsequently lactic acid is increased, contributing to local acidosis. Lactic acid stimulates free nerve endings in muscles and then creates muscle pain (Benjamin & Johnson, 2000: 119). Therefore, pain occurs from noxious stimuli such as mechanical stimuli which are muscle contraction and muscle spasm and chemical stimuli which are histamine and prostaglandin etc., which activate the nociceptors of A-delta fibers and C fibers which produce transduction pain impulse. Then pain is transmitted by the afferent fibers of the A-delta and the C which transmit impulses to the spinal cord and brain. Next, pain perception occurs. Finally, the impulses from the brain descend (descending pain pathway) to the spinal cord to modulate the appropriateness of pain.

Cryotherapy is the application of cold modalities that have a temperature range between 0 °C and 18.33 °C to treat tissue trauma in the acute or subacute period and decrease pain from exercise or rehabilitation activities after orthopedic surgery (McDowell, et al., 1994: 21; Prentice, 1999: 227; Starkey, 1999: 110). Cold application to the site of injury can alter physiological responses as follow:

Decreased cellular metabolic rate. Cold reduces the energy needs of the cell, consequently decreasing the amount of oxygen required by the cell to survive. Therefore, the number of cells killed by a lack of oxygen is decreased so chemical substances of tissue damage are inhibited. Moreover, lactic acid from anaerobic metabolism is reduced. Additionally, cold produces vasoconstriction to limit blood loss resulting in decreased haematoma formation and decreased edema (McDowell, et al., 1994: 22; Starkey, 1999: 114).

Increased stiffness of collagen and increased muscle endurance. Collagen is the major component of connective tissue, which is found in the structure of ligaments, tendons, and muscles. Collagen exhibits primary elastic properties, which allows these structures to flex and extend. Cold has been shown to enhance the elastic properties of collagen by increasing the stiffness and resistance to stretch results in increased muscle endurance (McDowell, et al., 1994: 22).

Decreased nerve conduction velocity. Cold can decrease nerve conduction velocity include sensory nerves of muscle spindles, motor nerves and nerves of pain impulse (Starkey, 1999: 116).

The pain processes and cryotherapy to relieve pain. The investigator will explain the effects of cold to reduce pain during passive exercise with CPM machine in TKR patients in each step of the pain processes. Cold application can reduce pain from the first steps of pain processes by decreasing transduction of pain. The noxious stimuli in the step of the transduction of pain are decreased as follow:

Decreased stimulation of relative nerves in the stretch reflex mechanism of muscles during passive exercise. The cold decreases nerve conduction velocity of sensory nerves in muscle spindles which are primary endings and secondary endings that respond to the stretching of muscles. Then the motor nerves at the spinal cord, namely the alpha motor and the gamma motor receive less impulse for stretching. Also, cold decreases directly nerve conduction velocity of motor nerves. For this reason, cold can reduce noxious stimuli in the transduction of pain and this effect can facilitate a decrease in muscle contraction and muscle spasm.

Decreased muscle contraction and muscle spasm from stretch reflex. The structures that function in the stretch reflex of the knee joint are muscles, tendons and ligaments. The major component of these structures is collagen. As cold increases the stiffness of collagen, consequently it causes increased muscle endurance that assists in decreasing muscle spasm. In addition, a decrease in muscle contraction and muscle spasm can result in a protective effect on the area of the surgical site.

Decreased chemical substances such as histamine and lactic acid etc. which stimulate the painful fibers. Because cold can decrease the cellular metabolic rate, so the cells around the surgical site which are activated by passive exercise will use less energy. For this reason, the chemical substances which are released from damaged cells will decrease because the dead cells from lack of oxygen are decreasing. Moreover, during exercise the cells will create anaerobic metabolism to supply adequate energy and produce waste products like lactic acid. When the cells need less energy under cold condition, consequently a decrease of the anaerobic metabolism and lactic acid happens.

Furthermore, cold application can reduce pain by decreasing transmission of pain. Cold can decrease nerve conduction velocity of pain fibers, namely the A-delta fibers and the C fibers. Therefore, the transmission of pain impulses to the spinal cord and the brain are reduced, consequently a decreased in pain perception occurs.

The effects of cold compression on physiological pain in TKR patients when performing passive exercise by CPM machine is shown in Figure 1.

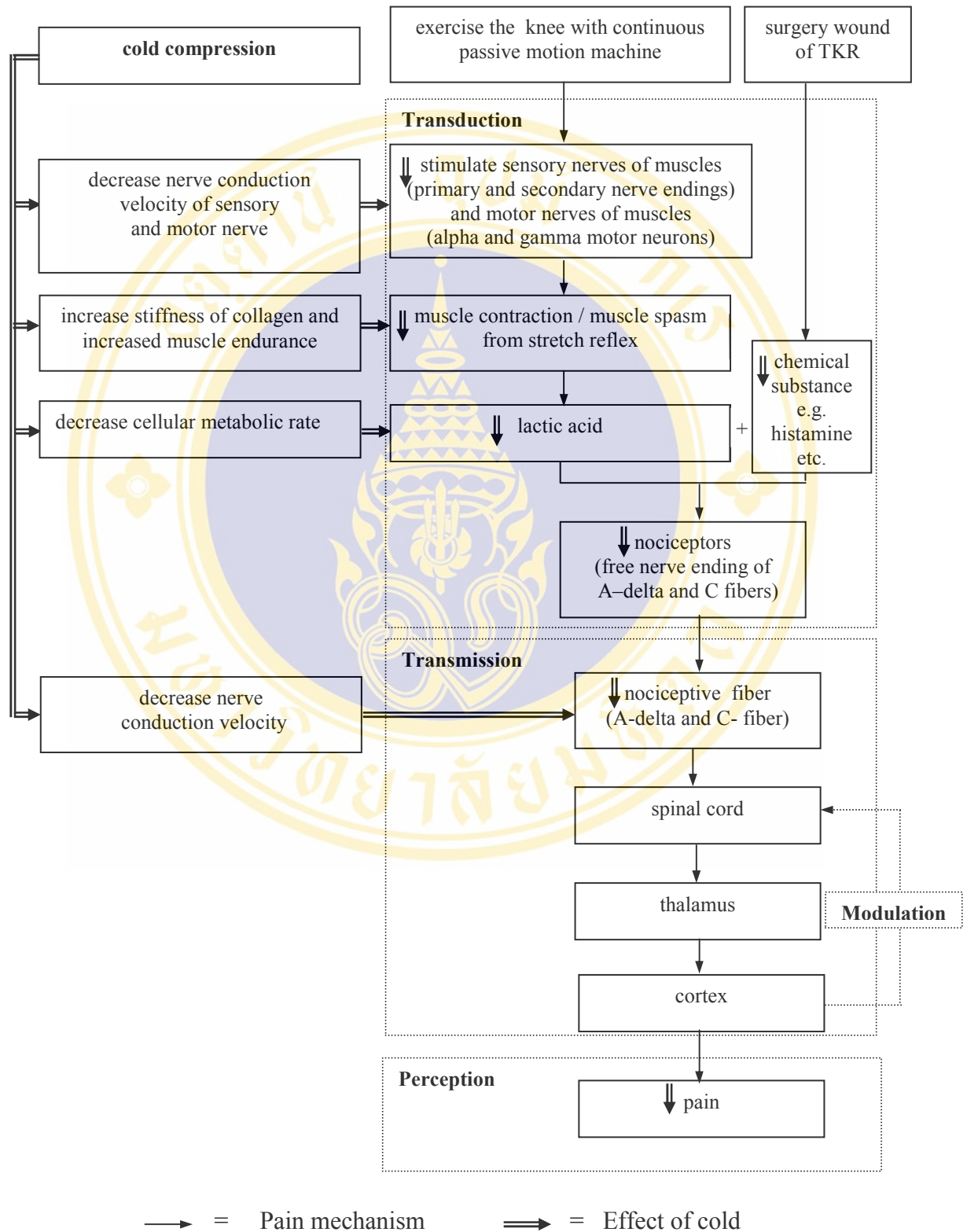


Figure 1: Effect of cold compression on physiological pain during passive exercise

Because of the pain processes and cryotherapy, the investigator has applied this knowledge to use for the practice of nursing care in order to relief pain during passive exercise with CPM machine for TKR patients. Then the investigator designed two methods of cold compression to compare the effectiveness of cold compression between cold compression before passive exercise (method B), and cold compression both before and during passive exercise (method A). These methods can explain the effect as follow:

The patients who have undergone a TKR operation are suffering from postoperative pain due to pain fibers that respond to noxious stimuli that are mechanical and chemical. The mechanical stimulus is the surgical wound and the chemical stimuli are the substances that are released from damaged tissue such as prostaglandin and histamine etc. When the investigator uses method B, that is a cold compression which has temperature between 0°C and 18.33°C for 20 minutes before passive exercise with TKR patients, it reduces pain by decreasing transduction, transmission, and perception of pain before the beginning of exercise. As cold produces vasoconstriction and a decreased cellular metabolic rate, consequently the amount of oxygen required by cells to survive is decreased. As the number of cells killed by lack of oxygen is decreased, the chemical substances of tissue damage are reduced. Decreasing inflammatory substances reduces inflammation and edema, resulting in decreased muscle tension around the surgical wound. Also, cold increases muscle endurance and decreases nerve conduction velocity of muscle spindles and motor neurons and results in decreased muscle spasm that can have a protective effect on the area of the surgical site. Furthermore, cold decreases nerve conduction velocity of pain fibers, the A-delta and the C, and results in decreased perception of pain. Therefore, cold compression with method B reduces pain due to the surgical site before the TKR patients perform passive exercise with CPM machine.

However, when the TKR patients perform passive exercise with the CPM machine the physiological responses increase the metabolic rate to supply energy to tissues and muscles around the knee joint that results in heat production. The heat production produces warm tissue and muscles around the knee and results in reduced effects of cold compression before passive exercise. Also, the lactic acid which is the result from when metabolism is increased stimulates pain. In addition, passive exercise

produces stretch reflexes that control muscle contraction during flexion and extension of the knee joint. However, the surgical wound releases chemical substances that produce hyperactivity of stretch reflexes resulting in muscle spasm. As a result, when the TKR patients perform exercise, the nociceptors are more stimulated because the effects of cold compression before passive exercise are reduced due to heat production, and noxious stimuli such as lactic acid, muscle contraction, and muscle spasm are increased. For this reason, the effect of cold to relieve the pain that the patients have had since before exercise may be inadequate.

Therefore, the investigator designed method A that is cold compression both before, and during passive exercise for the purpose of continuing the effect of cold. After finishing cold compression for 20 minutes before exercise, the investigator will remove the previous cold gel packs and put the new cold gel packs to compress at the start of until the finish of exercise. Through 30 minutes of exercise the cold gel packs have a temperature between 0°C and 18.33°C . Cold compression during exercise is continuous cold therapy that reduces pain by decreasing noxious stimuli which occur from exercise. As continuous cold compression reduces the energy need of cells during exercise, the metabolism of tissues and muscles around the knee is decreased, consequently this decreases heat production and lactic acid. In addition, cold compression during exercise reduces nerve conduction velocity of sensory and motor nerves, consequently reducing the stretch reflex. As a result, during exercise with cold compression muscle contraction occurs due to functioning of the knee whereas muscle spasm is inhibited. Furthermore, continuous cold therapy increases the stiffness of collagen which is the major component of muscles that can cause increased muscle endurance that assists in decreased muscle spasm. Moreover, cold compression during exercise decreases nerve conduction velocity of pain fibers, the A-delta and the C, which results in decreased perception of pain during exercise. Therefore, continuous cold compression can reduce pain by decreasing transduction, transmission, and perception of pain through passive exercise. The conceptual of framework guide to this research is shown in Figure 2.

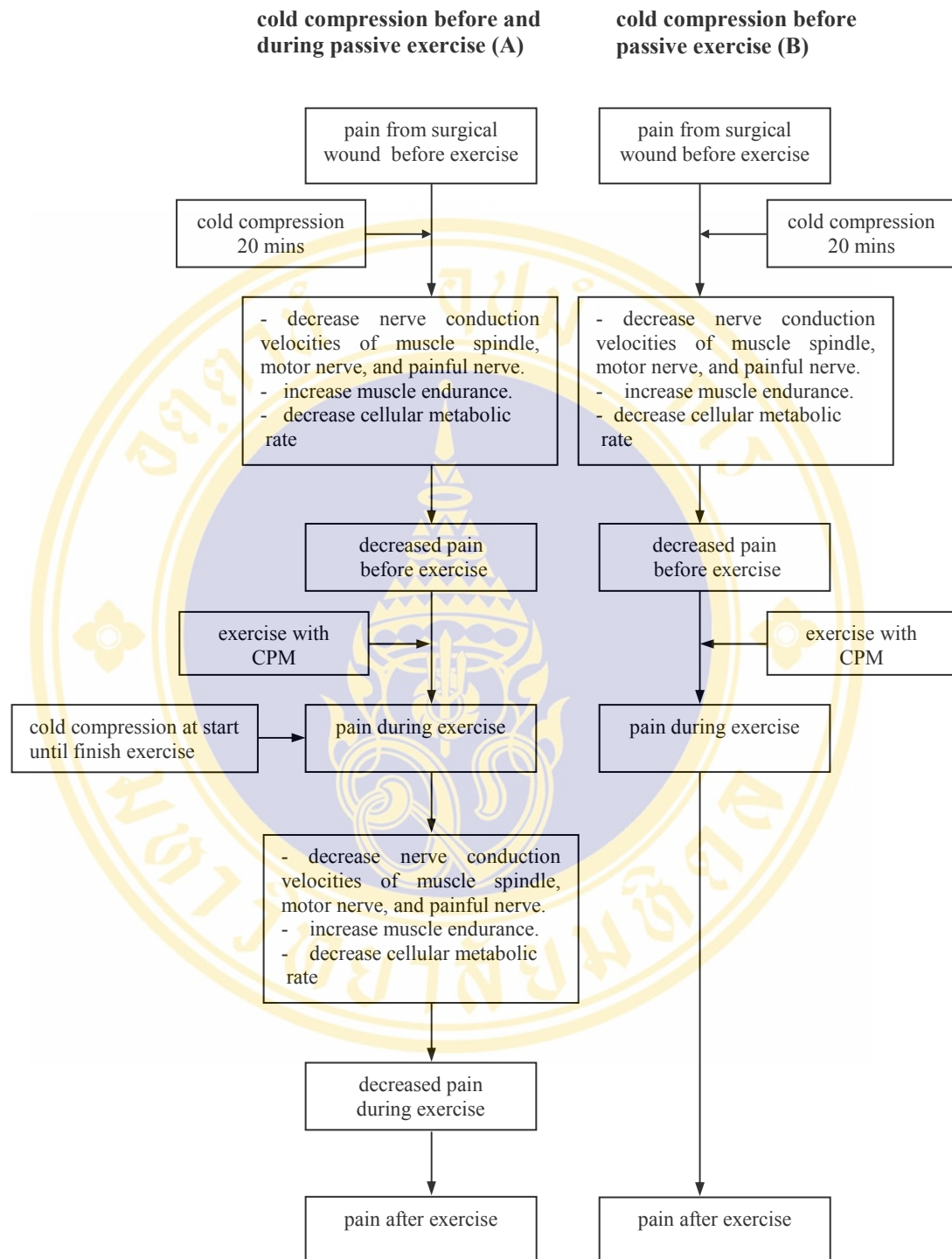


Figure 2: Conceptual framework to compare between method A and method B of cold compression.

Hypothesis

The cold compression both before and during passive exercise can reduce pain better than cold compression before passive exercise using a continuous passive motion machine with total knee replacement patient.

Scope of the study

To study the effectiveness of pain reduction between cold compression before passive exercise, and cold compression both before and during passive exercise using a continuous passive motion machine for primary osteoarthritis patients who had undergone total knee replacement on the fourth postoperative day. It involved elective cases only, including males and females, who had been admitted at the private ward, Orthopaedic Department, Siriraj Hospital, Bangkok, Thailand, between February to July 2003.

Definition of terms

Cold compression method refers to the application of a pair of cold gel packs at one time. This pair of cold gel packs has a temperature of 0°C to 0.5°C , container in a bag and put on the skin of postoperative knees. The pair of cold gel packs are aligned bilaterally with the surgical wounds of TKR patient. There are two methods of cold compression as follow:

Method A = The cold compression both before and during passive exercise.

- the 1st minute - Cold compression with a pair of cold gel packs which have a temperature of 0°C to 0.5°C for 20 minutes.
- the 20th minute - Remove the cold compression.
- the 21st minute - Cold compression with a new pair of cold gel packs which have a temperature of 0°C to 0.5°C replaces the old one.
- the 21st to the 50th minute - The patients exercise their knee with the CPM machine for 30 minutes and have a new pair of cold gel packs from the 21st to 50th minute.

Method B = The cold compression before passive exercise.

- the 1st minute - Cold compression with a pair of cold gel packs which have a temperature of 0⁰ C to 0.5⁰ C for 20 minutes.
- the 20th minute - Removal the cold compression
- the 21st to the 50th minute
 - The patients exercise their knee for 30 minutes with the CPM machine.

During cold compression, the patient's room temperature is controlled between 23.5⁰ C and 25.5⁰ C in order to control any increase in cold gel packs temperature. Also, the temperature of cold gel packs will still have a therapeutic effect through cold compression when between 0⁰ C to 18.33⁰ C.

Pain refers to an individual's feeling of unpleasant sensations after TKR surgery during passive exercise with CPM machine due to surgical incision, muscle contraction, and muscle spasm of the TKR limb. Self-report of pain intensity was measured by a vertical 0–10 Numeric Rating Scales. This tool has been developed by McCaffery and Beebe in 1989, and 1994 and the latest was developed by McCaffery and Pasero in 1999.

Exercise with continuous passive motion (CPM) machine after total knee replacement (TKR) refers to the exercise that uses an electric device to help TKR patient to perform passive continuous flexion and extension of the operative knee in order to produce a normal range of motion.

Expected outcomes and benefits

1. A guideline for nurses to select the best method of cold compression to alleviate pain suffering in total knee replacement patient using a continuous passive motion machine in the rehabilitation period.
2. A guideline for those interested in studying the effects of cold compression on other types of pain in the future.

CHAPTER II

LITERATURE REVIEW

This research aimed to study a comparison between the effectiveness of pain reduction by using two methods of cold compression, cold compression before passive exercise, and cold compression both before and during passive exercise using a continuous passive motion machine for total knee replacement patient. The review of literature on the theoretical basis is categorized into four parts as follow:

1. Total knee replacement (TKR) surgery and rehabilitation
2. Concept of pain
 - 2.1 Definition of pain
 - 2.2 Pain processes and Type of pain
 - 2.3 Factors influencing the pain perception and pain response
 - 2.4 Pain assessment
 - 2.5 Nursing intervention for pain relief
3. Pathophysiology of pain in TKR patient during exercise with CPM machine.
4. Cryotherapy and pain reduction in TKR patient during exercise with CPM machine.
 - 4.1 Cryotherapy
 - 4.2 Effect of cryotherapy on pain reduction in TKR patient during exercise with CPM machine.

1. Total knee replacement (TKR) surgery and rehabilitation.

Total knee replacement (TKR) is treatment for osteoarthritis of the knee that has caused degeneration of cartilage and tissue around the knee, resulting in disability and chronic pain. The procedures of total knee replacement are implanting a proper knee prostheses for an improvement in joint mechanics for mobility and stability. Furthermore, the patients have pain relief and an improvement in their quality of life (Hawker, et al., 1998: 163–164).

Indications for total knee replacement (Sledge, et al., 1994: 802)

- 1) Rheumatoid panarthritis.
- 2) Osteoarthritis of the knee. Total knee replacement should be avoided in patients younger than 60 years of age, in manual laborers, in athletes, and in those who are grossly overweight.
- 3) Post-traumatic osteoarthritis.
- 4) Failure of high tibial osteotomy.
- 5) Patellofemoral osteoarthritis.
- 6) The neuropathic joint that results in instability and deformity of the knee.

Contraindications for total knee replacement (Koopman, 2001: 1066; Sledge, et al., 1994: 802; Unhanun, A., 1996: 24–26).

- 1) Active infection in knee joint.
- 2) Advanced diabetes or other disease caused sensible loss in knee joint.
- 3) Osteoporosis.
- 4) Muscular weakness due to paralysis or general health is weakness.
- 5) Gross overweight. The prospects of successful replacement are not good and hardly for rehabilitation.
- 6) Young people who have high-activity expectation and long life expectancy more than lifetime of prostheses.
- 7) The patients who are not cooperate or don't want to surgery.

Surgical procedures of total knee replacement

- 1) Resection of upper tibia. The upper tibia is resected by a saw and the remaining area drilled for the grooves of the prostheses dowels.
- 2) Resection of distal femur. The distal femur is cut at anteroposterior, lateral, and medial dimensions and a groove is drilled or cement is put in the remainder area for a prostheses dowel that depends on the type of prostheses.
- 3) Resection of patella. The surface of the patella is cut and drilled for prostheses dowel or cement is put in the remainder area depending on the type of prostheses.
- 4) The surgeon has chosen suitable prosthetic materials.
- 5) After surgeon has closed wound by layer, a posterior slab will be applied to the surgical knee in full extension position, and ultimately the Robert Jones compression bandage which includes of cotton crepe and an elastic bandage will be applied to the patient at the end of the surgical procedures.

Rehabilitation after total knee replacement surgery

The rehabilitation after TKR surgery is important to promote health. The ultimate goal of rehabilitation is to restore symptom-free movement and function, allowing individual to return to their normal activity. However, the rehabilitation program gradually depends on individual health conditions and the discretion of surgeons. The steps of the rehabilitation program are as follow. (Satyawiwat, W., et al., 1996: 195):

The 1st–2nd postoperative day

- 1) The TKR patients stay in bed and the postoperative leg is lifted to 45 degree by supporting pillows. This position helps to reduce blood loss, blood congestion in the foot area, and prevent stiffness of knee joint in flex position.
- 2) The patients are stimulated to have deep breathing exercise in order to have lung exercise and prevent pneumonitis.
- 3) The patients are encouraged to perform ankle plantar flexion and dorsiflexion exercise to promote blood circulation and prevent nerve compression in the leg's lateral region.

The 2nd–3rd postoperative day

- 1) After suction drainage is removed, the patient should perform quadriceps exercise in a straight leg position supported by pillows.
- 2) The patients should often hang on the bar for buttocks lifting and turn their position so as to prevent pressure sores.

The 3rd–4th postoperative day

- 1) Continue quadriceps exercise.
- 2) After surgeon removes the posterior slab and the Robert Jones compression bandage, the patients attempt a straight leg position and are always supported by two pillows.
- 3) The patients must try straight leg rise exercise by themselves or by the aid of assistants who are nurses or relatives.
- 4) Exercise with continuous passive motion (CPM) machine or other aid instrument for about 15 to 30 minutes / time.
- 5) The patients can do most activities of daily living by themselves such as sitting on the bed, eating, and scrubbing their face etc.

The 4th–5th postoperative day

- 1) Continuous, quadriceps exercise and exercise with aid instrument are done.
- 2) When the surgeon permits patient to start flexion the postoperative knee by sitting on the chair or the bed in position of hanging the postoperative knee, the patients should attempt to have as much flexion as possible at least 90 degree of knee flexion.
- 3) Cold compression is used on the postoperative knee to relieve pain and edema in knee joint, in addition to prevent bleeding from the surgical wound.

The 5th–7th postoperative day

- 1) Exercise similar to exercise in the 4th–5th postoperative day is done.
- 2) The patients try to move to the chair, sit, stand and attempt to flex postoperative knee to 90 degree by themselves. These actions are in order to prevent stiff knee.
- 3) Patients are trained to stand and walk with a pickup walker and the operated knee has weight bearing as much as possible.

The 7th–10th postoperative day and post stitch removal from the surgical wound.

- 1) Continue quadriceps exercise.
- 2) Stand and walk with a pickup walker.
- 3) Extreme flexion and extension of the postoperative knee for 90 degrees of knee flexion or above.

Physiology change in TKR patients during exercise with CPM machine.

Passive exercise by using a CPM machine with TKR patient causes movement in the sagittal line of postoperative knee. During exercise, the TKR patient does not use his or her force but the CPM machine which is an electric device assists the patient to perform continuous exercise to increase flexion and extension of the postoperative knee. The factors that are related in performing flexion and extension of knee includes, the factor of knee joint which is joint mobility and the factor outside the knee joint which is soft tissue mobility. The joint mobility depends on the properties of the knee prostheses. Otherwise, the factors outside the knee joint involved with soft tissues that are composed of tendons, ligaments, joint capsules, muscles with their fascial coatings, blood vessels, and nerves (Boonnak, Y., 1996: 161-162; Clilliet, 1996: 1).

Skeletal muscles are ensheathed by connective tissue, the epimysium, which in some muscles has the form of a dense fascia (Mense & Simons, 2001: 20). The connective tissue consists of ground substance and three types of fibers which are collagen, elastin, and reticulin. The properties of fibers in connective tissue can explain that collagen is the major component which has a dry weight of about 80% in connective tissue, contributing stiffness and tensile strength of muscle whereas elastin and reticulin are the minor components. The elastin promotes capability of extensible muscles and reticulin helps to form bulk characteristics. Besides, tendons and ligaments are related to joints by promoting strength. Tendons and ligaments combine mostly with collagen, tendons have one extreme or both connect to the skeletal muscles whereas the ligaments have extremes connecting between bones (Boonnak, Y., 1996: 161-162).

When the TKR patient performs passive exercise with CPM machine, the physiological response occurs due to stretching the quadriceps muscle that is known as

stretch reflex, or myotactic reflex, which is a simple spinal reflex. The neural circuit responsible for the stretch reflex which shows in Figure 3 is a simple two neurons reflex elicited by stimulation of muscle spindles and producing activation of the motor unit. The compositions of this neural circuit are discussed as follow (Benarroch, et al., 1999: 202-203; Floeter, 1999: 891; Kandel, 2000: 717; Roywimut, S., 1998: 59-71; Snell, 2001: 98).

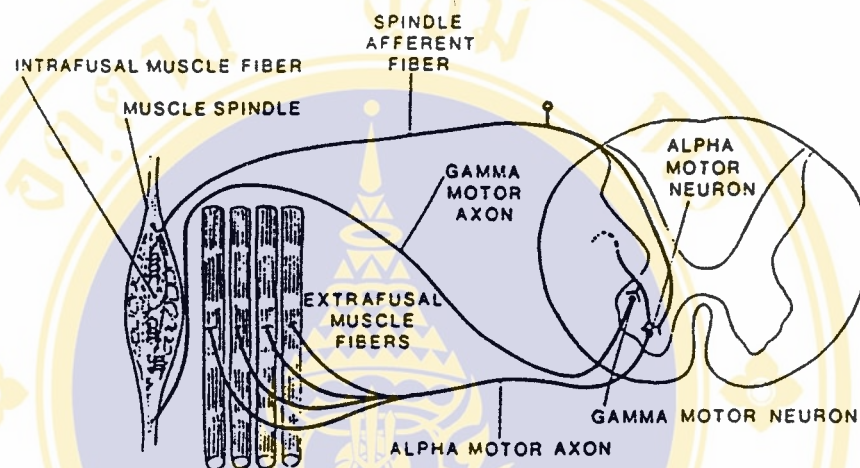


Figure 3: Neural circuit of stretch reflex (Benarroch, et al., 1999: 205)

1) Stimulator refers to the stretching of quadriceps muscle during passive exercise result to increase the length of muscles.

2) Receptors refer to muscle spindles or intrafusal fibers. Quadriceps muscles are the skeletal muscles that are composed of extrafusal muscle fibers and intrafusal muscle fibers. Extrafusal muscle fibers are the regular muscle fibers and only have the function of contraction whereas intrafusal muscle fibers or also called muscle spindles are smaller, shorter, and have lesser amount than extrafusal muscle fibers, but they have important functions. Muscle spindles are encapsulated within a collagenous sheath and lie parallel with extrafusal muscle fibers (Floeter, 1999: 880). Moreover, muscle spindles provide sensory information that is used by the central nervous system in the control of the muscles activity. There are two types of muscle spindles fibers which are the nuclear bag fibers and nuclear chain fibers. The bag fibers can be divided into two groups, static and dynamic. Nuclear bag fibers respond to sudden changes in muscle spindle length (a static response) and velocity of stretching (a dynamic response) whereas nuclear chain fibers only respond to sudden

changes in muscle spindle length (Kandel, 2000: 718; Roywimut, S., 1998: 61; Smith, et al., 1996: 103; Snell, 2001: 96).

3) Afferent fibers refer to two types of myelinated sensory nerve fibers of muscle stretching that innervate the muscle spindles (Figure 4).

(3.1) Primary endings (group Ia or group A alpha), or annulospiral endings, are situated at the equator of muscle spindles. The diameters are about 12 to 20 micrometers and the estimated nerve conduction velocity is about 72 to 120 meters per second (Kingsley, 2000: 211; Snell, 2001: 96).

(3.2) Secondary endings (group II or group A beta), or flower spray ending, are situated mainly on the nuclear chain fibers some distance away from the equatorial region. The diameters are about 4 to 12 micrometers and the estimated nerve conduction velocity about 24 to 72 meters per second (Kingsley, 2000: 211; Snell, 2001: 96).

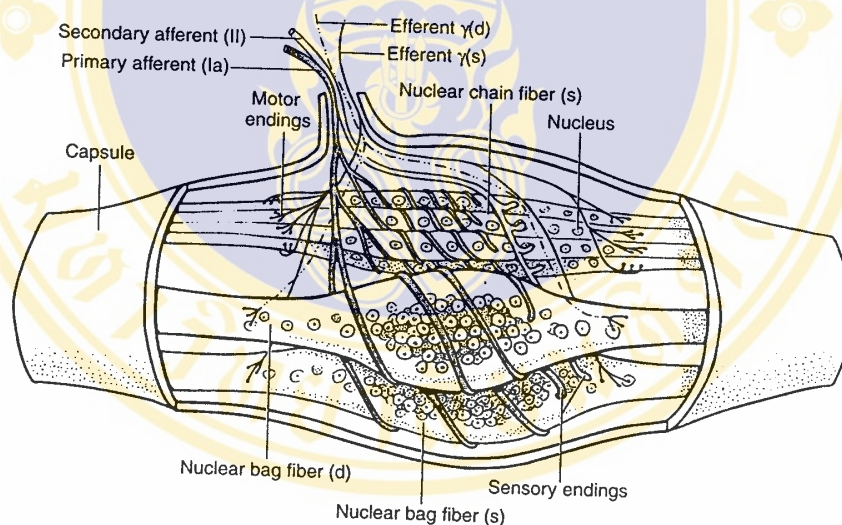


Figure 4: Muscle spindle and its fibers

(Shumway-Cook & Woollacott, 2001: 58)

4) Reflex center of quadriceps muscle stretching is situated on the anterior horn of spinal cord that comprises cells of the alpha motor neurons and gamma motor neurons.

5) Efferent fibers are the two types of motor neurons, namely alpha and gamma. These neurons are myelinated so that alpha neurons innervate to extrafusal muscle fibers, in other words called skeletomotor neurons, and gamma neurons innervate to intrafusal muscle fibers in other words called fusimotor neurons.

The diameters of alpha neurons are about 8 to 13 micrometers and the estimated nerve conduction velocity is about 44 to 78 meters per second whereas gamma neurons have 3 to 8 micrometers of diameter and an estimated nerve conduction velocity of about 18 to 48 meters per second (Kingsley, 2000: 211).

6) Effectors refer to the quadriceps muscle.

7) Response of stretch reflex is quadriceps muscle contraction.

When the TKR patients perform passive exercise with CPM machine by flexing and extending their knee, the stretching of quadriceps muscle stimulates the muscle spindles which function as a mechanoreceptor to produce stretch reflex (Roywimut, S., 1998: 26). The stretch depolarize the nuclear bag and nuclear chain fibers in the muscle spindles, causing an increase in the firing rate of the primary ending (group Ia fiber) and secondary ending (group II fiber) axons (Kingsley, 2000: 216). Moreover, this stretch also increases the firing rate of gamma motor neurons, or fusimotor neurons, because these neurons innervate intrafusal muscle fibers at the motor end-plate, so that it produces a stretch reflex easier. When the stretch responsive channels, which are situated on the neurons membrane, are stimulated the positive charged ions in extracellular fluid, i.e. sodium ions, calcium ions, rush into the cell creating a temporary positive charge relative to the outside, so depolarization occurs. Then the negative charged ions in the cell body, i.e. potassium ions, rush to the outside for repolarization. Consequently, an action potential is created and converted to a nerve impulse. This impulse is sent to the central nervous system especially the anterior horn of the spinal cord, into the synaptic cleft area which releases neurotransmitters such as glutamine by afferent fibers, namely the primary endings (group Ia fibers) and secondary endings (group II fibers). Next, the alpha and gamma motor neurons receive impulses and release the acetylcholine to reach the nicotinic receptors on the motor end-plate of quadriceps muscle membrane. Once the acetylcholine-gate channels are opened, depolarization and repolarization occurs by the exchanging of positive charged ions in extracellular fluid, i.e. sodium ions, calcium ions, and negative charged ions in cell body, i.e. potassium. The action potential will be created and the impulses from the motor neurons produce quadriceps muscle contraction. Therefore, this stretch reflex is known as monosynaptic reflex because it involves a single synapse. The quadriceps muscles contraction results in increasing

muscles tension. The physiological responses receive muscle tension by Golgi tendon organs that are situated at the junction between muscle fibers and tendons. Each tendon organ is innervated by the nerve fiber neuron in group Ib, or A alpha fiber, that is the large myelinated neuron, having diameters of about 12 to 18 micrometers, and estimated nerve conduction velocity is 72 to 108 meters per second. The Golgi tendon organs provide a tension feedback mechanism by sending the impulse to inhibit the alpha motor neurons that innervate the quadriceps muscle, resulting in quadriceps muscle relaxation (Benarroch, 1999: 206; Kandel, 2000: 723; Kingsley, 2000: 211). The characteristics of nerves which relate to muscle contraction and pain are shown in Figure 5 in order to summarize them.

Group number	Fiber type	Receptor	Size (μm) (micrometer)	Conduction velocity (m/sec)
Ia	A α	primary muscle spindle	12–20	72–120
Ib	A α	Golgi tendon organ	12–18	72–108
II	A β	secondary muscle spindle	4–12	24–72
III	A δ	pain, cold, and some touch	2–5	12–30
IV	C	pain, temperature, and other	0.4–1.2	0.5–2
	alpha motor neuron	extrafusal muscle	8–13	44–78
	gamma motor neuron	intrafusal muscle (muscle spindle)	3–8	18–48

Figure 5: The characteristics of nerves and their functions that relate with muscle contraction and pain.

(Benjamin & Johnson, 2000: 117; Ganong, 1995: 53; Kingsley, 2000: 211)

The contraction of quadriceps muscle or other skeletal muscles is an active process that expends energy from adenosine triphosphate (ATP). Four sources of ATP

are potentially available to muscles that store ATP, phosphocreatine, anaerobic glycolysis, and oxidative, or aerobic, metabolism. Muscle cells store enough ATP to sustain contraction for approximately 6 seconds. Then phosphocreatine, a high-energy compound unique to muscles, may transfer energy and a phosphate group to adenosine diphosphate (ADP) to regenerate ATP, sustaining muscle work for another 5 or 10 seconds. Afterwards, if the contraction of the muscle goes on, anaerobic glycolysis can generate small amounts of ATP from stored muscle glycogen, but this metabolic pathway also produces lactic acid, contributing to local acidosis that induces muscle pain and fatigue. In the presence of oxygen, the pyruvic acid produced during glycolysis is not converted to lactic acid, but rather enters the Krebs cycle and, ultimately, becomes mitochondrial oxidative phosphorylation. Oxidative metabolism produces much more ATP than anaerobic glycolysis, but does not produce it as quickly.

The efficiency in either anaerobic glycolysis or oxidative metabolism depends on their predominant fiber types of muscle (Hansen, 1998: 1020–1021). Skeletal muscle fiber types are classified as slow oxidative (type I or “slow twitch”), fast oxidative (type IIA “fast twitch”) or fast glycolytic (type IIB “fast twitch”). Type I fibers appears red because the present of myoglobin, an iron containing molecules that facilitates diffusion of oxygen for oxidative metabolism. Oxidative metabolism provides a slow and continuous supply of oxygen, so the muscles with majority of type I fibers can maintain contraction for a long period without or with less fatigue. Otherwise, type II fibers, type IIA fibers are delicate shades of red because they contain myoglobin and glycogen. Glycogen can be quickly converted to adenosine triphosphate (ATP) via glycolysis, producing quickly much energy for muscle contraction. Type IIB fibers appear white because of the absence of myoglobin. They have large glycogen stores and rely almost exclusively on anaerobic glycolysis for ATP production. Although, energy can be generated quickly by type II fibers glycogen stores are quickly depleted, consequently lactic acid is created and it leads to local acidosis. So, type IIA fibers fatigue more quickly than type I but not as quickly as type IIB. Generally, a person who is not an athlete has estimated type I muscle fibers of about 45% to 55 % and the quantity of type II fibers is equal between type IIA and type IIB. However, the distributions of muscle fiber types in a body depend on the

functions of muscles. Furthermore, older adults or persons who lack exercise have increased type I of muscle fibers (Hansen, 1998: 1021–1022; Cantaratanakul, V., 2000: 150-151). In addition, during exercise the physiological responses of the body increase blood supply to muscles, at the same time maintaining blood volume to the brain and the heart. As a result, these physiological responses increase the heart rate in order to elevate cardiac output for blood supply of muscles, increase blood pressure, and increase the respiratory rate in order to supply oxygen and deplete carbon dioxide (Cantaratanakul, V., 2000: 153-156). In short, the physiological changes of the TKR patient when performing passive exercise with CPM machine include the joint functions, relative nervous system, metabolism, circulation system, and respiratory system.

2. Concept of pain

2.1 Definition of pain. Many researchers gave the meaning of pain as follow:

Sternbach (1968 cited in Ignatavicius, et al., 1995) asserted that “pain is an abstract concept which refers to a personal, private sensation of hurt, a harmful stimulus which signals current or impending tissue damage, and a pattern of responses to protect the organism from harm”.

Jeans & Melzack (1992: 11–12) stated that “pain is a highly personal and subjective experience that is influenced by cultural learning, the meaning of the situation in which it occurs, attention, anxiety, and a host of other cognitive and psychological variables. It is generally acknowledged that pain is a signal that body tissues are being or have been injured”.

McCaffery & Pasero (1999: 17) stated that “pain is whatever the experiencing person says it is, existing whenever the experiencing person says it does”.

Turk & Okifuji (2001 :17) stated that “pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” which is the same as the definition of The International Association for the Study of Pain.

In summary, pain refers to an unpleasant sensory and emotional experience associated with actual or potential tissue damage or psychological threat that has

individual differences, and depends on cultural learning and the meaning of the situation.

2.2 Pain processes and Type of pain

Pain processes. McCaffery & Pasero (1999: 17) stated that the pain pathway is revealed in 4 processes as shown in Figure 6:

- 1) Transduction
- 2) Transmission
- 3) Perception
- 4) Modulation

1) Transduction. Transduction is the first process involved in nociception which is the term used to explain how pain becomes conscious. It begins at the periphery (skin, subcutaneous, tissue, visceral, and somatic structures, except capillary) where primary afferent neurons, called nociceptors, are distributed throughout. Nociceptors are free nerve endings with the capacity to distinguish between noxious and innocuous stimuli (McCaffery & Pasero, 1999: 18; Roywimut, S., 1998: 28). When the nociceptors are exposed in sufficient quantity to mechanical, thermal, or chemical noxious stimuli, tissue damage or potential damage occurs. The pain stimulus is changed to an impulse and moves from the periphery to the spinal cord, an action potential is created. All cells in the body, including neurons, have a membrane potential. The inside of a neuron is negatively charged relative to the outside. This is called the resting membrane potential. In relation to pain transmission, sufficient amounts of noxious stimulation cause the membrane to become permeable to sodium ions, allowing the ions to rush into the cell and create a temporary positive charge relative to the outside. This is called depolarization. Other ion transfers also occur. For example, an efflux of potassium changes inside the cell back to a negative one relative to the outside. This is called repolarization. If enough depolarization and repolarization occur, an action potential is created and the stimulus is converted to an impulse. Transduction, which takes just milliseconds to occur, is then complete. The impulse is ready to be transmitted along the nociceptor fibers that extend from the nociceptor cell body (McCaffery & Pasero, 1999: 18).

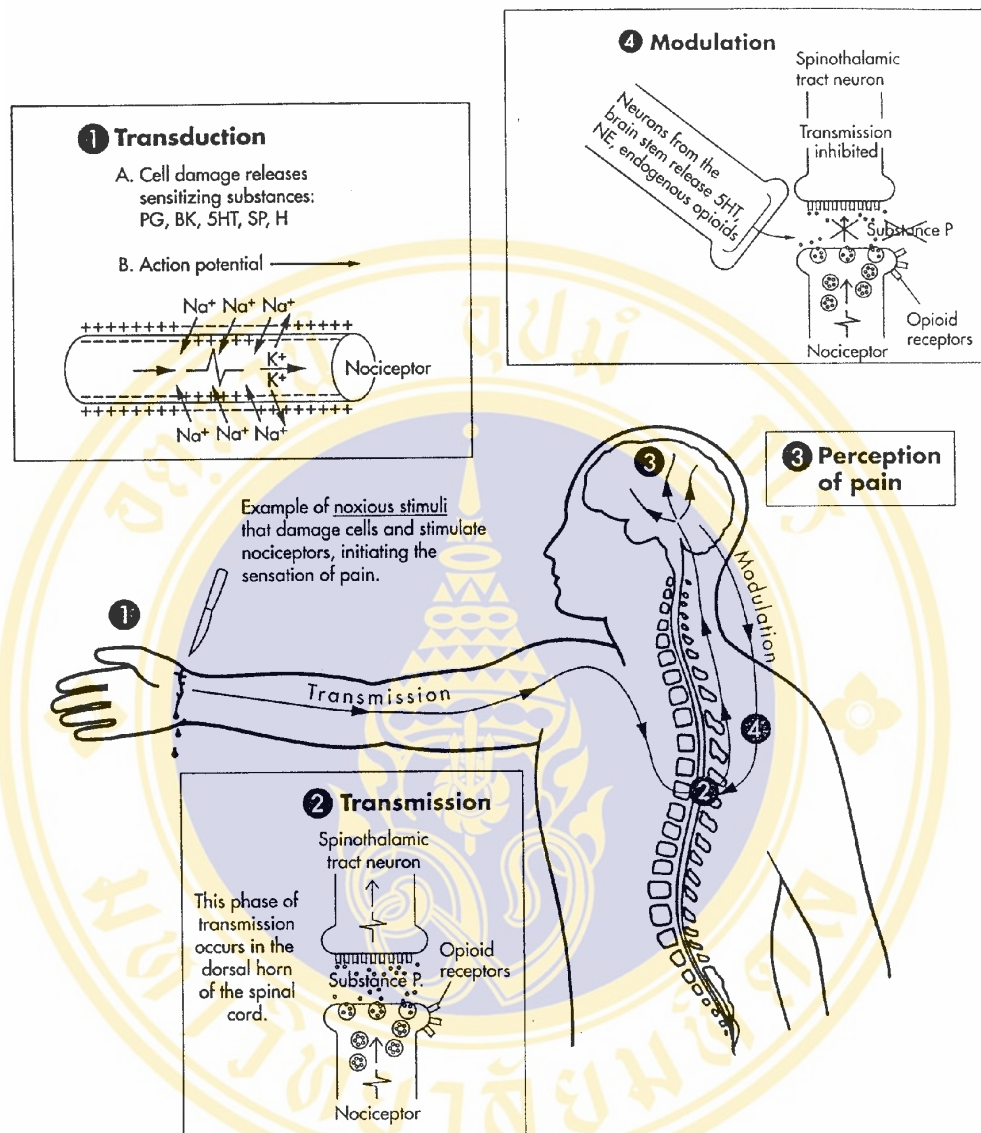


Figure 6: Illustration of the four basic processes involved in pain pathway:

1) transduction 2) transmission 3) perception 4) modulation

(McCaffery & Pasero, 1999: 21)

Noxious stimuli are divided into 3 categories as follow:

- (1) Mechanical stimuli which are the physical injury or damaging of tissue such as surgical incision, tumor growth which compress organs or nerves, swelling infection, and contraction or spasm of muscles (Starkey, 1999: 16–27).
- (2) Temperature stimuli which are heat, cold, and electric current.
- (3) Chemical stimuli which are extrinsic substances of the body such as acid, base, and poison from plants and animals or intrinsic substances which are created

within the body from the physical injury or damaging of tissue to activate or sensitize pain.

Nowadays, many intrinsic substances have been discovered such as histamine, serotonin, potassium, bradykinin, prostaglandins, acetylcholine, substance P, and leukotrienes etc. (Byer & Bonica, 2001: 52). Intrinsic substances can be divided into three types by their functions in dealing with nociceptors which includes:

(1) Direct activation to the nociceptors. These substances include histamine, serotonin, potassium, bradykinin, and acetylcholine etc.

(2) Sensitize the nociceptors which induce nociceptors to be more easily excited but do not activate nociceptors directly. These substances are such as prostaglandins and leukotrienes etc. (Benjamin & Johnson, 2000: 117).

(3) Spread of sensitization of nociceptors. These substances created capillary extravasation by increased permeability of capillaries. Furthermore, bradykinin is accumulated and also caused the release of histamine from mast cells and serotonin from platelets. These substances are substance P and calcitonin gene-related peptide etc.

2) Transmission. Transmission is the second process involved in nociception. There are three segments. The first segment is transmission of the impulse along the nociceptor fibers to the level of the spinal cord. Next, the second segment is transmission from the spinal cord to the brain stem and thalamus. Finally, the third segment involves transmission of the impulse through connections between the thalamus and the cortex (McCaffery & Pasero, 1999: 22). **In the first segment**, two types of nociceptor fibers are responsible for the transmission of pain from the site of transduction to the spinal cord, which are the A-delta afferent and the C afferent fibers.

The A-delta afferent fibers are discovered in skin and muscle. These nerve fibers are small nerve fibers that have a diameter from 2 to 5 micrometers (Ganong, 1995: 53), sparsely myelinated, and the conduction velocity is about 5 to 30 meters per second (Benjamin & Johnson, 2000: 117). The A-delta afferent fibers are sensitive primarily to mechanical and thermal stimuli, transmitting well-localized, and sharp pricking pain (Ignatavicius, et al., 1995: 122).

The C afferent fibers are discovered in muscles, tendons, joint capsules, and visceral organs. These nerve fibers are unmyelinated small nerve fibers that have a diameter from 0.4 to 1.2 micrometers (Ganong, 1995: 53), and the conduction velocity is about 0.5 to 2 meters per second (Benjamin & Johnson, 2000: 117). The C afferent fibers are sensitive primarily to mechanical, thermal, and chemical stimuli, transmitting poorly localized, dull, and burning pain (Ignatavicius, et al., 1995: 122).

The nociceptors carry the impulse from the periphery terminate to the dorsal horn of the spinal cord. In this area of the spinal cord, neurotransmitters such as substance P, glutamate, and adenosine triphosphate (ATP) are created from primary afferent fibers or inflamed cells (Byers & Bonica, 2001: 52). The neurotransmitters are media for transmitting a pain impulse from the nociceptors to the dorsal horn of the spinal cord (Byers & Bonica, 2001: 87–94). The different pain impulses terminate in different laminae of the dorsal horn of the spinal cord. The A-delta afferent fibers terminate in lamina I, II, V, and X of the dorsal horn and the C afferent fibers terminate in lamina I, II, and V of the dorsal horn as shown in Figure 7 (Terman & Bonica, 2001: 76).

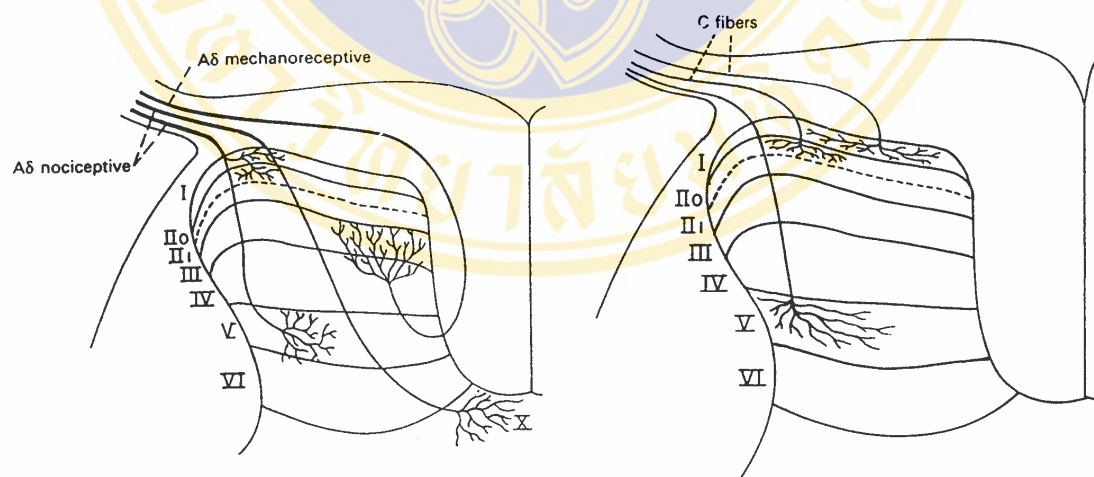


Figure 7: A schematic diagram of the course and termination of the A-delta afferent fibers and the C afferent fibers in the dorsal horn of the spinal cord.
(Byers & Bonica. 2001: 36-37)

Each lamina of the dorsal horn has different functions as follow:

Lamina I has two types of neurons of interest which are the nociceptive-specific neurons (NS) which specially respond to the noxious stimuli of the A-delta afferent fibers and the C afferent fibers. In addition, wide-dynamic-range (WDR) cells in this lamina can respond to noxious and innocuous stimuli (Terman & Bonica, 2001: 78). These neurons are part of the cells that make up the long spinothalamic tract (Buxton, 1999: 42).

Lamina II has mostly substantial gelatinosa cells (SG cells), which contain small internuncial neurons that can excite or inhibit the transmission of noxious stimuli. Moreover, the small internuncial neurons in the SG cells send axons to the Lamina I and release enkephalin and gamma-aminobutyric acid, both of which inhibit the transmission of noxious stimuli (Buxton, 1999: 42; Terman & Bonica, 2001: 79).

Lamina III and Lamina IV are composed of wide-dynamic-range neuron cells and low-threshold mechanoreceptors that play a limited role in the transmission and modulation of pain (Buxton, 1999: 42).

Lamina V is important in nociception and pain because the most common cells are the wide-dynamic-range or multireceptive neurons. By definition, they respond to a variety of inputs from low-threshold and high-threshold mechanical, thermal, and chemical stimuli by way of large and small afferent fibers. Also, their axons contribute to lengthen the spinothalamic tract, spinomecencephalic tract, and spinoreticular tract (Terman & Bonica, 2001: 81).

Lamina X consists of a group of specialized cells. This group of cells may constitute one of the polysynaptic chains linking the entire length of the cord and brain stem that is believed to be involved in transmission of nociceptive information (Terman & Bonica, 2001: 81).

In the first segment, we can consider that the lamina I, II, and V are important for transmission of pain. Next, **the second segment** is the transmission from the spinal cord to the brain stem and thalamus as shown in Figure 8 and this segment has tracts of impulse as follow.

The spinothalamic tract in which the A-delta and the C afferent fibers are terminated in the lamina I and V where wide-dynamic-range neuron cells transmit pain impulses to the brain via two different portions of the spinothalamic tract. The first

portion, the neospinothalamic tract receives input from the A-delta fibers that synapse with the nociceptive-specific neurons and the wide-dynamic-range neurons in lamina I and V. These neurons cross the ventral white column of the spinal cord to the opposite anterolateral white column. Once in the anterior horn, the fibers of neospinothalamic tract synapse with motor units or stimulate preganglionic neurons of the sympathetic or parasympathetic system and then communicate to the thalamus and send up impulses to the somatosensory cortex. This transmission is responsible for the motor and autonomic responses associated with tissue damage and information pertinent to the site, intensity, and duration of the full pain stimulus (Buxton, 1999: 44). Jeans and Melzack (1992: 25) describe the neospinothalamic tract as the sensory-discriminative aspect of pain. The second portion, the paleospinothalamic tract is located more medially than the neospinothalamic tract but is still in the anterolateral portion of the white matter of the spinal cord. This tract receives its input predominantly from the C fibers that synapse with the nociceptive-specific neurons and the wide-dynamic-range neurons in lamina I and V. Then they cross over the spinal cord and project impulses to the reticular formation, located in the central portion of brain stem. The neurons then course through a complicated network of synapses to the medulla oblongata, midbrain, periaqueductal gray, hypothalamus, thalamus, limbic system, and cortex. Jeans and Melzack (1992: 27) described the paleospinothalamic tract as the motivational-affective dimension of pain. The brain portions produce different pain responses as follow:

The reticular formation is responsible for evoking motor, sensory, and autonomic responses to noxious stimuli, allowing the injured person to respond rapidly to the stimuli.

The medulla oblongata controls functions of autonomic nervous system.

The midbrain serves as center for many reflexes and assists in coordinating movement and visual tracking.

The periaqueductal gray controls the release of β -endorphin and other pain reducing chemicals.

The hypothalamus controls the endocrine system's release of hormones. Through this mechanism, the hypothalamus regulates metabolism and stress response.

The thalamus controls mood and body movements that are associated with fear, anxiety, pain and rage.

The limbic system controls the visceral response to emotions and the sensation of pain and pleasure (Buxton, 1999: 44-46).

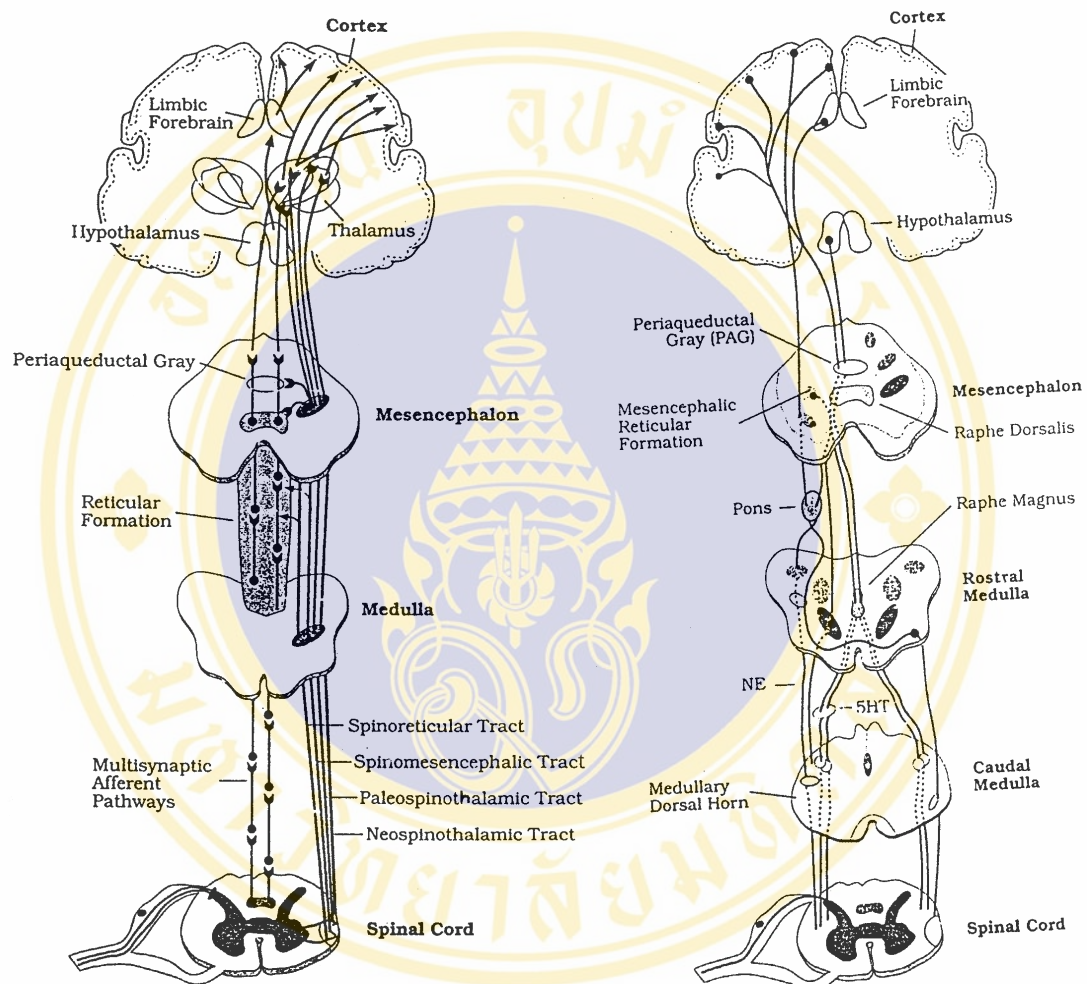


Figure 8: Ascending pain pathway (left) and descending pain pathway (right)
(Buxton, 1999: 45-47)

The spinoreticular tract has thinner fibers of which the diameters of axons are 1 to 5 micrometers. This tract sends through impulses from the spinal cord to the medulla, pons, reticular formation, periaqueductal gray, and thalamus that functions to stimulate the emotional response of pain, somatic nociceptive response, and autonomic nociceptive reflex (Terman & Bonica, 2001: 120-121).

The spinomesencephalic tract is sometimes classified with the spinoreticular tract because this tract has the relative nerve pathway and the same size thin fibers

(1-5 micrometers). Most of the spinomesencephalic tract cell bodies are in lamina I and V of the spinal cord, but some are scattered in other laminae. The nerve impulse ascends to the medulla, pons, reticular formation, periaqueductal gray, and thalamus simultaneously with the spinoreticular tract in order to discriminate the somatic function and stimulate emotional responses to pain (Terman & Bonica, 2001: 120-121).

The third segment of pain transmission is involved in the transmission of the impulse through the connection between the thalamus and the cortex. The thalamus has three parts. The first part is the posterior nuclear complex in which its neurons have the same functions with the wide-dynamic-range cells of responding to noxious and innocuous stimuli. Next, the second part is the ventrobasal complex which transmits impulses to the somatosensory cortex to respond to the innocuous stimuli, thermal change, and joint movement. In addition, this part consists of the ventroposterolateral axis which is responsible for the nociceptive impulse (Yaksh, 2001: 16). Moreover, the cells in this second part play important roles in discriminative functions of pain in sending them to the cerebral cortex. Finally, the last part is the medial intralaminar nuclear complex which is concerned with the motor and emotional response. It receives impulses from the spinothalamic tract. Then the impulse is sent to the cerebral cortex and limbic region. (Chudler & Bonica, 2001: 159-161; Yaksh, 2001: 16).

3) Perception. Perception is the third process in pain processes, and is the end result of the neural activity of pain transmission. At this point pain has become a conscious experience. A number of central structures are involved. For example, it is believed that the reticular system is responsible for the autonomic response to pain and for warning the individual to attend to it. The somatosensory cortex localizes and characterizes pain (McCaffery & Pasero, 1999: 22). The limbic system helps to integrate the higher brain functions for emotional and behavioral responses of pain. Moreover, these behaviors are brought on by the integration of the limbic system with the reticular formation, thalamus, and cortex (Wallace, 1992: 8).

Like the pain mechanism, the pain impulse from the brain level moves through the descending pathways. The limbic system which is the center for feeling and control of the emotional expression is activated by sensory input from the cerebral

cortex. Some of the tracts of the pain impulse from thalamus descend to the hypothalamus which integrates and regulates the autonomic nervous system, such as it increases heart rate, respiration rate, blood pressure, muscle contraction, diaphoresis, and neuroendocrine responses. For the endocrine system, the pituitary gland is stimulated from the hypothalamus to release adrenocorticotropic hormone (ACTH) which stimulates the adrenal cortex to release cortisol. Consequently, blood pressure is increased. These results, indirectly affect pain.

It is believed that pain perception occurs in the cerebral cortex (McCaffery & Pasero, 1999: 22). Every individual perceives and interprets pain based on individual experience. Pain perception depends on physical stimuli and psychosocial factors. Although, there is little consensus on the specific effects of these factors, it known that anxiety, experience, attention, expectation, and the meaning of the situation in which injury occurs affect pain perception (Black & Jacobs-Matassarin, 1997: 345).

Pain perception is the point at which a person is aware of pain and its cause and reports it. Jeans & Melzack (1992: 25-30) and Potter & Perry (1995: 746) stated that there are three interaction systems of pain perception; sensory-discriminative, motivational-affective, and cognitive-evaluative.

Sensory-discriminative is the process of nerve transmission which occurs between the thalamus and the sensory cortex. It perceives the location, severity, and character of pain.

Motivational-affective is an interaction between the reticular formation and limbic system resulting in pain perception. The reticular formation creates a defensive response, causing a person to interrupt or avoid pain stimuli. The limbic system controls emotional response and coping with pain.

Cognitive-evaluative concerns higher cortical centers in the brain which influence perception. Culture, experience with pain, and emotions influence a person's evaluation of the pain experience which helps a person to interpret the intensity and quality of pain so that an appropriate action can be taken.

4) Modulation. The forth process involved in nociception is modulation, which refers to changing or inhibiting pain impulses (McCaffery & Pasero, 1999: 22). There are a variety of mechanisms that contribute to this modulation (Black & Jacobs-Matassarin, 1997: 344-345; Starkey, 1999: 46-48).

Modulation via the dorsal horn. Nowadays, the dorsal horn is known to contain extremely complex circuitry and multiple biochemical agents that both transmit and modulate nociceptive input such as gamma-aminobutyric acid (GABA), glycine, and adenosine etc. (Terman & Bonica, 2001: 98-99). The dorsal horn is now thought to modulate the nociceptive impulse rather than simply receive and transmit this impulse. A high degree of processing the impulse occurs at this level.

Modulation via descending pathways. The descending serotonergic inhibitory fibers originate in the periaqueductal gray matter of the midbrain which receives impulses from the cortex, limbic system, hypothalamus, and paleospinothalamic tract and subsequently, they descend downward into the nucleus raphe magnus which in the lower pons and upper medulla. Neurons from the periaqueductal gray matter project downward into the dorsal horn of the spinal cord at the first, the second, and the fifth lamina level. The neurotransmitters such as serotonin (5HT), norepinephrine (NE), and substance P etc. are released into these areas, contributing to the modulation of pain, is shown in Figure 8.

Modulation via endogenous chemicals. The descending pain pathways are associated with releasing endogenous opioids which have properties similar to morphine and other opioid analgesics for inhibiting transmission of pain or reducing pain. Endogenous opioids must bind to opioids receptor sites to proceed for function and degrade too quickly (McCaffery & Pasero, 1999: 23). Endogenous opioids are divided into three groups.

(1) Enkephalins comprise of five amino acid peptides and are found in two types, namely leucine enkephalin and methionine enkephalin (Terman & Bonica, 2001: 99-103). Enkephalins are found throughout the central nervous system but particularly in the dorsal horn. Moreover, descending input from periaqueductal gray matter activates enkephalins release in lamina I, II, III, and V of dorsal horn to inhibit pain at the spinal cord level and inhibit transmission of pain to the brain (Starkey, 1999: 47).

(2) Beta-endorphin (β -endorphin) is sent by the hypothalamus via neurons to the periaqueductal gray matter, subsequently it is sent in lamina I, II, and V of dorsal horn so as to inhibit pain at the spinal cord level and impede transmission of pain to the brain (Starkey, 1999: 46). Moreover, beta-endorphins are larger peptides and exert

more prolonged analgesic effects than do the enkephalins (Ignatavicius, et al., 1995: 123).

(3) Dynorphins are primarily located in lamina I and V of dorsal horn, making it feasible for them to inhibit pain (Starkey, 1999: 48).

Type of pain. There are two types of pain as follow.

Acute pain. Pain elicited by the injury of body tissues and activation of nociceptive transducers at the site of local tissue damage. The local injury alters the response characteristics of the nociceptors and perhaps their central connections and the autonomic nervous system in the region. In general, the state of acute pain lasts for a relatively limited time and generally remits when the underlying pathology resolves. It occurs frequently after trauma, surgical interventions, and some disease processes (Turk & Okifuji, 2001:17). This type of pain is of mild to severe intensity and cause fright, anxiousness, and requires relief quickly to the person. Furthermore, acute pain seriously threatens a person's recovery by hampering the person's ability to become active and involved in self-care. Rehabilitation may be delayed and hospitalization prolonged if acute pain is not controlled. Therefore, after acute pain is relieved, the person can direct full attention toward recovery (Delaune & Ladner, 1998: 831; Potter & Perry, 1995: 748).

Chronic pain. It is usually elicited by an injury but may be perpetuated by factors that are both pathogenetically and physically remote from the originating cause. Chronic pain extends for a long period of time, and represents low levels of underlying pathology that do not explain the presence and extent of pain, or both. This type of pain prompts patients frequently to seek health care, and it is rarely effectively treated. Because the pain persists, it is likely that environmental and affective factors eventually interact with the tissue damage, contributing to the persistence of pain and illness behaviors (Turk & Okifuji, 2001: 17). Chronic pain varies in intensity and usually last more than 6 months. Consequently, chronic pain is a major cause of psychological and physical disability, leading to problems such as job loss, inability to perform simple daily activities, sexual dysfunction, and social isolation (Potter & Perry, 1995: 748).

2.3 Factors influencing the pain perception and pain response. A person's pain experience is affected by a number of factors, including age, sex, culture, meaning of pain, attention, anxiety, fatigue, previous experience, coping style, and family and social support. These factors may increase or decrease the client's perception of pain, increase or decrease tolerance for pain, and affect the manner of responses to pain. These factors are discussed as follows (Potter & Perry, 1995: 748).

Age. Developmental differences influence how children and older adults react to pain. Children have trouble understanding pain and without full vocabularies also have difficulty verbally describing and expressing pain to parents or care givers (Potter & Perry, 1995: 748). When comparing children with younger adults having the same medical diagnoses, children received fewer medication doses. On the other hand, older adults generally receive less analgesia and tend to report pain less often than do younger adults (Ignatavicius, et al., 1995: 123). There is controversy about pain in the elderly. Pain is often thought of by the elderly as a natural manifestation of aging however, there is no reason to assume that pain reception alters in the elderly unless some damage has occurred in the central nervous system. The transmission and perception might be slow with aging, but this does not diminish the pain that is felt. Moreover, the ability of older adults to interpret pain can be complicated by multiple diseases and vague symptoms affecting similar part of the body. On the other hand older adults may not report pain because they may believe pain is a part of aging, fear the unknown, fear death, use inadequate terms to describe pain, or believe showing pain is unacceptable (Black & Jacobs-Matassarin, 1997: 346-349; Potter & Perry, 1995: 748).

Sex and culture. Generally, men and women do not differ significantly in pain responses. However, cultural influences on gender may produce different expression of pain. For example, it is less acceptable for a little boy not to be brave and cry, whereas a little girl in the same situation may cry. It is likely that cultural factors contribute considerably to these differences, with males being expected to tolerate more pain than females. Understanding cultural background, socioeconomic, and personal characteristics helps the nurse more accurately assess pain and its meaning for clients (Potter & Perry, 1995: 749).

Meaning of pain. The meaning of pain is associated with pain effect on the pain experience. Clients perceive pain differently if it suggests a threat, loss, punishment, or challenge. Frequently, a client will report unbearable pain before a hospital admission. That is to say, the degree and quality of pain perceived by client are related to the meaning of pain.

Attention. The degree to which a client focuses on pain can influence pain perception. Increased attention has been associated with increased pain, whereas distraction has been associated with decreased pain. Nurses apply this concept in pain-relief therapies such as relaxation and guided imagery.

Anxiety. There is relationship between pain and anxiety. Elevated anxiety levels cause an increase in pain perception. Therefore, a person who is emotionally healthy is usually able to tolerate moderate or even severe pain better than those less stable emotionally.

Fatigue. Fatigue heightens pain perception. This intensifies pain and decrease coping abilities. Pain is often experienced less after a restful sleep than at the end of a tiring day.

Previous experience. Just because a client has a previous pain experience does not necessarily mean the client will accept pain more easily in the future. Frequent episodes of pain without relief or bouts of severe pain may produce anxiety or fear. In contrast, experiences with the same type of pain that has successfully been relieved makes it easier for the client to interpret the pain sensation. As a result, the client is better prepared to take steps to relieve the pain. On the other hand, a client who has had no experience with pain may have an impaired ability to cope with it. For example, a postoperative client, unprepared for surgical incision pain, may be reluctant to ambulate or increase activity.

Coping style. Frequently clients feel a loss of control in being unable to control their environment or the outcome of events. Coping style thus influences the ability to deal with pain. Clients with internal loci of control perceive themselves as having personal control over their environments and the outcome of events. In contrast, clients with external loci of control perceive other factors in their environment, such as nurses, as being responsible for the outcome of the event. Those with internal loci of control report less severe pain than those with external loci.

Family and social support. A client often depends on the support of spouse, family, or friends when coping with pain. Although pain still exists, the presence of loved one can minimize loneliness and fear. Clients of different sociocultural groups have different expectation of people to whom they complain about pain. For example, clients in pain often depend on family members for support, assistance, or protection. Absent family or friends can often make the pain experience more stressful. Furthermore, the presence of parents is especially important for children's pain.

2.4 Pain assessment. Pain is a subjective experience that the patient might not be able to describe fully. McCaffery & Pasero (1999: 17) has defined pain as whatever the experiencing person say it is, existing whenever he or she says it does. In addition, Potter & Perry (1995, 775) contended that patients manifest both verbal and nonverbal ways to communicate pain. Therefore, pain assessment can be divided into two ways that are subjective data and objective data which includes physiological manifestations and behavioral manifestations.

1) Subjective data. Subjective data are obtained from both writing and verbally that a patient's statements about his or her pain are most important in pain assessment. Because pain is a subjective phenomenon, thus the nurse must accept that the patient knows best about the intensity of pain. It is thought that the intensity of an individual's pain is the primary factor that determines the impact of pain on the person's overall functioning and sense of well-being. Thus, pain intensity serves as a benchmark for comparison of pathological conditions over time and is important for determining the effect of intervention strategies (Herr & Garand, 2001: 464). Self-reported pain rating scales are most commonly used to quantify pain's intensity in daily clinical practice. (Black & Jacobs-Matassarin, 1997: 365; McCaffery & Pasero, 1999: 62). Self-reported pain intensity tools are such as visual analogue scale (VAS), numeric rating scales (NRS), faces rating scales (FRS), and simple descriptors scales (SDS) (Herr & Garand, 2001: 465). They are illustrated as follow:

Visual analogue scale (VAS) The VAS is the scale most widely used to assess acute postoperative pain. The VAS is represented as a straight line, both horizontal and sometimes vertical, 10 centimeters in length. At either end of line are

two poles with words such as “no pain” on the left side whereas “worst possible pain” is indicated on the right side (Figure 9). The patient is asked to make a mark along the line to represent pain intensity. From this marking a number is concreted by measuring in millimeters or centimeters and can be obtained and use for analysis.



Figure 9: Visual analogue scale (McCaffery & Pasero, 1999: 62)

Face rating scale is based on the idea of VAS. This scale shows six facial expressions suggesting various pains intensity ranging from a sad, crying face to that of a happy face. Furthermore, it may be displayed along with a numerical pain rating scale of 0 to 5 or 10 (Figure 10).

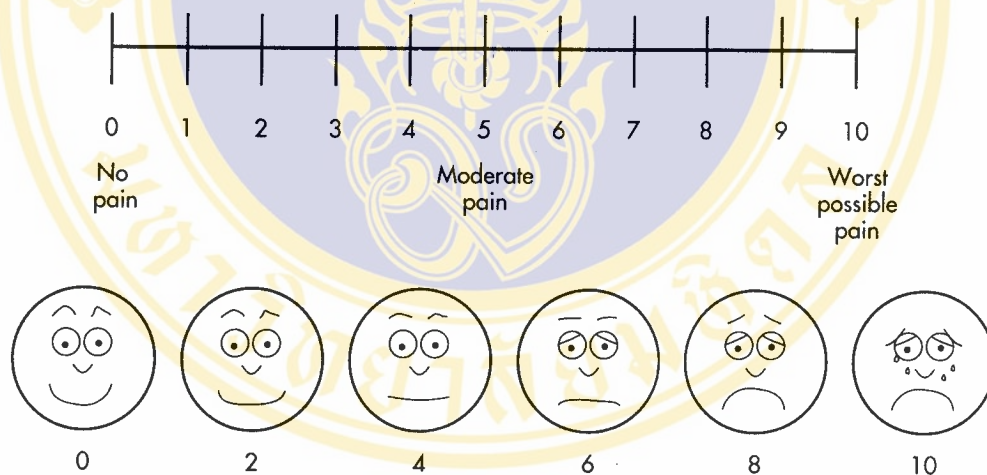
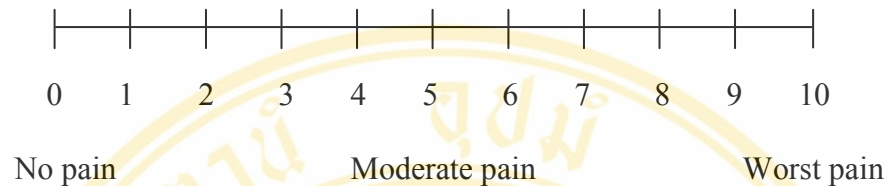


Figure 10: Face rating scale
(McCaffery & Pasero, 1999: 67)

Numeric rating scale (NRS) / Graphic rating scale (GRS) These scales built on the VAS by adding to the measurement line either words or numbers between the extreme ends of the scale. If words are added, such as no pain, mild, moderate, and severe, it is called a verbal graphic rating scale (GRS). If numbers are added, such as 0 through 10, it becomes a numeric rating scale (NRS). There are two versions: the horizontal version and vertical version as shown in Figure 11. The patient

is asked to rate pain intensity from 0 to 10, with 0 equaling no pain and 10 equaling the worst possible pain (McCaffery & Pasero, 1999: 63).

Horizontal version



Vertical version

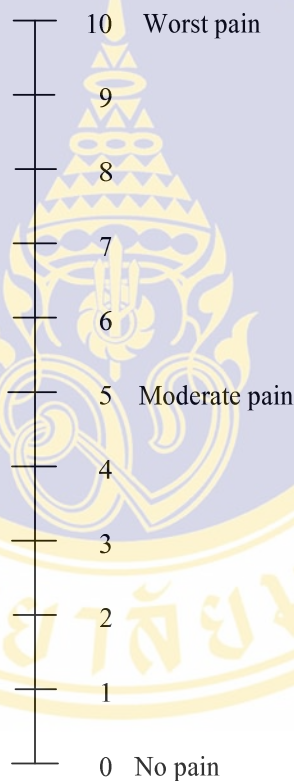


Figure 11: Numeric rating scale; the horizontal version and the vertical version
(McCaffery & Pasero, 1999: 63)

Simple descriptor scale (SDS) This is a list of adjectives describing different levels of pain intensity, including no pain, mild, moderate, and severe pain. These words are easily understood and scored from 0 to 3. The SDS with many words are not recommended because they are time consuming to users and some patients do not understand the words used (Jensen & Karoly, 1992).

The VAS and NRS are recognized for their validity and reliability and appear adaptable to assess acute pain in the postoperative period (Puntillo, 1991 cited by Hancock, 1996: 346). Researchers have found that the correlation between the VAS and NRS was strong for supporting the validity and reliability of administering the NRS (Berthier, et al., 1998: 133; DeLoach, et al., 1998: 105; Herr & Mobily, 1993: 42; Paice & Cohen, 1997: 88). The appropriate tool of pain measure involves determining the individual's ability to read, hear, and understand the direction for completing the tool (Herr & Garand, 2001: 465). Although the VAS is relatively easy to use, it requires abstract thinking abilities so that patients tend to have more difficulty understanding and using a VAS than the other scales such as the NRS. Moreover, the NRS seems to be a suitable option because 0 to 10 has been well established and it is potentially more sensitive to change in pain intensity. Besides, it minimizes confusion of both clinicians and patients (McCaffery & Pasero, 1999: 65). Although the NRS can be oriented either vertically or horizontally, a vertical presentation may be easier for persons with alterations in abstract thinking and is often preferred by the elderly (Herr & Mobily, 1993: 45; Jensen & Karoly, 1992: 135-151).

As the reasons mentioned above, in this study, the vertical 0-10 NRS was chosen to assess pain intensity. This tool has been developed by McCaffery & Beebe in 1989, and 1994, and the latest was developed by McCaffery & Pasero in 1999. The vertical pain of NRS has reliability and validity of the pain intensity scale when used among older adults (Herr & Garand, 2001: 465). Moreover, it is easily administered either orally or in writing and is easy to score and record.

2) Objective data. Objective data of pain has two types that are physiological and behavioral manifestations. These are obtained by measurement or observation that can supplement subjective data. However, the objective data can not replace the subjective data. Physiological manifestations are result of the activation of the autonomic nervous system. With acute pain, the general responses observed include diaphoresis, tachycardia, increased respiratory rate, elevated blood pressure, and increased muscle tension etc. Although, assessing the client's vital signs such as heart rate, respiratory rate, and blood pressure is important for obtaining baseline information, particularly before a potentially painful procedure or situation. However,

for clients who have difficulty expressing pain or are unable to do so, the vital signs readings and comparisons before and after pain relief measures may be useful but not conclusive for acute pain evaluation, because many other factors can also influence vital signs. Furthermore, pain is an individual's sensation and can not be interpreted by a lack of symptoms Behavioral manifestations are not specific to pain. The behavioral responses to acute pain are various such as rigid body position, restlessness, frowning, clenched teeth, crying, and moaning etc. Sometimes the client's behavior does not seem to match his or her verbalization of pain. For example, the client who is sleepy but complains of severe pain may be exhausted from pain (Craven & Hirnle, 2000: 1155; Watt-Watson, 1999: 336).

2.5 Nursing intervention for pain relief. Nursing interventions for pain relief are divided into two methods, namely pharmacological and nonpharmacological methods.

Pharmacological method for pain relief is the most common approach to pain by administering analgesic medications. Although the analgesic medication are ordered by the physician, the nurse is responsible for giving the drugs, evaluating and documenting their effectiveness or side effects, and notifying the physician if the relief obtained is inadequate or if it has the side effect that are not desirable. Analgesics may be separated into three major groups as follow (Craven & Hirnle, 2000: 1161).

(1) Nonopioid analgesics include aspirin, nonsteroidal anti-inflammatory drugs (NSAIDs), and acetaminophen. These drugs are used as single-agent therapy principally for mild pain but can be combined with opioids to improve pain control for mild, moderate, and severe pain (Craven & Hirnle, 2000: 1161-1163).

(2) Opioid analgesics are a group of naturally occurring and synthetic agents for relief of moderate to severe pain in the postoperative period or post traumatic situation. However, use of opioids or combination of opioid and non opioid analgesics may have side effect such as respiratory depression, nausea, vomiting, and constipation etc. (Craven & Hirnle, 2000: 1163-1166).

(3) Adjuvant analgesics include corticosteroids, tricyclic antidepressants, antihistamines, benzodiazepines, caffeine, anticonvulsants, local

anesthetics, and psychostimulants. The purpose of administering these drugs is in order to promote the effect of analgesics or counteract the side effects of analgesics (Craven & Hirnle, 2000: 1163-1167).

Nonpharmacological method for pain relief includes physical pain relief, cognitive pain relief that focuses on client's beliefs, attitudes, expectations, control, and cognitive coping, and behavioral pain relief focuses on target actions under the client's control (Craven & Hirnle, 2000: 1158-1163).

Physical pain relief techniques are discussed as follow:

(1) Cutaneous stimulation. Cutaneous stimulation relieves acute or chronic pain. For example, the application of cold modalities which have a temperature range of between 0 °C and 18.33 °C can reduce pain because they reduce or inhibit transmission and perception of pain. Moreover, cold application can help reduce causes of pain by inducing vasoconstriction for decreased blood loss, decreased cellular metabolism for reduced inflammation and edema, and diminished muscle contraction and muscle spasm. Besides, there are other methods of cutaneous stimulation such as pressure, massage, and vibration etc. Moreover, cutaneous stimulation should be moderate in frequency and duration, and its use should be determined by the extent of pain relief. Areas that can be used include the skin over or near the pain site.

(2) Positioning and hygiene. For clients who spend many hours in bed, regularly changing position can help alleviate pain because pressure areas are created by lying in one posture too long, contributing to pain. Furthermore, the supervision of hygiene can promote more comfortable feelings in the client

Cognitive pain relief techniques are discussed as follow

(1) Anticipatory guidance. Because fear and anxiety may enhance or precipitate pain, therefore providing information about pain and promoting the expression of client's feelings about pain will help nurses and clients share information. Consequently, the client can usually manage the pain better knowing what to expect and how to manage

(2) Distraction. Distraction is useful when clients are undergoing brief periods of sharp, intense pain such as dressing changes and wound debridement. In helping to decrease pain, this technique is limited to

concentrated perception of pain stimuli for mild to moderate pain. Distraction is most effective if it is something the client enjoys doing such as watching television and listening to music etc.

(3) Guided imagery. Guided imagery is a technique in which the person focuses on a pleasant, relaxed mental image as a way to decrease the intensity of pain.

(4) Hypnosis. This blocks the awareness of pain through suggestions by substituting another feeling for pain, altering the pain's meaning, increasing pain tolerance, and, in extreme case, dissociating the perception of the body from the person's awareness.

Behavioral pain relief techniques are discussed as follow:

(1) Relaxation. Relaxation techniques can counteract the effects of the fight-or-flight response and promote mental and physical freedom from tension and stress. As a result, it can decrease body consumption of oxygen, heart rate, respiratory rate, and muscle tension etc.

(2) Meditation. This is a technique in which the person focuses on a single thought or sound to decrease perception of severity of noxious stimuli. Consequently, the clients feel relaxed and have less pain.

(3) Biofeedback. In this technique, the client learns voluntary control over autonomic functions, such as heart rate, hand temperature, and muscle tension. Electrodes are placed on the client's body and auditory or visual feedback provides the client with information about muscle relaxation, heart rate, blood pressure, and skin temperature. After baseline data are obtained, the client learns relaxation and deep-breathing exercises. The relaxation decreases pain by decreasing anxiety and increasing the client's sense of control over pain. In addition, motivation in this technique is an important component in its success, because it requires extensive training.

3. Pathophysiology of pain in TKR patient during exercise with CPM machine.

Postoperative pain perception is largely a physiological phenomenon that is influenced primarily by the tissue damage caused by incision, manipulation, retraction, and excision. The total knee replacement procedure injures the supportive structures of the knee that consists of three layers that blend together. Layer I is an extension of deep fascia covering the quadriceps and tendon expansion of the sartorius. The frontage of layer I is blended with the frontage of layer II. Next, layer II contains the superficial collateral ligaments including medial collateral ligament (MCL), originating at the medial femoral epicondyle and extending distally on medial surface of the tibia, and posterior oblique ligament (POL), originating at the femoral epicondyle, blending with the capsule and extending to the posterior of the tibia. Layer III is the capsule of the knee joint which is distinguishable from layer II, except at the edge in front of the patella bone where the capsule is thinner. Underneath the superficial MCL it is thickened and called the deep MCL. Its fibers consist of menisiofemoral and menisiotibial ligaments (Rojanasatian, S. & Padungkiat, S., 1990: 63). During the TKR, these structures are always released from the bone as their attached bone is removed for prosthetic replacement. After the TKR, the incision is extremely painful. Therefore, the stimuli of pain in the postoperative period especially during exercise can be separated as follow.

1) Mechanical stimuli refer to the surgical wound, muscle contraction, and muscle spasm

2) Chemical stimuli refer to the chemical substances which are released from damage tissue and chemical substance which is the result from glycolysis metabolism that is lactic acid. When a cut or mechanical distortion of tissue occurs, substances such as histamine, prostaglandins, substance P, and others are released or manufactured. These substances cause three reactions; direct activation to the nociceptors, sensitization of pain fibers so that another substance can initiate nociception, and extravasation of substances that can cause spread of nociception.

Because of the pain processes and muscles stretch reflex principle, pain of the TKR patient during passive exercise occurs when the muscles are stretched by the CPM machine. This results in a stimulation of myelinated sensory nerve fibers at the muscle spindles, namely the primary endings and the secondary endings, and produces

nerve impulses to the motor neurons which are the alpha and gamma motor neurons at the spinal cord. Then the motor neurons return their impulse to produce muscle contraction in order to respond to stretching of muscles around the knee that is so-called the stretch reflex. At the same time, the chemical substances from the surgical wound such as histamine etc. which stimulate nociceptors and decrease the function of Golgi tendon organ results in failure to modify suitably tension of muscles. For these two reasons, which are the chemical substances from damaged tissue increases pain perception and the failure of the function of the Golgi tendon organ which are the factors promoting hyperactivity of stretch reflex, consequently muscles spasms occur. Muscles spasms cause blood vessel constriction and results in tissue hypoxia. The condition where muscles contain less oxygen during knee exercise continuously create anaerobic metabolism which increases lactic acid. Lactic acid can not be eradicated due to vasoconstriction that contributes to local acidosis and creates muscle pain. In summary, at the first steps of pain processes the noxious stimuli which are mechanical stimuli, i.e. muscle contraction and muscle spasm, and chemical stimuli, i.e. histamine and prostaglandin etc., activate the nociceptors of the A-delta fibers and the C fibers that produce transduction of pain impulses. Then pain is transmitted to the afferent fiber of the A-delta fibers and the C fibers which transmit impulses to the spinal cord and brain. Next, pain perception occurs. Finally, the impulses from the brain descend (descending pain pathways) to the spinal cord to modulate the appropriateness of pain.

4. Cryotherapy and pain reduction in TKR patients during exercise with CPM machine.

4.1 Cryotherapy. Cryotherapy is the application of cold modalities that have a temperature range of between 0 °C and 18.33 °C to treat the tissue trauma in acute or subacute period and decrease pain from exercise or activities of rehabilitations after orthopedic surgery (McDowell, et al., 1994: 21; Prentice, 1999: 227; Starkey, 1999: 110). During cryotherapy, heat is removed from the body and absorbed by the cold modality, causing the body to respond with a series of local and systemic responses. The magnitude of these effects is related to the temperature of the modality, the duration of the treatment, and the surface area exposed to the treatment. To obtain

therapeutic benefits, the skin temperature must be decreased to approximately 13.88°C (57°F), for the optimal decrease in local blood flow to occur and to approximately 14.44°C (58°F) for analgesia to occur (Starkey, 1999: 110).

Cold modalities and transfer of the temperature. All forms of cryotherapy are considered superficial cooling agents. Three methods of temperature transfer are discussed as follow (Braddom, 1996: 457; Hixson, 1994: 386; Robert, 2001: 311).

(1) Conduction occurs during direct contact with the cold modality which absorbs heat from the skin. Mostly cold modalities transfer temperature by conduction such as reusable cold gel packs, ice packs, ice massage, and cold water immersion etc.

(2) Convection is the transfer of heat through contact with a motion of air or water across the body skin surface. An example of this method is the whirlpool bath.

(3) Evaporation occurs when the water evaporates from skin surface, and heat is absorbed. The example of this method is the vapocoolant spray.

Degree of cold. The degree of cold are divided into 4 levels as follow (Lewis & Timby, 1993: 559).

Tepid has temperature between 26.6 and 33.8°C

Cool has temperature between 18.3 and 26.6°C

Cold has temperature between 10.0 and 18.3°C

Very cold has temperature lower 10°C

Indications of cryotherapy (Starkey, 1999: 113)

- (1) Acute injury or inflammation.
- (2) Acute or chronic pain.
- (3) Superficial first-degree burns.
- (4) Postsurgical pain and edema.
- (5) Use in conjunction with rehabilitation exercises.
- (6) Spasticity accompanying central nervous system disorders.
- (7) Acute or chronic muscle spasm.

(8) Neuralgia.

Contraindications of cryotherapy (Starkey, 1999: 113)

- (1) Cardiac or respiratory involvement.
- (2) Uncovered open wounds.
- (3) Circulatory insufficiency.
- (4) Hypersensitivity to cold or cold allergy.
- (5) Anesthetic skin.
- (6) Advanced diabetes.
- (7) Having Raynaud's phenomenon that occurs from systemic sclerosis results in circulatory insufficiency. When apply cold agent to the skin the vessels, especially vascular extremities, are immediately responsive severity.
- (8) Having rheumatoid arthritis.

Physiological effect of local cryotherapy. The local effects of cold application which have a temperature of between 0 °C and 18.33 °C include vasoconstriction, decreased cellular metabolic rate, decreased inflammation, decreased muscle spasm, and decreased pain. Each of the effects can be explained as follows:

(1) Cellular response. Cold decreases the cellular metabolic rate and chemical substances released by damaged tissue such as prostaglandins and histamine etc. (Linchitz & Sorell III, 2000: 532). When normal tissues are injured, a hypoxic environment is created. The physiological responses are to increase the cellular metabolic rate to prevent normal oxygen perfusion. A cold environment decreases cellular metabolic rate, consequently decreasing the amount of oxygen required by the cell to survive. By reducing the number of cells killed by a lack of oxygen, the degree of secondary hypoxic injury is limited. Because fewer cells are damaged from secondary hypoxic injury, reduced amounts of inflammatory mediators are released into the area, containing the scope of the injury. In addition, during a 20-minutes treatment, cell metabolism decreases by 19% (McDowell, et al., 1994: 22; Starkey, 1999: 114).

(2) Vascular and fluid dynamic response. Vasodilation which is stimulated by inflammatory chemical substances such as prostaglandins occurs

immediately after tissue injury. Rising hydrostatic pressure in dilated capillaries increases serous fluid extravasation, which leads to increased swelling around the injured site. Additionally, capillary rupture occurs due to the force of insult from an injury or incision. Hemorrhage of whole blood and tissue debris from the primary incision are broken down by macrophages into free protein, consequently forming hematoma. The hematoma formations increase the interstitial concentration, which creates an osmotic gradient between the interstitial cell and intravascular space. This environment favors fluid flow into the extravascular space, which increases swelling. When cold is applied after injury or surgery, the body attempts to preserve core heat by stimulating the local nerve receptors, triggering a response from the sympathetic nervous system instructing the superficial cutaneous vessels to constrict that is known as vasoconstriction. Afterwards, the molecular motion of the blood and tissue are slowed resulting in increasing their viscosity. For the reasons mentioned above, vasoconstriction leads to decreasing blood circulation in the injury area, decreased capillary permeability and hemorrhaging, consequently decreased hematoma formation and swelling (McDowell et al., 1994: 21; Starkey, 1999: 114-116).

Besides, when cold application is maintained over a longer period of time, or skin temperature is reduced below 10°C (50°F), it is believed a cold-induced vasodilation occurs. This phenomenon, it is believed indicates that a cold decreases norepinephrine, and decreases the agility of alpha adrenergic receptors which exist in the vascular smooth muscle. These receptors respond to the norepinephrine and epinephrine from the sympathetic nervous system which causes vasoconstriction. Then vasodilation warms the tissue to rise above 10°C and results in again releasing norepinephrine to sensitize receptors, and the vasoconstriction properties of cold take over once again. The cyclical periods are called the “hunting response”. This “hunting” of temperature is believed to be a mechanism by which peripheral exposed parts of the body are protected from cold injury and it is reversed every 5 to 10 minutes (Anderson & Hall, 1995: 162; Braddom, 1996: 457-458; Hixson, 1994: 392).

(3) Effect on inflammatory process. Cold decreases cellular metabolism which in turn reduces the damaged tissue's requirement for oxygen. Afterwards, bradykinins, prostaglandins and histamines, which all potentiate the inflammatory process, are inhibited from release at the point of tissue damage after

cold is applied. Additionally, cold produces vasoconstriction, leading to decreased capillary permeability and hemorrhaging results in a decrease of swelling. In short, the cold application can suppress the inflammatory responses.

(4) Effect on muscles. The cold decreases muscle sensitivity and muscle spasms by two actions that are explained as follow.

(4.1) Cold decrease nerve conduction velocity of myelinated sensory nerve fibers that innervate muscle spindles, namely primary endings and secondary endings. As a result, the muscle spindles that control muscle contraction by concern with the sudden changes in muscle length and velocity of stretching are slowed, consequently decreased muscle contraction occurs. In addition, the vasoconstriction after cold application results in decreased blood circulation in muscles that causes decreased muscle contraction ability.

(4.2) Cold increases the stiffness of collagen and increases muscle endurance. Collagen is the major component of connective tissue, which is found in the structure of ligaments, tendons, and muscles. Collagen exhibits primary elastic properties, which allows theses structures to flex and extend. Cold has been shown to enhance the elastic properties of collagen by increasing the stiffness and resistance to stretch that result in increased muscle endurance. For this reason, cold yield benefit for decrease pain due to muscle stretching (McDowell, et al., 1994: 22).

(5) Effect on neurological structure. Cold decreases the speed of nerve conduction by slowing communication at the synapse. As previously described, cold decreases nerve conduction velocity of myelinated sensory nerve fibers that innervate muscle spindles, namely primary endings and secondary endings. In addition, cold can decrease the nerve conduction velocity of motor neurons, namely alpha motor and gamma motor at the spinal cord which send impulses to the motor end-plate of muscles to stimulate muscle contraction. For this reason, the stretch reflex which is the circuit of muscle stretching and contracting is decreased. Moreover, cold decrease nerve conduction velocity of pain fibers, namely the A-delta fibers and the C fibers and results in decreased pain (McDowell et al., 1994: 23). Furthermore, the myelinated nerve fibers are quicker to exhibit a change in their conduction velocity than unmyelinated nerve fibers and the small-diameter myelinated nerve fibers respond to cold before the large-diameter myelinated nerve fibers (Starkey, 1999: 116-

117). Therefore, the sequence of a change on nerve conduction velocity after cold application means that the first exhibited changes are the small-diameter myelinated nerve fibers, namely the A-delta and the gamma motor neurons. Next, the large-diameter myelinated nerve fibers which are the alpha motor neurons decrease their speed of conduction. Finally, the last nerves that respond to cryotherapy are the small-diameter unmyelinated nerve fibers, namely the C fibers. Besides, the sequence of nerve fiber activation can provide an explanation for the sequence of sensations that accompany cryotherapy. The first sensation of cold is followed by a cold or a stinging feeling, then a burning and aching feeling, and finally numbness. Each stage is related to the nerve ending as they temporarily cease to function as a result of decreased blood flow. Numbness is a result of decreasing the nerve conduction velocity and increasing the threshold required to fire the nerves (Prentice, 1999: 227; Starkey, 1999: 117).

Cold modalities and duration of treatment with cryotherapy. Cryotherapy is usually applied for 15 to 30 minutes per treatment (Anderson & Hall, 1995: 163). The differences in cold modalities bring about different durations of cryotherapy. For instance, reusable cold gel packs and ice packs have duration of treatment for 15 to 30 minutes, ice massage has treatment times ranging from 5 to 15 minutes, cold water immersion is continued treatment for 10 to 20 minutes, and initial whirlpool bath are given for 5 to 10 minutes, but subsequently may be increased to 20 to 30 minute as the treatment program progresses. However, the duration of skin exposed to the cold may change, depending on the properties of skin such as surface area, character, and location.

Orthopedics patients who are in the postoperative period often use reusable cold gel packs after physical therapy for relief pain, especially the patients who have had the total knee replacement operation (McDowell et al., 1994: 26). Reusable cold gel packs contain a gel consisting of silica, water, and a form of antifreeze sealed in a plastic pouch. These gel packs have a temperatures cooled to -12°C and have treatment times ranging from 15 to 30 minutes. Because the component of the reusable cold gel packs is not comparable with true ice, it may lower the skin temperature below the freezing point. Therefore, when using these packs on the postoperative patients, a medium such as a thin dry dressing must be placed between the packs and

the skin. However, the reusable cold pack may lose its effective treatment after 20 minutes of use. For this reason, the reusable cold pack may be repeated as needed for continuing therapeutic effects. In addition, the interval of treatment should be 2 hours to distinguish each treatment (Starkey, 1999: 133-146).

Complications of cryotherapy. The complication of cryotherapy is called frostbite which is the damage to tissue arising from excessive of cold application. Frostbite occurs when the skin temperature falls below freezing that it is at -0.6°C to -2°C , or the subcutaneous temperature falls below 12.77°C (55°F). In general, frostbite occurs when skin is exposed to cold which has a temperature below 0°C (32°F) for longer than 30 minutes (McDowell, 1994: 23; Robert, 2001: 313; Starkey, 1999: 118). A frostbite victim will often experience itching as the first sign of freezing tissue. Symptoms progress to pain, paresthesia, numbness, and loss of function. The clinical appearance of frostbite is red, swollen tissue progressing to white, waxy, cold, firm or hard tissue. There is obvious loss of blood flow when the tissue is frozen. Frostbite can be graded on the basis of the clinical appearance at the initial examination as superficial, with mobile subcutaneous tissue, or deep, with hard tissue extending deep to the bone and intensive tissue post thawing. In addition, frostbite can be classified by a frostbite severity rating which is assessed after several days. Frostbite severity rating has 4 degrees and the first degree has symptoms of numbness, erythema, and edema. Then the second degree has clear fluid-filled blisters, erythema, and edema. Next, the third degree, symptoms progress to hemorrhagic blisters. Finally, the fourth degree, the patient will have injury to both bones and muscles, subsequently the tissue is mottled and lifeless (Robert, 2001: 313-314). As a result, nurses must be caution about frostbite in order to prevent the tissue damage. During cold application, the circulation to the extremities can be checked by monitoring the flow of blood to the nailbeds that known as capillary refill. Gently squeezing the nail removes the blood, making it turn white or pale. When the force is removed, the original color should return within five seconds (Wilke & Weiner, 2003: 307). If it fails return, circulatory impairment should be suspected. If frostbite is suspected, immediately remove the patient from the source of the cold. Rewarm the body part by immersing it

in water or compressing with heat modality at 37.77⁰ C (100⁰ F), and refer the patient to a physician for follow up evaluation (Starkey, 1999: 119).

4.2 Effect of cryotherapy on pain reduction in TKR patient during exercise with CPM machine. From the understanding, pain of the TKR patient during passive exercise with the CPM machine occurs when the nociceptors are activated by noxious stimuli. The noxious stimuli include the mechanical stimuli, namely surgical wound, muscle contraction, and muscle spasm, and the chemical stimuli e.g. histamine, prostaglandins, and lactic acid etc. These stimuli excite the nociceptors of the A-delta fibers and the C fibers that produce transduction of pain impulses. Then pain is transmitted to the afferent fibers of the A-delta fibers and the C fibers which transmit impulses to the spinal cord and brain. Next, pain perception occurs. Finally, the impulses from the brain descend (descending pain pathways) to the spinal cord to modulate the appropriateness of pain.

According to the pain processes and cryotherapy to relieve pain in the TKR patients when passive exercise with CPM machine. Cryotherapy can reduce pain from the first step of pain processes by decreasing transduction of pain. The noxious stimuli in the step of the transduction of pain are decreased as follow:

Decreased stimulation of relative nerves in the stretch reflex mechanism of muscles during passive exercise. The cold decreases nerve conduction velocity of sensory nerves in muscle spindles which are primary endings and secondary endings that respond to the stretching of muscles. Then the motor nerves at the spinal cord, namely the alpha motor and the gamma motor receive less impulse for stretching. Also, cold decreases directly nerve conduction velocity of motor nerves. For this reason, cold can reduce noxious stimuli in the transduction of pain and this effect can facilitate a decrease in muscle contraction and muscle spasm.

Decreased muscle contraction and muscle spasm from stretch reflex. The structures that function in the stretch reflex of the knee joint are muscles, tendons and ligaments. The major component of these structures is collagen. As cold increases the stiffness of collagen, consequently it causes increased muscle endurance that assists in decreasing muscle spasm. In addition, a decrease in muscle contraction and muscle spasm can result in a protective effect on the area of the surgical site.

Decreased chemical substances such as histamine and lactic acid etc. which stimulate the painful fibers. Because cold can decrease the cellular metabolic rate, so the cells around the surgical site which are activated by passive exercise will use less energy. For this reason, the chemical substances which are released from damaged cells will decrease because the dead cells from lack of oxygen are decreasing. Moreover, during exercise the cells will create anaerobic metabolism to supply adequate energy and produce waste products like lactic acid. When the cells need less energy under cold condition, consequently a decrease of the anaerobic metabolism and lactic acid happens.

Furthermore, cold application can reduce pain by decreasing transmission of pain. Cold decrease nerve conduction velocity of pain fibers, namely the A-delta fibers and the C fibers. Therefore, the transmissions of pain impulses to the spinal cord and the brain are reduce, consequently a decrease in pain perception occurs.

Cryotherapy has been used as an adjunct in the rehabilitation of acute musculoskeletal injury and orthopaedics surgery (Dervin, et al., 1998: 403). Many researchers have found that when using a continuous cryotherapy device to the immediate surgical wound for 2 days or more that it could decrease pain, analgesic consumption, blood loss and increase the range of motion of the postoperative knee (Levy & Marmar, 1993: 174-178; Morsi, 2002: 718-722; Ohkoshi, et al., 1999: 357-362; Webb, et al., 1998: 59-61). This device is expensive and is not preferred in Thailand. However, other researchers used intermittent cryotherapy by other cold modalities such as cold gel pack, ice pack and ice massage, to decrease pain and change physiological responses that are related to the cause of pain. The physiological responses that change after cold application are blood loss, edema, blood circulation, function of muscles, and transmission of nerve impulses. The intermittent cryotherapy with cold modalities is widely used in Thailand. The times of intermittent cryotherapy are 10 to 30 minutes per treatment and depend on the type of cold modality. The local application of cold in postoperative orthopedic patients in Thailand commonly uses a reusable cold gel pack as it is inexpensive, easily purchasable and convenient in application. Many researchers have found that reusable cold gel packs have plenty of therapeutic effects such as decreased edema, blood circulation in the injury area, and

superficial tissue temperature, ultimately it helps to decrease pain (Enwemeka, et al., 2002; Hecht, et al., 1983; Taber, et al., 1992; Weston, et al., 1994).

In conclusion, the problem of pain frequently occurs in TKR patients who perform exercise in the rehabilitation period. The ultimate goal of pain management is to provide pain relief and enable the patient to carry on with the activities of daily living and do necessary exercises in as comfortable a manner as possible. In clinical settings, the nurses spend more time with patients in pain than do any other health professionals. Moreover, nurses have responsibility for pain management by assessment, prevention, and implementation of nursing care to reduce pain. As a result, nurses must be sufficiently prepared to undertake pain management. The local cold application with the cold gel pack is the most commonly used method that can relieve pain in the TKR patients, particularly during flexion and extension exercise with the CPM machine. Although, pain is considered temporary and can go away with rest and analgesics, in some patients it causes delay of rehabilitation and possibly the failure of treatment. Cold application to the surgical wound is effective in reducing pain by decreasing nerve conduction velocity of pain and decreasing source of pain such as producing vasoconstriction to limit blood loss, decrease cellular metabolic rate to restrict the area of inflammation and edema, and decrease muscle tension around the surgical wound. Cold application before the TKR patients start exercise can relieve pain that exists due to surgical incision and the activities of daily living. However, when these patients have exercise, particularly an increasing range of motion of the knee joint, pain occurs again. The nociceptors are more stimulated because the effects of cold compression before passive exercise are reduced due to heat production from metabolism, and noxious stimuli such as lactic acid, muscle contraction, and muscle spasm are increased. For this reason, the effect of cold to relieve pain that the patients have taken before exercise could be inadequate. As a result, cold application during exercise may be necessary for these patients in order to relieve pain that occurs. Therefore, the two methods of cold compression were designed in order to compare the effectiveness of cryotherapy in these patients. These methods are the cold compression before passive exercise (method B) and the cold compression both before and during passive exercise (method A). The investigator will control the temperature

of cold gel packs to be between 0°C and 18.33°C that gives therapeutic effects through each method of cold compression. The investigator intends to find the better method of local cold application with cold gel pack for pain relief in the TKR patients, particularly during flexion and extension exercise with the CPM machine in order for it to be a guideline for the practice of nursing.



CHAPTER III

METHODOLOGY

Research Design

This study is a quasi-experimental study aimed to compare the effectiveness of pain reduction by using two methods of cold compression between cold compression before passive exercise (method B) and cold compression both before and during passive exercise (method A) in total knee replacement patient using continuous passive motion machine. Simple cross over design was used for this study that when chosen patients following inclusion criteria, each patient received both methods of cold compression.

Population and Sampling

The target populations in this study were primary osteoarthritis patients who had undergone total knee replacement on the 4th postoperative day. These patients exercised to increase the range of motion of the knee by using a CPM machine and were admitted in the private ward, Orthopedics Department, Siriraj Hospital, Bangkok, between February to July 2003.

The total participants were thirty patients and were recruited according to the following inclusion criteria.

1. Exercised with a CPM machine for thirty minutes and the range of motion of the knee was between zero and thirty degrees. This exercise was twice per a day.
2. Had the first unilateral total knee replacement operation by the same orthopedic surgeon.
3. Before started the experiment, pain score which measured by the vertical 0–10 numeric rating scale was 5 or above.
4. The room temperature was 23.5 °C to 25.5 °C.
5. The participant had taken analgesic medications such as Tramal[®], Paracetamol[®], Vioxx[®], and Tylenol with Codiene[®] more than 2 hours.

The exclusion criteria were as follow:

1. Having postoperative complications such as shock, embolism, and fracture during operation etc.
2. Having acute cardiac or respiratory problem.
3. Having uncovered open wounds in cold compression region.
4. Having acute circulatory insufficiency.
5. Having hypersensitivity or allergy to cold.
6. Having anesthetic skin.
7. Having advanced diabetes.
8. Having Raynaud's phenomenon or rheumatoid arthritis.

A simple cross over design was used in this study. Thirty participants who met the inclusion criteria were alternately placed in either of two groups using different methods of cold compression. There were two equal patterns of cold compression, pattern I and pattern II. The investigator randomly assigned one pattern of cold compression to each participant, the participants who received pattern I or pattern II are detailed as follow:

- Pattern I - The participant received cold compression both before and during passive exercise (method A) in the morning and it was followed by cold compression before passive exercise (method B) in the afternoon.
- Pattern II - The participant received cold compression before passive exercise (method B) in the morning and it was followed by cold compression both before and during passive exercise (method A) in the afternoon.

In addition, the interval of each method of cold compression was longer than two hours in order to separate the effects of each method of cold compression. This design was used to control external variables that could have had an effect on an individual's pain. The number of the participants that were placed in pattern I or pattern II is shown Figure 12.

Participant No.	1	2	3	4	5	6	7	8	9	10
Morning	A	B	A	A	B	B	B	A	A	A
Afternoon	B	A	B	B	A	A	A	B	B	B

Participant No.	11	12	13	14	15	16	17	18	19	20
Morning	B	B	A	B	A	B	A	B	B	A
Afternoon	A	A	B	A	B	A	B	A	A	B

Participant No.	21	22	23	24	25	26	27	28	29	30
Morning	A	B	A	B	B	B	A	B	A	A
Afternoon	B	A	B	A	A	A	B	A	B	B

Figure 12: The number of thirty participants that were placed in pattern I (method A in the morning) or pattern II (method A in the afternoon).

Method A group = The cold compression both before and during passive exercise group.

Method B group = The cold compression before passive exercise group.

Setting

The study was conducted at the private rooms in ten wards, Orthopedic Department, Siriraj Hospital. Ten wards include the 4th floor east of the 84th Years Building, the 5th and 6th floor both east and west of the 84th Years Building, the 5th floor, both east and west of 72nd Years Building, the 2nd flood of Traumatic Surgery Building, the 5th floor of Paob Nop Supatra Rabeab Building, and the 3rd floor of Vibullak Building, Siriraj Hospital. Here, the TKR patients were admitted and were in the same ward until discharge. The routine postoperative care and the activities of rehabilitation of TKR patients depended on each surgeon. Therefore, this study was conducted on the TKR patients who had been operated on by the same orthopedic surgeon in order to have the same routine postoperative care and the same activities of

rehabilitation among the participants. The private room of Siriraj Hospital has a temperature of about 25⁰ C. Moreover, the routine nursing practice to relieve pain in the TKR patients who exercised by using a CPM machine was cold compression with a cold gel pack. However, the methods of cold compression are various and depend on the consideration of nurses who practice. As a result, the responsibility of pain relief in these patients belongs to the nurses. So, this setting is appropriate for the present study.

Instrumentation

The instruments for this study were composed of two parts as follow:

Part 1: Intervention instruments

1.1) The Reusable cold gel packs (4 pieces).

1.2) A bag which can keep 2 pieces of cold gel packs as shown in Figure 13.

This bag has two sides that are the internal side and external side. The internal side is in contact with the skin of patients and is made from cotton fabric, whereas the external side is made from synthetic fiber similar to swimming suit. This synthetic fiber is soft and flexible. Moreover, the external side of the bag has 2 zips in order to easily change the cold gel packs without removing the bag from the knee. In addition, the cold gel packs were in the bilateral line of the postoperative knee.



Figure 13: The bag of cold gel packs

1.3) A digital thermometer (Oakton thermometer, water resistant, range -10⁰ C to 200⁰ C, accuracy $\pm 1.0^0$ C, Oakton Co., Ltd., China) to measure room temperature and cold gel packs.

1.4) A thermometer to measure body temperature.

1.5) A sphygmomanometer to measure blood pressure.

1.6) A Continuous passive motion machine (same type in each participant) to perform passive exercise.

Part 2: Data collection instruments which has name “Tool for assess about pain” (Appendix D). Four record forms were developed to gather relevant information:

2.1) Demographic Data Form. This form was used to record general characteristics of patients, e.g. name, hospital number, age, sex, marital status, educational level, occupation, adequacy of income, and type of the payment.

2.2) Medical History Data Form. This form was used to record histories of illness and operation about bone and joint and others, diagnosis of disease, operation, date of operation, type of analgesic, history of analgesic medication that patient received before intervention, and vital signs.

2.3) Vertical 0–10 Numeric Rating Scale (NRS) Form. This form included table for record pain score and the vertical 0–10 numeric rating scale that has been developed by McCaffery and Beebe in 1989, and 1994 and the latest was developed by McCaffery and Pasero in 1999. The vertical pain of NRS consisted of a scale ranging from 0-10, with the minimum score of 0 representing no pain, the medium score of 5 representing moderate pain, and the maximum score of 10 representing worst pain. This tool has a reliability and validity of the pain intensity scale when use among older adult (Herr & Garand, 2001: 465). Moreover, it is easily administered either orally or in writing and is easy to score and record. The study participants were asked to report their pain according to the scale, and the participants then marked the pain level in the form.

2.4) Questionnaire Form. The purposes of this form were to record the thinking and feelings of patients who had received the two methods of cold compression in order to confirm their effectiveness and satisfaction with cold compression as therapy. In addition, this form has both close-end questions and open-end questions.

Validity and Reliability of the Instruments

Validity

1. The content validity of the “Tool for assess about pain” was evaluated by four experts including a physician specializing in total joint replacement, an

orthopedic nurse, and two nursing instructors: one was specialized in orthopedic nursing, and the other in pain management.

2. To test the temperature of cold gel packs (Celsius degree), the investigator used the same digital thermometer (Oakton thermometer, water resistance range -10°C to 200°C , accuracy $\pm 1.0^{\circ}\text{C}$, Oakton Co., Ltd., China) as an instrumentation in testing every pack. The method of measuring was suggested by Customer Service Department, 3M Co., Ltd., Bangkok, Thailand. The measurement of temperature is done by rolling the cold gel pack and inserting the probe of thermometer and reading the temperature of the cold gel pack from the screen of the thermometer.

Reliability

1. A digital thermometer (Oakton thermometer, water resistant, range -10°C to 200°C , accuracy $\pm 1.0^{\circ}\text{C}$, Oakton Co., Ltd., China) to measure room temperature and cold gel packs was tested for reliability by Pearson product moment correlation coefficient. The investigator used this thermometer to measure the consistent room temperature in the morning and the afternoon of a day. For ten days of data collection, the Pearson product moment correlation coefficient of the measured temperature in one day was 0.97.

2. The vertical 0–10 Numeric Rating Scale (NRS) tool was tested for reliability by the Pearson product moment correlation coefficient. The investigator asked 10 TKR patients to report their pain according to the scale in the morning and the afternoon of a day (the same day). The interval of pain measurement ranged from 3 to 4 hours. This measurement aimed to evaluate the TKR patients who can score their pain intensity with this tool. The Pearson product moment correlation coefficient of pain score in one day was 0.92.

Data Collection

The data were collected after the Faculty of Graduate Studies; Mahidol University approved the research proposal. The process for data collecting was as follow:

1. A letter of introduction from the Faculty of Graduate Studies, Mahidol University was submitted to The Dean of Faculty of Medicine, Siriraj Hospital, as well

as The Director of Research Division of Siriraj Hospital for requested permission and co-operation in data collection.

2. A permission letter from The Dean of the Faculty of Medicine, Siriraj Hospital, as well as The Ethical Committee on Research Involving Human Participant of Siriraj Hospital was presented to the Director of Orthopedics Department, the Director of Nursing Department, the Head of Private Patient Nursing Division, the Head of Surgical and Orthopedic Nursing Division, and the Head Nurse of ten Private Wards that have orthopedic patients (Appendix B).

4. The investigator explained the objective of study and steps of collection data to the head nurse of each ward and asked for co-operation.

5. Before the intervention was started, the investigator trained a registered nurse to assist in collecting the data in order to make a blind study. The assistant nurse assessed pain scores from the participants during intervention. Therefore, the assistant nurse could understand the vertical 0–10 Numeric Rating Scale and could advise participants how to evaluate pain by this tool.

6. The participants were selected according to the inclusion criteria. In addition, the exclusion criteria were examined by asking the participants about their underlying disease and history of cold allergy. If the participants indicated complications of their disease or a history of cold allergy, they will be excluded from the study. Then the investigator introduced herself to the patients, and informed the patients about the process and the objectives of this study and their right in their decision-making on participation or withdrawal from this study. They could withdraw at anytime if they desired or they had side effects, or frostbite, from the intervention with no negative effect on the treatment they received from the hospital. After the patients signed the information consent sheet, the demographic data and medical history data of the patient were collected.

7. Participants were assigned to pattern I or pattern II by random sampling, as show in Figure 12. All participants were placed either in the cold compression both before and during passive exercise group (method A) and the cold compression before passive exercise group (method B). During intervention of cold compression and passive exercise, participants were assessed for pain intensity by the research assistant that is detailed as follow:

Method A = The cold compression both before and during passive exercise.

- the 0 minute - Set position of participant on the CPM machine.
- Assess pain intensity by using the vertical 0–10 NRS for the first time.
- the 1st minute - Cold compression with a pair of cold gel packs which have a temperature of 0⁰ C to 0.5⁰ C for 20 minutes.
- the 20th minute - Assess pain intensity by using the vertical 0–10 NRS for a second time.
- Remove the cold compression.
- the 21st minute - Cold compression with a new pair of cold gel packs which have a temperature of 0⁰ C to 0.5⁰ C for 30 minutes. (These cold packs continue compression from the 21st minute to 50th minute)
- Start exercise for 15 minutes + cold compression
- the 35th minute - Assess pain intensity by using the vertical 0–10 NRS for the third time.
- the 36th minute - Continue the exercise for 15 minutes + cold compression.
- the 50th minute - Assess pain intensity by using the vertical 0–10 NRS for the fourth time.
- Remove the cold compression and the CPM machine.

Method B = The cold compression before passive exercise.

- the 0 minute - Set position of participant on the CPM machine.
- Assess pain intensity by using the vertical 0–10 NRS for the first time.
- the 1st minute - Cold compression with a pair of cold gel packs which have a temperature of 0⁰ C to 0.5⁰ C for 20 minutes.
- the 20th minute - Assess pain intensity by using the vertical 0–10 NRS for a second time.
- Remove the cold compression.
- the 21st minute - Start exercise for 15 minutes.
- the 35th minute - Assess pain intensity by using the vertical 0–10 NRS

for the third time.

- the 36th minute
- the 50th minute
- Continue the exercise for 15 minutes.
- Assess pain intensity by using the vertical 0–10 NRS for the fourth time.
- Remove the CPM machine.

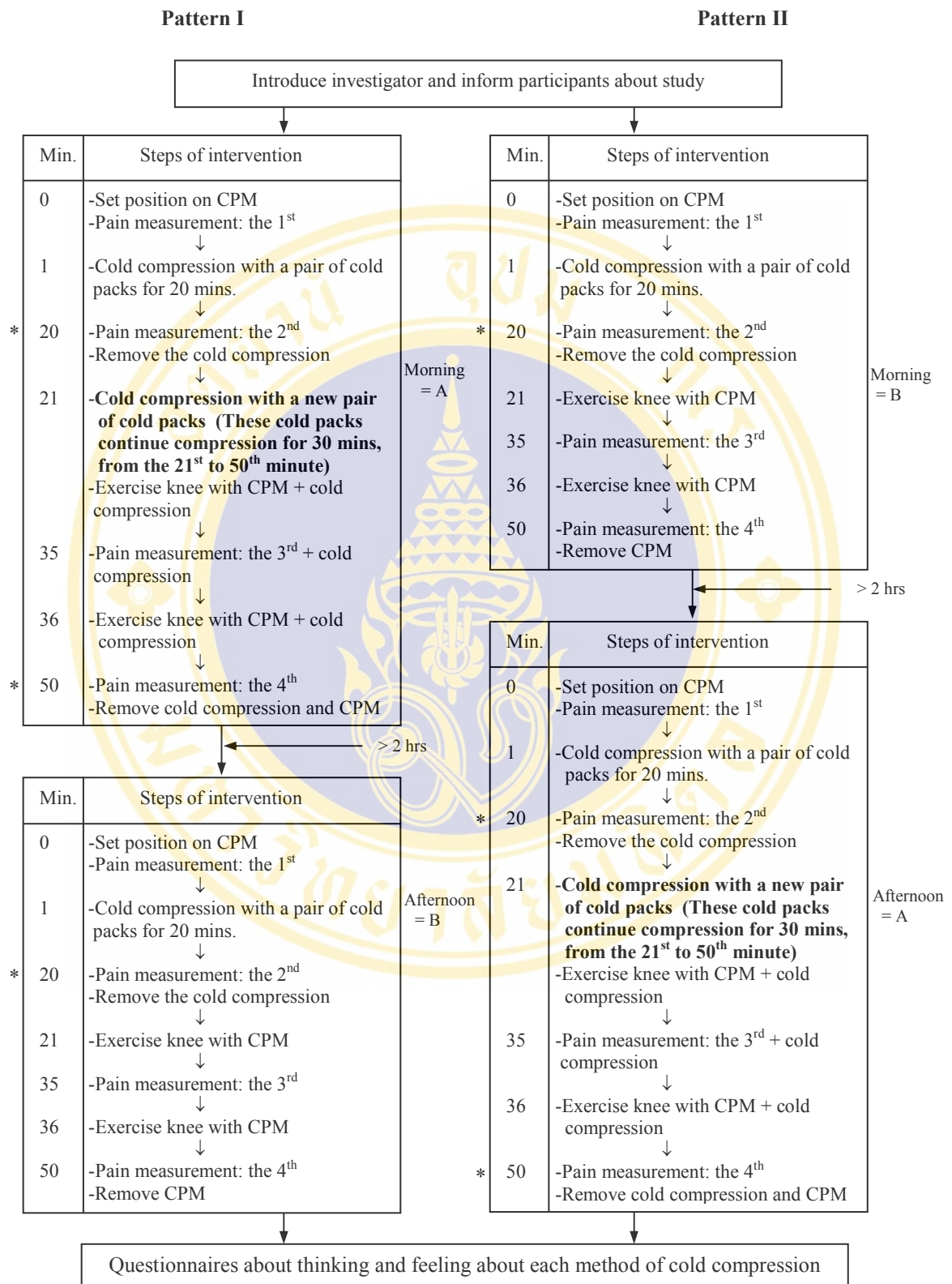
During cold compression, the patient's room temperature is controlled between 23.5⁰ C and 25.5⁰ C in order to control any increase in cold gel packs temperature. The investigator confirmed the therapeutic effects of cold compression by measured the temperature of cold gel packs immediately after removal from the skin through the intervention. In method A, the investigator measured the temperature of cold gel packs at the 20th and 50th minute, and in method B, measured the temperature of cold gel packs at the 20th minute.

8. The investigator was careful about prevention of tissue damage, or frostbite. If the participant has frostbite, the investigator will stop the study. Therefore, during cold compression the circulation to the extremities is checked by monitoring the flow of blood to the nailbeds that is known as capillary refill. Gently squeezing the nail removes the blood, making it turn white or pale. When the force is removed, the original color should return within five seconds. If it fails to return, circulatory impairment should be suspected. If frostbite is suspected, immediately the investigator will remove the cold compression. Then warm the skin with heat modality such as hot gel pack which has a temperature at 37.77⁰ C (100⁰ F), and notify the patient to a physician for follow up evaluation.

9. When the participant has completed the intervention of cold compression the questionnaires about thoughts and feelings about the two methods of the cold compression were completed.

10. If the physical therapists visit the participants during the experiment, the investigator will request them to visit the other patients that they are responsible for, and make the appointed time of finishing the experiment with them. When the investigator finished the experiment, the physical therapists came back to the participants to instruct them about walking and exercise.

The summary of data collection procedures on research implementation for this study is shown at Figure 14.



* = The times that confirm the temperature of the cold gel packs still have a therapeutic effect.

Figure 14: The summary of data collection procedures for pattern I and pattern II.

Termination of the study

1. The temperature of cold gel packs were not between 0°C and 18.33°C .
2. The participants desired to terminate the experiment.
3. The participants had the signs of frostbite.
4. The participants were suffered from worst pain.

Protection of Human Participants

The research was undertaken with the permission of The Ethical Committee of Siriraj Hospital on human rights related to research involving human participants (Appendix B). The investigator introduced herself and objective of this study to the participants. Before collecting the data, the investigator asked for consent from the participants to protect their human rights. They could withdraw at anytime if they desired or they had side effects such as frostbite from intervention without any effect on the treatment they received from the hospital. They were able to get information from the investigator at any time during the study. The participants did not identify who they were. The individual data from these participants would not be made public but would only be used in this research. All data were presented as a group and they were assured that all of the responses would remain confidential (Appendix C).

Data Analysis

The data were analyzed as follow:

1. Frequency and percentage were used to analyze demographic data, medical history data, and thinking and feeling to each method of cold compression data.
2. Mean and standard deviation were used to determine the pain scores on the 0, 20th, 35th, and 50th minute of each method of cold compression.
3. Analysis of Variance (ANOVA) for a simple cross over design was used to test the pain scores between the cold compression both before and during passive exercise group (method A) and the cold compression before passive exercise group (method B).

CHAPTER IV

RESULTS

This study is a quasi-experimental study, simple cross over design, was applied to compare the effects of pain reduction between cold compression both before and during passive exercise (method A), and cold compression before passive exercise (method B) in total knee replacement patients using a continuous passive motion machine. The participants were thirty hospitalized patients of Siriraj Hospital with osteoarthritis of the knee and who had undergone the first experience of unilateral total knee replacement. The study was conducted between February to July 2003. The results of the study will be presented as follows:

- Part 1. Demographic characteristics of the participants
- Part 2. Medical histories of the participants
- Part 3. The results related to pain scores in the cold compression both before and during passive exercise (method A) and the cold compression before passive exercise (method B) groups.
- Part 4. The results related to comparative pain scores between the cold compression both before and during passive exercise (method A) and the cold compression before passive exercise (method B) groups.
- Part 5. Thinking and feelings of the participants about each method of cold compression.

Part 1. Demographic characteristics of the participants**Table 1.** Number and percentage of the participants classified by gender, age, marital status, and educational level (n=30)

Characteristic of participants	Number	Percentage
Gender		
Female	28	93.3
Male	2	6.7
Age		
50-59	5	16.7
60-69	14	46.7
70-79	9	30.0
80 and over	2	6.7
Marital status		
Single	2	6.7
Married	22	73.3
Widowed	6	20
Education level		
Uneducated	3	10
Primary	18	60
Secondary	6	20
Bachelor	3	10

Table 1 showed that most of the participants of this study (93.3 %) were female, with the age of the participants ranging from 60 to 69 years (46.7%). In terms of marital status, more than half of the participants (73.3%) were married. The educational level of more than half of the participants was primary school (60%).

Table 2. Number and percentage of the participants classified by current occupation, adequacy of incomes, and type of payment for hospitalization (n=30)

Characteristic of participants	Number	Percentage
Current occupation		
Unemployed	26	86.7
Pensioner of Government	1	3.3
Merchant	2	6.7
Government enterprise	1	3.3
Adequacy of incomes		
Adequate income	29	96.7
Adequate income with reserve	1	3.3
Type of payment for hospital		
Social welfare	24	80
Self-payment	6	20

Table 2 indicated that most of the participants (86.7%) were unemployed. All participants have enough income (100%). Most of the participants paid for their hospitalization by social welfare (80%).

Part 2. Medical histories of the participants

Table 3. Number and percentage of the participants classified by side of TKR, history of surgery, underlying disease, analgesic drugs around the clock, analgesic drugs when required, and vital signs condition (n=30)

Characteristic of participants	Number	Percentage
Side of TKR		
Left	16	53.3
Right	14	46.7
History of surgery		
None	17	56.7
Abdominal surgery	7	23.3
Eye surgery	4	13.3
Spinal surgery	2	6.7
Underlying disease		
None	14	46.7
Hypertension	7	23.3
Hypertension and Heart	4	13.3
Hypertension and Diabetic mellitus	2	6.7
Others	3	10
Analgesic drugs around the clock (participants received more than 2 hours before the experiment)		
Vioxx [®] (25mg.) 1 tablet oral after breakfast (once a day)	11	36.7
Tramal [®] (50mg.) 1 capsule oral every 6 hours	7	26.4
Paracetamol [®] (500mg.) 2 tablets oral every 6 hours	6	23.3
Tylenol with Codiene [®] 1 tablet oral after meals (three times a day)	1	3.3
Vioxx [®] (25mg.) 1 tablet oral after breakfast (once a day) and Tramal [®] (50mg.) 1 capsule oral every 6 hours	3	10
Vioxx [®] (25mg.) 1 tablet oral after breakfast (once a day) and Paracetamol (500mg.) 1 tablet oral every 6 hours	2	6.7

Table 3. Number and percentage of the participants classified by side of TKR, history of surgery, underlying disease, analgesic drugs around the clock, analgesic drugs when required, and vital signs condition (n=30) (continue).

Characteristic of participants	Number	Percentage
Analgesic drugs when required (participants received more than 2 hours before the experiment)		
Not required analgesic drug	28	93.4
Required Tramal® 50mg. muscular injection	1	3.3
Required Pethidine 50 mg. muscular injection	1	3.3
Vital signs condition		
Normal	30	100

Table 3 showed that more than half of the participants (53.3%) had left side of the TKR operation and more than half of them had no history of surgery (56.7%). In addition, 46.7% of the participants had no underlying disease. In term of analgesic drugs around the clock, 36.7% of the participants received Vioxx® more than 2 hours before the experiment and most of them (93.4%) had not requested the analgesic drugs that were ordered for them when required. All the participants had a normal condition of vital signs through out the experiment (100%).

Part 3. The results related to pain scores in the cold compression both before and during passive exercise (method A) and the cold compression before passive exercise (method B) groups.

Table 4. The arithmetic mean and standard deviation of pain scores at the 0, 20th, 35th, and 50th minute that using both method A and method B of cold compression.

Time	Pain score of method A			Pain score of method B		
	range	$\bar{X}$	S.D.	range	$\bar{X}$	S.D.
At 0 minute (before exercise)	5-9	5.47	0.90	5-8	5.50	0.90
At the 20 th minute	2-5	2.83	0.87	2-4	3.27	0.78
At the 35 th minute	0-4	1.87	0.82	3-6	4.37	0.89
At the 50 th minute(after exercise)	0-4	1.03	0.85	4-7	5.53	0.94

Table 4 showed that the mean and standard deviation of pain scores at the 0 and 50th minute had decreases with in method A group, but increases within method B group. In method A group, before exercise, the mean of pain scores = 5.47, with a standard deviation = 0.90, and after exercise mean of pain scores = 1.03, and a standard deviation = 0.85. In method B group, before exercise, the mean of pain scores = 5.50, with a standard deviation = 0.90, and after exercise mean of pain scores = 5.53, and a standard deviation = 0.94.

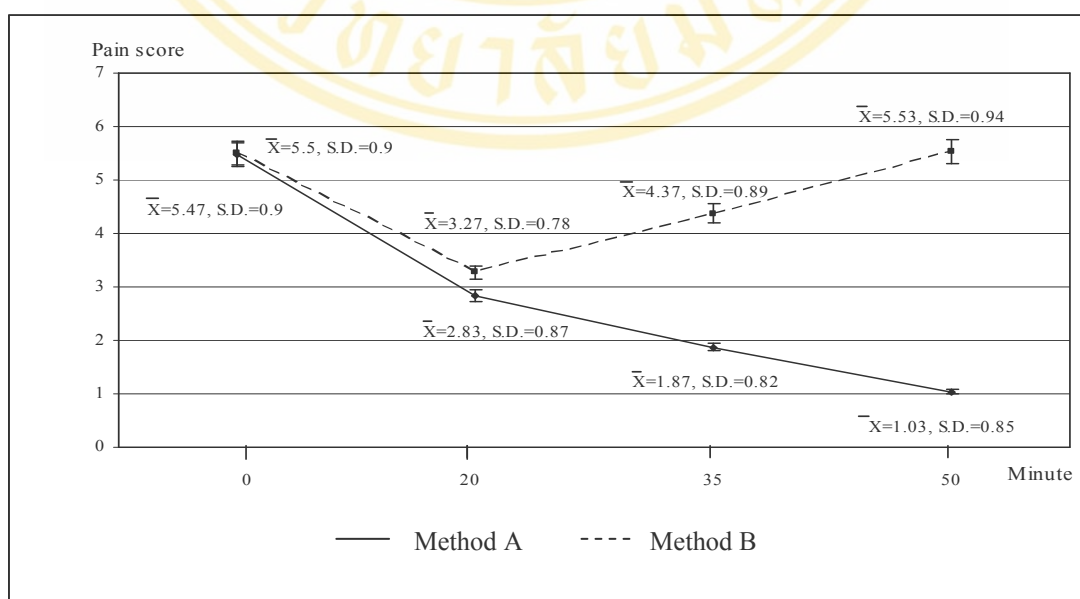


Figure 14: Means and standard deviations of pain score at the 0, 20th, 35th, and 50th minute for method A and method B.

Part 4. The results related to comparative pain scores between the cold compression both before and during passive exercise (method A) and the cold compression before passive exercise (method B) groups.

Table 5. Comparison of pain scores between the cold compression both before and during passive exercise (method A) and the cold compression before passive exercise (method B) groups using Analysis of Variance (ANOVA) for a simple cross over design.

Source	df	SS	MS	F
Individual	29	29.6		
Period	1	0.06		
Treatment	1	299.26	299.26	498.77***
Error	28	16.68	0.60	
Total	59	345.6		

*** $p < .001$

Table 5 showed that the TKR patients, who received method A of cold compression had statistically significant lower pain scores than those of the TKR patients who received method B of cold compression ($p < .001$).

Part 5. Thinking and feelings of the participants about each method of cold compression

Table 6. Number and percentage of the participants classified by satisfaction and effects to each method of cold compression (n=30)

Characteristics	Method A		Method B	
	Number	Percentage	Number	Percentage
Satisfaction				
• Most	30	100	0	0.00
• Moderate	0	0.00	26	86.7
• Little	0	0.00	4	13.3
• No	0	0.00	0	0.00
Cold compression effects (Participants could more answer than 1 item)				
• Relief / reduced pain	30	100	12	40
• Comfortable	28	93.3	27	90
• Increase ease of knee flexion	26	86.7	3	10
• Increase confidence or morale for exercise	12	40	2	6.7
• no different in pain before and after exercise	0	0.00	2	6.7

Table 6 showed that method A of cold compression was rated most satisfaction by all of participants (100%) whereas method B of cold compression was rated with moderated satisfaction by 86.7% of the participants. In term of cold compression effects, all participants felt reduced pain in method A whereas 40% of the participants felt reduced pain in method B.

Table 7. Number and percentage of the participants about their thinking and feeling with cold compression as a therapy were categorized in each aspect (n=30)

Characteristics	Number	Percentage
Patients' preferred times for cold compression		
(participants could more answer than 1 item)		
• Both before and during exercise	30	100
• Others time		
- Before walking	15	50.0
- After exercise	8	26.7
- During less pain	7	23.3
In the future, if patient has the TKR operation again		
• Desire cold compression	30	100
• Not desire cold compression	0	0.00

Table 7 showed that all of the participants (100%) preferred cold compression both before and during exercise. The other time it was found that 50% of the participants preferred cold compression before walking. In addition, all participants (100%) would desire cold compression if they had the TKR operation again.

CHAPTER V

DISCUSSION

This study was a quasi-experimental research, with a one group cross over design, to compare the effects of pain reduction between cold compression before passive exercise (method B), and cold compression both before and during passive exercise (method A) in total knee replacement patients using a continuous passive motion machine, on the 4th postoperative day. This result supported the hypothesis that the participants who received method A of cold compression had statistically significant lower pain scores than those of the participants who received method B of cold compression. This chapter discussed pain reduction resulting from cold compression based on the formulated hypothesis in three aspects as follows:

1. Pain reduction from using cold compression before passive exercise (method B)
2. Pain reduction from using cold compression before and during passive exercise (method A)
3. Method A could reduce pain better than method B of cold compression

The TKR patients in this study had pain due to surgical wound before the experiment was started. When the osteoarthritis patients underwent the TKR surgery, the tissues were damaged as a result of extensive dissection and prolonged retraction of muscles and fascia. The damaged tissues continuously excreted chemical substances such as histamine and prostaglandins which combined with nociceptors to initiate the neural transmission associated with pain (Coda & Bonica, 2001: 236-237). McCaffery & Pasero (1999: 18-20) have explained that chemical substances activate the nociceptors to receive and convert a signal from the noxious stimuli to the pain impulses in the transduction step of pain processes. Then pain impulses were transmitted along the afferent fibers of the A-delta and the C to the spinal cord, after

which the information is sent quickly to higher centers in the brain, including the reticular formation, limbic system, thalamus, and sensory cortex. Next, pain perception occurred, and subsequently the brain sent impulses via the descending pain pathways to the spinal cord to modulate the appropriateness of pain perception and pain responses.

The finding from this study revealed that patients after TKR in the rehabilitation period on the fourth postoperative day had moderate to severe pain levels. The minimum pain score was 5 and the maximum pain score was 9. However, the reason for the minimum pain score was related to the inclusion criteria that selected participants who had a pain score of 5 or above. This study found that more than half (70%) of the participants' pain scores before the experiment both in the method A and the method B of cold compression were 5 (Appendix F). Previous study of TKR patients who were in rehabilitation period have indicated that the TKR patients report moderate to severe pain for 10 days after surgery, particularly during a range of motions of the postoperative knee (Cheville, 1999 cited by Ginsberg, 2001: 38).

Analgesics used were considered necessary in post TKR patients throughout the rehabilitation period, not only to counter the pain due to surgical incision, but also as a counter to the pain caused by exercise and the range of motions of the knee joint after surgery. The amount of analgesics used was different in each patient and depended on the perception of pain of individuals. In this study, although participants received different analgesics, all of them received analgesics more than 2 hours before starting the experiment by method A and method B of cold compression. Cold compression is nonpharmacological methods that could serve as adjuncts to relieve postoperative pain in TKR patients. In this study, cold compression could reduce pain in TKR patients who received method B or method A of cold compression as in the following discussion.

1. Pain reduction from using cold compression before passive exercise (method B)

Cold compression for 20 minutes before passive exercise reduced pain due to surgical incision, by decreasing noxious stimuli from the wound. Cold produced vasoconstriction and decreased cellular metabolism, consequently the amount of oxygen required by cells to survive was decreased. As the number of cells killed by lack of oxygen was decreased, the chemical substances of tissue damage were reduced.

Decreased inflammatory substances reduced inflammation and edema and resulted in decreasing muscle tension around the surgical wound. Therefore, the noxious stimuli that initiated transduction of pain were decreased, which consequently decreased pain. In addition, cold decreased nerve conduction velocity of the A-delta and the C fibers and resulted in decreased perception of pain. However, after 20 minutes of cold compression, the cold gel packs were removed from the skin. Then the participants were passively exercised by the CPM machine. During exercise, the physiological response increased the metabolism for energy supply to tissues and muscles around the knee which resulted in heat production. As heat produced warm tissues and muscles around the knee, the effects of cold compression before passive exercise were reduced chronologically after exercise. Moreover, exercise increased noxious stimuli that initiated pain such as lactic acid which resulted from the increased metabolism, and muscle contraction and muscle spasm which occurred from stretch reflex.

For the reasons mentioned above, the participants who received method B of cold compression had increased pain after passive exercise by the CPM machine (Pain score: before exercise $\bar{X}=5.50$, S.D.=0.9; after cold compression $\bar{X}=3.27$, S.D.=0.78; and after exercise $\bar{X}=5.53$, S.D.=0.94) (Table 4). The result of the method B suggested that cold compression with a temperature of between 0°C and 18.33°C for 20 minutes reduced pain due to surgical incision but it was inadequate to decrease pain in TKR patients who performed exercise because after exercise the pain score was higher than before exercise. However, method B was rated as “moderate satisfaction” by 86.7% of the participants and they gave the reasons for satisfaction that the pain score after exercise was slightly increased. When asked to respond to their thinking and feelings about the method B, 90% of them felt comfortable, 10% of them felt increased ease of knee flexion, and 6.7% of them had confidence and morale for exercise. As after exercise pain slightly increased, 40% of the participants who expected worst pain after exercise felt method B could reduce pain, but 6.7% of them reported their perception of pain was equal between before and after exercise (Table 6).

Pain reduction by using cold compression for 20 minutes in this study was in agreement with previous studies. Enwemeka and colleagues (2001) studied the effect of cold gel pack compression for 20 minutes on temperature of normal quadriceps femoris muscles in the participants who lay down on the bed and had tissue temperature

recorded. They found that cold gel pack produced significant cooling of the superficial tissue within 20 minutes of its application. This result yielded benefits of cryotherapy to reduce pain such as decreased inflammation, edema, and nerve conduction velocity of pain fibers. Also, Weston and colleagues (1994) studied the effects of cold gel pack compression for 20 minutes on local blood volume in traumatized ankle patients. This study found that compression with a cold gel pack for 20 minutes could decrease blood volume in the injury area and it resulted in decreased inflammation process and pain. Likewise, Hecht and colleagues (1983) found that using a cold gel pack compression for 20 minutes, before the TKR patients performed knee exercise with the assistance of physical therapist on the 14th postoperative day, had statistically significant decreased edema of the knee after exercise. Moreover, 38% of the participants in this study indicated that cold gel packs compression made them feel comfortable.

2. Pain reduction from using cold compression both before and during passive exercise (method A)

Cold compression before and during passive exercise had two times of cold compressions that were before exercise and during exercise. The participants received cold compression which had a temperature between 0^o C and 18.33^o C for 20 minutes, which reduced pain due to surgical incision under the same conditions as method B. Afterwards, when they had finished cold compression for 20 minutes, the investigator removed the previous cold gel packs and put the new cold gel packs to compress at the start until the finish of exercise. Through 30 minutes of exercise the cold gel packs had a temperature between 0^o C and 18.33^o C.

Cold compression during exercise was the continuous cold therapy that reduced pain by decreasing noxious stimuli which occurred from exercise. As continuous cold compression reduced the energy need of cells during exercise, the metabolism of tissues and muscles around the knee was decreased, consequently decreased heat production and lactic acid occurred. In addition, passive exercise produced a stretch reflex that controlled muscle contraction of the knee function. As the surgical wound released chemical substances that produced hyperactivity of the stretch reflex, the muscle spasm occurred. Cold compression during exercise reduced nerve conduction velocity of sensory and motor nerves, consequently it reduced the stretch reflex.

As a result, during exercise with cold compression muscle contraction occurred due to the function of the knee whereas muscle spasm was inhibited. Furthermore, continuous cold therapy increased the stiffness of collagen which is the major component of muscles and caused increase muscle endurance that assisted in decreasing muscle spasm. Moreover, cold compression during exercise decreased nerve conduction velocity of the A delta and the C fibers resulting in decreased perception of pain during exercise.

For the reasons mentioned above, cold compression before and during passive exercise could reduced pain after exercise in TKR patients who performed passive exercise by the CPM machine (Pain score: before exercise $\bar{X}=5.47$, S.D.=0.9; after cold compression $\bar{X}=2.83$, S.D.=0.87; and after exercise $\bar{X}=1.03$, S.D.=0.85) (Table 4). All of the participants rated “most satisfaction” to method A of cold compression and stated their feelings that this method could reduce pain. When asked to respond about thinking and feelings about method A, 93.3% of them felt comfortable, 83.7% of them felt increased ease of knee flexion, and 40% of them had confidence and morale for exercise (Table 6).

Method A used continuous cold therapy for 50 minutes that included 20 minutes before exercise, and 30 minutes during exercise. This result agreed with the study of Morsi (2002) who studied the effects of a continuous cryotherapy device on the surgical wound of TKR patients. The patients who were in the experimental group received this device for 6 days postoperatively except for short periods for ambulatory and knee mobilization exercises. The skin temperature of patients who were in the experimental group was kept at $7^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for the first 2 hours postoperatively. After that the skin temperature was maintained at $12^{\circ}\text{C} \pm 3^{\circ}\text{C}$. This study found that the patients who received continuous cryotherapy device had statistically significant lower pain, analgesic consumption, and blood loss than those patients who did not receive this device. In addition, in terms of wound healing there was no difference between the experimental group and control group. Moreover, the experimental group did not have frostbite. Although the situation of the continuous cold to the surgical wound of TKR in Morsi's study was different to the A method of cold compression in this study, the continuous cryotherapy was used in a period that needed the effect of cold. Moreover in method A, all of participants did not have frostbite. Furthermore, the continuous

cryotherapy device was used on surgical wounds of TKR in other studies such as Webb and colleagues (1998) who found that when using a continuous cryotherapy device for 2 days postoperatively in the TKR patients, it could decrease pain and blood loss from the surgical wound. Likewise, Levy & Marmar (1993) found that when a continuous cryotherapy device was used for 3 days postoperatively with the TKR patients, it could decrease pain and blood loss of the surgical wound and increased range of motions of the postoperative knee.

Furthermore, the analgesic effects of cryotherapy were found in other studies. Kimura and colleagues (1997), and Thompson and colleagues (1994) found that immersing the leg in 10⁰ C ice bath for 30 minutes did not affect the strength of muscles but it did increase muscle endurance when the participants used a range of motions of the knee and ankle. Whilst, Ernst & Fialka (1994) reviewed 13 articles that examined the effects of cryotherapy on decreasing painful nerve conduction velocity, decreasing inflammation, and decreasing muscle spasm. They reported that seven articles found that cryotherapy decreased painful nerve conduction velocity. Five articles found that cryotherapy decreased inflammation and two articles found that cryotherapy decreased muscle spasm. Furthermore, Harlarr and colleagues (2001) found that cryotherapy decreased pain due to muscle spasm in spasticity of lower extremities patients.

3. Method A could reduce pain better than method B of cold compression

From the discussion of each method of cold compression as provided above, the continuous cold compression in method A had a strong point that differed from method B. Method A not only decreased pain due to surgical incision, but also decreased pain that occurred during exercise whereas the method B only decreased pain due to surgical incision. Before exercise, at 0 minute, the mean of pain score between the method A and the method B were approximately equal, but after exercise, at the 50th minute, the mean pain score of the method A was lower than the mean pain score of the method B (Pain score of method A: before exercise $\bar{X}$ =5.47, S.D.=0.9; after exercise $\bar{X}$ =1.03, S.D.=0.85, Pain score of method B: before exercise $\bar{X}$ =5.50, S.D.=0.9; after exercise $\bar{X}$ =5.53, S.D.=0.94) (Table 4). After finishing cold compression for 20 minutes, the pain score of method A decreased chronologically

after exercise whereas the pain score of method B increased chronologically after exercise (Figure 15). Moreover, the investigator found that some of the participants (26.7%) who had pain and needed cold compression after exercise were in method B (Table 7). This finding confirmed that method B is inadequate to reduce pain during exercise, and caused the TKR patients to need cold compression after exercise in order to be comfortable. The investigator tested the effect of cold compression between method A and method B on pain score with Analysis of Variance for a simple cross over design. The result of the test supported the hypothesis that the participants who received method A of cold compression had statistically significant lower pain score than those of the participants who received method B of cold compression ($p<.001$) (Table 5). Therefore, the continuous cold compression during exercise in method A was better than discontinuous cold compression in method B. Although foreign countries used the continuous cryotherapy device but it was not used in Thailand because it was expensive. As a result, Thailand preferred to use the reusable cold gel pack because it was inexpensive, easily purchasable, and convenient in application. Furthermore, the participants demonstrated the other times that they preferred cold compression such as 50% of them need cold compression before walking, and 23.3% of them needed cold compression when they had less pain (Table 7).

In conclusion, the method A of cold compression was the application of the cold gel packs to form continuous cryotherapy that could produce the effective nursing practice to reduce pain in the TKR patients who performed passive exercise with the CPM machine in the rehabilitation period. The effective pain reduction could promote exercise which in turn leads to early ambulation of TKR patients.

CHAPTER VI

CONCLUSION

Summary of the study

This study was a quasi-experimental research study to compare the reduction of pain in patients who had undergone total knee replacement, during passive exercise with the continuous passive motion machine between cold compression before passive exercise (method B) and cold compression both before and during passive exercise (method A) groups. The participants included 30 patients who had undergone TKR by the same surgeon on the 4th postoperative day, and who were admitted at the Private Ward, Orthopedics Department, Siriraj Hospital, Faculty of Medicine, Mahidol University, Bangkok, between February to July 2003. A simple cross over design was used for this study to control external variables that could have affected an individual's pain. All participants received both methods of cold compression. There were two equal patterns of cold compression that were the pattern I and pattern II. In pattern I the participants received method A before method B, and in pattern II the participants received method B before method A. All participants were assigned to pattern I or pattern II by random sampling. A registered nurse was the research assistant. She measured participants' pain intensity by using the vertical 0-10 NRS and recorded pain through intervention in order to make a blind study.

The instruments of this study consisted of the intervention instruments and the data collection instruments. The intervention instruments included a digital thermometer (Oakton thermometer, water resistant, range -10°C to 200°C , accuracy $\pm 1.0^{\circ}\text{C}$, Oakton Co., Ltd., China), four pieces of reusable cold gel pack, a bag which can keep 2 pieces of cold gel pack, and the CPM machine. The data collection instruments included a demographic data form, medical history data form, the vertical 0-10 NRS, and the questionnaire form which recorded patient's thinking and feelings about each method of cold compression. Data were analyzed by frequency, percentage, mean, standard deviation, and Analysis of Variance for a simple

cross over design. The results supported the hypothesis that the TKR patients who received method A of cold compression had statistically significant lower pain scores than those of the TKR patients who received method B of cold compression ($p < .001$).

Implications and Recommendations

The recommendations for nursing practice are as follow:

1. To reduce pain in TKR patients who are in the rehabilitation period, particularly during performing passive exercise with the CPM machine, nurses should apply the cold gel pack for cold compression before and during passive exercise as a guideline for nursing intervention.

2. This study conducted was in private wards. The patient's room temperature was controlled between 23.5°C and 25.5°C in order to control any increase in cold gel packs temperature. If nurses apply cold compression before and during exercise to reduce pain in TKR patients who are admitted in a public ward, they will recognize that the cold gel packs should have a temperature of between 0°C and 18.33°C for therapeutic effects of cryotherapy. Therefore, the nurses of public wards should monitor and record the room's temperature and increase the cold gel pack's temperature in order to ensure a suitable time for replacing the old one by the new cold gel packs.

3. The assessment of pain level and contraindication of cold compression should be performed before exercise and cold compression. Although in this study frostbite was not found, during cold compression nurses should observe the capillary refill of the extremities in order to prevent tissue damage from cold. The capillary refill should return within five seconds during cold compression.

4. Nurse should recommend cold compression to discharged TKR patients and their caregivers for a self-care method of decreasing pain.

Implications for further studies

1. This finding can affect patients care outcome through decreasing pain during passive exercise with the CPM machine; further study may contribute by measuring the effects of cold compression on decreasing pain in others activities of rehabilitation such as straight leg rise exercise of postoperative knee, standing, and walking etc.

2. Because this study found that cold compression before and during passive exercise can reduce pain after exercise; further study may contribute to the study of the effects of cold compression before and during passive exercise that may affect a reduction in analgesic drugs which the patients receive.

3. In this study some patients who received cold compression before passive exercise needed cold compression after exercise; further study may contribute to the study of the effects of cold compression and the duration of pain relief after exercise.

4. This study conducted in private ward that the patient's room temperature is controlled between 23.5°C and 25.5°C in order to control any increase in cold gel packs temperature; further study may contribute to study the duration of the effects of the cold gel packs compression in public wards.

Limitation of the study

Sometimes during this study, as the experiment was being conducted, the visitors such as friends or relatives visited the participants. The participants had a chat with the visitors and enjoyed it. This environment may be an external variable which could produce a distraction that decreased the concentrated perception of pain stimuli of participants, consequently the participants rated less pain.

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APPENDIX A

List of experts

There were four experts who validated content of data collecting form.

1. Associate Professor Dr. Pongsri Srimoragot
Department of Surgical Nursing
Faculty of Nursing
Mahidol University.
2. Associate Professor Vilaisaree Sirihongthong
Department of Surgical Nursing
Faculty of Nursing
Mahidol University.
3. Instructor Pacharapol Udomkiat
Department of Orthopaedic Surgery
Faculty of Medicine Siriraj Hospital
Mahidol University.
4. Mrs. Sukontha Padungwatra
Operative Nursing Division
Nursing Department
Faculty of Medicine Siriraj Hospital
Mahidol University.

APPENDIX B

Permission for data collecting

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ห้องรองคณบดี คณะพยาบาลศาสตร์
เลขรับ.....
วันที่ 27 ส.ค. 2545
เวลา.....

คณะพยาบาลศาสตร์
เลขรับ.....
วันที่ 26 ส.ค. 2545
เวลา.....

บันทึกข้อความ

ส่วนราชการ คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล โทร. 0 2419 8940 ต่อ 6614

ที่ ทม 0807/ 15121 วันที่ 26 ธันวาคม 2545

เรื่อง ยินดีให้ความอนุเคราะห์ข้อมูลประกอบการทำวิทยานิพนธ์

เรียน คณบดีคณะพยาบาลศาสตร์ มหาวิทยาลัยมหิดล

ตามที่ คณะพยาบาลศาสตร์ มหาวิทยาลัยมหิดล มีความประสงค์ให้ นางสาวยุพาวรรณ จิตตาภิวัฒน์ นักศึกษาหลักสูตรพยาบาลศาสตรมหาบัณฑิต สาขาการพยาบาลผู้ใหญ่ คณะพยาบาลศาสตร์ มหาวิทยาลัยมหิดล เข้าเก็บข้อมูลเพื่อประกอบการทำวิทยานิพนธ์เรื่อง "เปรียบเทียบผลของการบรรเทาปวดด้วยการประคบเย็นก่อนการบริหาร และการประคบเย็นทั้งก่อนและขณะการบริหารในผู้ป่วยหลังผ่าตัดเปลี่ยนข้อเข่าเทียม ชนิดบริหารข้อเข่าด้วยเครื่องบริหารอย่างต่อเนื่องแบบพาสซีฟ" โดยการเก็บข้อมูลจากแฟ้มประวัติการเจ็บป่วย และโดยการสัมภาษณ์และการตอบแบบสอบถามจากผู้ป่วยข้อเข่าเทียมที่ได้รับการผ่าตัดเปลี่ยนข้อเข่าเทียมที่เข้ารับการรักษาในห้องพิเศษ หอผู้ป่วยในโรงพยาบาลศิริราช ความละเอียดดังแจ้งแล้วนั้น

คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล พิจารณาแล้วยินยอมให้ นางสาวยุพาวรรณ จิตตาภิวัฒน์ ดำเนินการเก็บข้อมูลตามที่เสนอขอมา แต่ทั้งนี้จะต้องได้รับการพิจารณาอนุมัติจากคณะกรรมการจริยธรรมการวิจัยในคน ของคณะแพทยศาสตร์ศิริราชพยาบาลเรียบร้อยแล้ว จึงจะดำเนินการเก็บข้อมูลได้

ขอได้โปรดติดต่อสำนักงานคณะกรรมการจริยธรรมการวิจัยในคน โทร. 0 2419 8940 ต่อ 6405-6 เพื่อขอรับการพิจารณาจากคณะกรรมการจริยธรรมการวิจัยในคน ของคณะแพทยศาสตร์ศิริราชพยาบาล ต่อไป

จึงเรียนมาเพื่อโปรดทราบ

เรียน รองคณบดีฝ่ายบัณฑิตศึกษา

เพื่อโปรดทราบ

เรื่องส่ง.....

๑ เม.ย. ๒๕๔๖

ทนาย + อธิการบดี

(รองศาสตราจารย์สายพิน เกษมกิจวัฒนา)

รองคณบดีฝ่ายบัณฑิตศึกษา

ปฏิบัติราชการแทน คณบดีคณะพยาบาลศาสตร์

27 ส.ค. 2545

(ผู้ช่วยศาสตราจารย์นายแพทย์ชัยวัฒน์ โมกขะเวส)

รองคณบดี คณะแพทยศาสตร์ศิริราชพยาบาล

ปฏิบัติราชการแทนคณบดี

๑๖ กุมภาพันธ์ ๒๕๔๖
๑ ม.ค. ๔๖

1603
Dingma



บันทึกข้อความ

ส่วนราชการ คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล โทร 0 2419 7683-4

ที่ ทม 0807/ 1167

วันที่ 28 มกราคม 2546

เรื่อง ยินดีให้ข้อมูลทางสถิติผู้ป่วยที่ได้รับการผ่าตัดเปลี่ยนข้อเข่าเทียม

เรียน ประธานคณะกรรมการบริหารหลักสูตรพยาบาลศาสตรมหาบัณฑิต

ตามหนังสือ หลักสูตรพยาบาลศาสตรมหาบัณฑิต คณะพยาบาลศาสตร์ มีความประสงค์ขอข้อมูลเกี่ยวกับสถิติจำนวนผู้ป่วยในที่ได้รับการผ่าตัดเปลี่ยนข้อเข่าเทียม ในปี พ.ศ. 2544 และในปี พ.ศ. 2545 ของภาควิชาศัลยศาสตร์ออร์โธปิดิกส์และกายภาพบำบัด คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล เพื่อเป็นข้อมูลในการจัดทำวิทยานิพนธ์เรื่อง “เปรียบเทียบผลของการบรรเทาปวดด้วยการประคบเย็นก่อนการบริหร และการประคบเย็นทั้งก่อนและขณะการบริหรในผู้ป่วยหลังผ่าตัดเปลี่ยนข้อเข่าเทียม ขณะบริหรข้อเข่าด้วยเครื่องบริหรอย่างต่อเนื่องแบบพาสซีฟ” ของนางสาวยุพาวรรณ จิตดาภิวัฒน์ นักศึกษาหลักสูตรพยาบาลศาสตรมหาบัณฑิต สาขาการพยาบาลผู้ใหญ่ คณะพยาบาลศาสตร์ ความละเอียดคงแจ้งในหนังสือ หลักสูตรพยาบาลศาสตรมหาบัณฑิต คณะพยาบาลศาสตร์ มหาวิทยาลัยมหิดล ที่ พย.ม 006/2545 ลงวันที่ 2 มกราคม 2546 นั้น

คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล ยินดีให้ข้อมูลเกี่ยวกับสถิติจำนวนของผู้ป่วยใน ที่ได้รับการผ่าตัดเปลี่ยนข้อเข่าเทียม ในปี พ.ศ. 2544 และปี พ.ศ. 2545 ตามที่ขอมาได้

(ผู้ช่วยศาสตราจารย์ นายแพทย์ชัยวัฒน์ โมกขะเวส)

รองคณบดีคณะแพทยศาสตร์ศิริราชพยาบาล

ปฏิบัติราชการแทนคณบดี

**บันทึกข้อความ**

ส่วนราชการ สำนักงานคณะกรรมการจริยธรรมการวิจัยในคน ตึกอศุลยเดชวิกรม ชั้น ๕ โทร.๖๔๐๕-๖
ที่ ทม. ๐๘๐๗/ ๑๔๕๖ วันที่ ๓๑ มกราคม ๒๕๔๖
เรื่อง แจ้งผลการพิจารณาโครงการวิจัย

เรียน นางสาวยุพวรรณ จิตตาภิวัฒน์

ตามที่ท่านได้ส่งโครงการวิจัยเรื่อง “เปรียบเทียบผลของการบรรเทาปวดด้วยการประคบเย็น
ก่อนการบริหารและการประคบเย็นทั้งก่อนและขณะการบริหาร ในผู้ป่วยหลังผ่าตัดเปลี่ยนข้อเข่าเทียม ขณะ
บริหารข้อเข่าด้วยเครื่องบริหารอย่างต่อเนื่องแบบพาสซีฟ ” ซึ่งท่านเป็นหัวหน้าโครงการเพื่อขอรับการ
พิจารณาด้านจริยธรรม

คณะกรรมการจริยธรรมการวิจัยในคน ได้พิจารณาด้านจริยธรรมของโครงการดังกล่าวเมื่อ
วันที่ ๓ มกราคม ๒๕๔๖ มีมติรับรองในหลักการ โดยขอให้แก้ไขเพิ่มเติมและท่านได้แก้ไขตามคำชี้แจง
ของคณะกรรมการฯ แล้วนั้น

คณะกรรมการฯ ได้พิจารณาโครงการที่ได้แก้ไขแล้วและมีมติรับรอง พร้อมนี้ได้ส่งเอกสารมาด้วย

จึงแจ้งมาเพื่อทราบ

(ศาสตราจารย์แพทย์หญิงสุมาลี นิมนานโตย)
ประธานคณะกรรมการจริยธรรมการวิจัยในคน

เอกสารรับรองคณะกรรมการจริยธรรมการวิจัยในคน
คณะแพทยศาสตร์ศิริราชพยาบาล

เลขที่ 31/2003

ชื่อโครงการ	เปรียบเทียบผลของการบรรเทาปวดด้วยการประคบเย็นก่อนการบริหารและการประคบเย็น ทั้งก่อนและขณะการบริหาร ในผู้ป่วยหลังผ่าตัดเปลี่ยนข้อเข่าเทียม ขณะบริหารข้อเข่าด้วย เครื่องบริหารอย่างต่อเนื่องแบบพาสซีฟ
ชื่อหัวหน้าโครงการ	นางสาวยุพาวรรณ จิตตาภิวัฒน์
เลขที่โครงการ/รหัส	_____
สังกัดหน่วยงาน	คณะพยาบาลศาสตร์
เอกสารที่รับรอง	- โครงการวิจัย - หนังสือยินยอมและสมัครใจเข้าร่วมโครงการโดยได้รับการอธิบาย

ได้ผ่านการพิจารณาและรับรองโดยคณะกรรมการจริยธรรมการวิจัยในคนเมื่อวันที่ 30 มกราคม 2546

ลงนาม
 (ศาสตราจารย์แพทย์หญิงสุมาลี นิมนานิตย์)
 ประธานคณะกรรมการจริยธรรมการวิจัยในคน

ลงนาม
 (ศาสตราจารย์คลินิกนายแพทย์ปิยะสกล สกลสัตยาทร)
 คณบดี คณะแพทยศาสตร์ศิริราชพยาบาล

๒ ถนนพราหมณ์ บางกอกน้อย กรุงเทพฯ ๑๐๓๐๐
 โทร. (๖๖-๒) ๔๑๑-๑๔๒๕, ๔๑๑-๓๒๕๓
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Faculty of Medicine Siriraj Hospital
 Mahidol University

The Ethical Committee on Research Involving Human Subject
 Faculty of Medicine Siriraj Hospital, Mahidol University

No. 31/2003

Protocol Title	A comparison of pain reduction between cold compression before passive exercise to combination of cold compression before and during passive exercise using continuous passive motion machine in total knee replacement patient
Protocol Number	_____
Principal Investigator	Miss. Yuphawan Chittapiwat
Name of Department	Faculty of Nursing

The aforementioned project and informed consent have been reviewed and approved by the Ethical Committee, Faculty of Medicine Siriraj Hospital, Mahidol University, based on the Declaration of Helsinki on January 30, 2003

Signature of Chairman

.....
 (Prof. Sumalee Nimmannit)

Signature of Dean

.....
 (Clin. Prof. Piyasakol Saklsatayadorn)

APPENDIX C

The consent form

คำชี้แจงและพิกัดสิทธิ์ของผู้เข้าร่วมวิจัย

ในปัจจุบันการบริการสาธารณสุขเน้นคุณภาพการบริการ ประารถนาให้ผู้ป่วยที่ได้รับการผ่าตัดเปลี่ยนข้อเข่าเทียม สามารถฟื้นฟูสภาพข้อเข่าภายหลังการผ่าตัดได้อย่างมีประสิทธิภาพ และกลับบ้านได้โดยเร็ว ไม่มีอาการแทรกซ้อน รวมทั้งไม่มีความทุกข์ทรมานจากอาการไม่สุขสบายต่าง ๆ อาการปวดเป็นความไม่สุขสบายที่ผู้ป่วยทุกคนไม่ต้องการ และเป็นอุปสรรคในการบริหารเพื่อฟื้นฟูสภาพข้อเข่าภายหลังการผ่าตัดเปลี่ยนข้อเข่าเทียม พยาบาลในฐานะที่เป็นบุคคลที่มีความใกล้ชิดในการดูแลผู้ป่วยที่ได้รับการผ่าตัดเปลี่ยนข้อเข่าเทียม จะให้การดูแลผู้ป่วยที่ได้รับการผ่าตัดให้มีอาการปวดน้อยที่สุดทั้งวิธีการให้ยา และการช่วยเหลืออื่น ๆ ซึ่งในการฟื้นฟูสภาพข้อเข่าโดยการบริหาร งอและเหยียดข้อด้วยเครื่องช่วยบริหาร ภายหลังการได้รับการใส่ข้อเข่าเทียม นอกจากพยาบาลจะให้ยาในการช่วยบรรเทาความปวดแล้ว พยาบาลยังให้การประคบเย็น เพื่อช่วยลดอาการอักเสบ และอาการปวดในช่วงที่ท่านได้รับการบริหารข้อเข่าด้วย

ดิฉัน นางสาวยุพาวรรณ จิตตาวีวัฒน์ กำลังศึกษาในหลักสูตรพยาบาลศาสตรมหาบัณฑิต สาขาการพยาบาลผู้ใหญ่ คณะพยาบาลศาสตร์ มหาวิทยาลัยมหิดล ได้ทำการวิจัยโดยการศึกษาเปรียบเทียบผลของการประคบเย็น 2 วิธี ในการลดความปวด ในขณะที่บริหารโดยวิธีงอและเหยียดข้อเข่าด้วยเครื่องช่วยบริหาร ภายหลังการผ่าตัดเปลี่ยนข้อเข่าเทียม โดยที่การประคบเย็นนี้จะไม่มีผลข้างเคียง หรือขัดต่อการรักษาของแพทย์ และได้รับอนุญาตจากแพทย์เจ้าของไข้แล้ว ขอความร่วมมือจากท่านในการเข้าร่วมการศึกษานี้ โดยจะสอบถามข้อมูลทั่วไปเกี่ยวกับท่าน และทำการประคบเย็นให้กับท่าน 2 วิธี ได้แก่ วิธีที่ 1 คือ การประคบเย็นให้ท่านก่อนที่ท่านจะเริ่มบริหารงอเหยียดข้อเข่าซึ่งทำผ่าตัด วิธีที่ 2 คือ การประคบเย็นให้ท่านก่อนที่ท่านจะเริ่มบริหารงอเหยียดข้อเข่าซึ่งทำผ่าตัด และเมื่อท่านเริ่มต้นบริหารก็จะประคบเย็นอันใหม่ให้ท่าน พร้อมกันนี้จะสอบถามความปวดของท่านไปด้วย ในขณะที่ท่านอยู่ในช่วงของการบริหารงอและเหยียดข้อเข่าในวันที่ 4 ภายหลังการผ่าตัด รวมทั้งการสอบถามความคิดเห็นของท่านในการประคบเย็นเพื่อบรรเทาอาการปวด

ทุกคำตอบของท่านจะมีความสำคัญที่จะเป็นพื้นฐานของการให้การพยาบาล เพื่อช่วยเหลือในการบรรเทาอาการปวดให้กับ ผู้ป่วยที่ได้รับการผ่าตัดเปลี่ยนข้อเข่าเทียม ในขณะที่มีการฟื้นฟูสภาพข้อเข่าโดยการบริหารงอและเหยียดข้อ

การเข้าร่วมการวิจัยครั้งนี้เป็นไปตามความสมัครใจของท่าน หากผู้วิจัยมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์หรือโทษที่เกี่ยวข้องกับการวิจัยนี้ ผู้วิจัยจะแจ้งให้ท่านทราบโดยเร็ว โดยไม่ปิดบัง หากท่านเปลี่ยนใจมีสิทธิ์ที่จะถอนตัวจากการวิจัยเมื่อไรก็ได้ โดยไม่ต้องให้เหตุผลหรือคำอธิบายใด ๆ กับผู้วิจัย และไม่มีผลกระทบใด ๆ ต่อการรักษาพยาบาลที่ท่านได้รับ ข้อมูลที่ได้รับจากท่านทั้งหมด จะถือเป็นความลับ และแสดงผลการศึกษาเป็นภาพรวมเท่านั้น

ในระหว่างการเข้าร่วมในการวิจัย หากท่านมีข้อสงสัยใด ๆ คิฉินยินดีตอบข้อสงสัยของท่านตลอดเวลา 24 ชั่วโมง ที่เบอร์โทรศัพท์ 01 – 7365247 และขอขอบพระคุณที่กรุณาให้ความร่วมมือ

ขอแสดงความนับถือ

นางสาวยุพาวรรณ จิตตาวัดน์

ผู้วิจัย

หนังสือแสดงเจตนายินยอมเข้าร่วมโครงการวิจัย

วันที่.....เดือน.....พ.ศ.....

ข้าพเจ้า (นาย / นาง / นางสาว).....อายุ.....ปี

อาศัยอยู่บ้านเลขที่.....หมู่บ้าน.....ซอย.....ถนน

.....แขวง.....เขต.....จังหวัด.....

โทรศัพท์.....โทรสาร.....

ขอแสดงเจตนายินยอมเข้าร่วมโครงการวิจัยเรื่อง “เปรียบเทียบผลของการบรรเทาปวดด้วยการ
ประคบเย็นก่อนการบริหาร และการประคบเย็นทั้งก่อนและขณะการบริหาร ในผู้ป่วยหลังผ่าตัด
เปลี่ยนข้อเข่าเทียม ขณะบริหารข้อเข่าด้วยเครื่องบริหารอย่างต่อเนื่องแบบพาสซีฟ”

โดยข้าพเจ้าได้รับทราบเกี่ยวกับรายละเอียดของโครงการ ดังต่อไปนี้

วัตถุประสงค์ของการวิจัย

เพื่อเปรียบเทียบความแตกต่างของการบรรเทาปวดในผู้ป่วยภายหลังการผ่าตัดเปลี่ยนข้อเข่า
เทียมขณะบริหารข้อเข่าด้วยเครื่องบริหารอย่างต่อเนื่องแบบพาสซีฟภายหลังการผ่าตัด โดยใช้วิธีการ
ประคบเย็นก่อนการบริหาร และวิธีการประคบเย็นทั้งก่อนและขณะการบริหาร

ประโยชน์ที่คาดว่าจะได้รับการวิจัยครั้งนี้

1. เป็นแนวทางในการให้การพยาบาลโดยการประคบด้วยเจลลี่เย็นเพื่อบรรเทาอาการปวดในผู้ป่วย
หลังผ่าตัดเปลี่ยนข้อเข่าเทียม ขณะที่มีการฟื้นฟูพิสัยการเคลื่อนไหวของข้อเข่าด้วยเครื่องบริหาร
อย่างต่อเนื่องแบบพาสซีฟ
2. เป็นแนวทางสำหรับการศึกษาวิธีการลดความเจ็บปวดในผู้ป่วยที่มีสาเหตุความเจ็บปวดในโรค
อื่นต่อไป

ความเสี่ยงหรือผลข้างเคียงที่อาจจะเกิดขึ้น

ผลข้างเคียงที่อาจจะเกิดขึ้นจากการวิจัย คือ การทำลายของเนื้อเยื่อจากความเย็นซึ่งมีโอกาส
เกิดขึ้นน้อยมาก เนื่องจากการประคบเย็นเป็นงานที่ทำประจำอยู่แล้ว ในการบริหารข้อเข่าภายหลัง
การผ่าตัดเปลี่ยนข้อเข่าเทียม และสามารถสังเกตอาการและป้องกันได้ตั้งแต่ก่อนมีผลข้างเคียงโดย
การสังเกตการไหลเวียนเลือดของขาข้างที่ประคบเย็น และแนะนำผู้ป่วยและญาติในการสังเกตและ
ตรวจสอบ รวมทั้งการประคบเย็นนี้ไม่ขัดต่อการรักษาของแพทย์ และได้รับอนุญาตจากแพทย์
เจ้าของไข้แล้ว

รายละเอียดและขั้นตอนที่ผู้ร่วมโครงการวิจัยจะได้รับการปฏิบัติ

1. ผู้ป่วยจะได้รับการประคบเย็นสองวิธี คือ การประคบเย็นทั้งก่อนและขณะการบริหาร และการประคบเย็นก่อนการบริหาร พร้อมกับการสอบถามระดับความปวด ในขณะที่มีการบริหารข้อเข่า ด้วยเครื่องบริหารอย่างต่อเนื่องแบบพาสซีฟ นาน 30 นาที
2. ผู้ป่วยจะได้รับการสังเกต และประเมินการไหลเวียนโลหิตของขาข้างที่มีการประคบเย็น เพื่อป้องกันไม่ให้เกิดผลข้างเคียงจากการประคบเย็น รวมทั้งแนะนำผู้ป่วยและญาติในการสังเกตด้วยตนเอง
3. ผู้ป่วยจะได้รับการตอบแบบสอบถามเกี่ยวกับ ข้อมูลส่วนบุคคล ข้อมูลเกี่ยวกับโรคและการรักษา และสอบถามความคิดเห็นในการประคบเย็นเพื่อบรรเทาอาการปวด เมื่อเสร็จสิ้นการประคบเย็นทั้งหมด รวมทั้งได้รับการประเมินสัญญาณชีพ ก่อนและหลังการประคบเย็น

การติดต่อกับผู้วิจัยในกรณีที่มีปัญหา (ตลอด 24 ชั่วโมง)

โทรศัพท์มือถือ (01) 736 – 5247

หากข้าพเจ้าได้รับผลข้างเคียงหรือฤทธิ์ไม่พึงประสงค์หรืออันตรายจากการวิจัย ข้าพเจ้าจะได้รับการปฏิบัติ / การชดเชยดังนี้

ข้าพเจ้าได้รับทราบเกี่ยวกับผลข้างเคียงของการวิจัยที่อาจจะเกิดขึ้น ซึ่งสามารถสังเกตอาการ และป้องกันได้ตั้งแต่ก่อนเกิดผลข้างเคียง และแนะนำผู้วิจัยได้ให้คำแนะนำในการสังเกตและตรวจสอบการไหลเวียนเลือด เพื่อป้องกันผลข้างเคียงให้กับข้าพเจ้าแล้ว ซึ่งทำได้โดยการสังเกตการซีดของสีเล็บเท้าของขาข้างที่ประคบเย็น และตรวจสอบการไหลเวียนเลือดโดยใช้นิ้วมือกดที่เล็บเท้าของขาข้างที่ประคบเย็นให้เล็บเป็นสีขาวแล้วปล่อย ถ้าสีเล็บกลับมาเป็นสีชมพูเหมือนก่อนที่จะกดภายใน 1–2 วินาที แสดงว่า การไหลเวียนเลือดยังอยู่ในเกณฑ์ดี และสังเกตเกี่ยวกับความรู้สึกที่เกิดขึ้นจากการประคบเย็นว่ามีอาการปวดหรือชาจนไม่รู้สึกริเวณที่มีการประคบเย็นหรือไม่ ถ้ามีอาการผิดปกติอย่างใดอย่างหนึ่งข้าพเจ้าจะแจ้งให้ผู้วิจัยทราบทันที เพื่อยุติการวิจัยและให้การช่วยเหลือต่อไป

หากผู้วิจัยมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์หรือโทษที่เกี่ยวข้องกับการวิจัยนี้ ผู้วิจัยจะแจ้งให้ข้าพเจ้าทราบโดยเร็ว โดยไม่ปิดบัง

ข้าพเจ้ามีสิทธิ์ที่จะขอการเข้าร่วมโครงการวิจัย โดยไม่ต้องแจ้งให้ทราบล่วงหน้า โดยการงดการเข้าร่วมการวิจัยนี้ จะไม่มีผลกระทบต่อการได้รับการบริการ หรือการรักษาที่ข้าพเจ้าจะได้รับแต่ประการใด

ข้าพเจ้าได้รับทราบข้อมูลของโครงการข้างต้น ตลอดจนข้อดี ข้อเสียที่จะได้รับการเข้าร่วมโครงการในครั้งนี้ และข้าพเจ้ายินยอมที่จะเข้าร่วมในโครงการดังกล่าว โดยขอให้ผู้วิจัยดำเนินการเปิดเผยชื่อ ประวัติ ตลอดจนข้อมูลที่เกี่ยวข้องกับข้าพเจ้า แก่ผู้อื่นได้รับทราบ

ลงชื่อ..... ผู้ให้ความยินยอม /ผู้แทน

(.....) โดยชอบธรรม (ระบุความเกี่ยวข้อง)

ลงชื่อ..... หัวหน้าโครงการวิจัย

(นางสาวยุพาวรรณ จิตตภาวิวัฒน์)

ลงชื่อ..... พยาน

(.....)

ลงชื่อ..... พยาน

(.....)

APPENDIX D

Data collection form

เครื่องมือประเมินเกี่ยวกับความปวด

หอผู้ป่วย.....วันที่บันทึก.....
 กลุ่มตัวอย่างรายที่.....
 เวลาเข้า เวลา.....น. ได้รับการประเมินวิธี.....
 เวลาเย็น เวลา.....น. ได้รับการประเมินวิธี.....

ส่วนที่ 1 ข้อมูลส่วนบุคคล

HN.....ชื่อ.....สกุล.....อายุ.....ปี เพศ.....

สถานภาพสมรส () โสด () คู่ () ม่าย () หย่า, แยก

ระดับการศึกษา () ไม่ได้เรียนหนังสือ () ประถมศึกษา

() มัธยมศึกษา / ปวช. () อนุปริญญา / ปวส.

() ปริญญาตรี / สูงกว่าปริญญาตรี

อาชีพ () เกษตรกร ระบุ.....() รับจ้าง ระบุ.....

() รับราชการ ระบุ.....() เอกชน ระบุ.....

() รัฐวิสาหกิจ ระบุ.....() ไม่มีอาชีพ

ความเพียงพอของรายได้ () เพียงพอ () ไม่เพียงพอ () เหลือเก็บ

การจ่ายค่ารักษาพยาบาล () จ่ายค่ารักษาพยาบาลเองทั้งหมด

() จ่ายค่ารักษาบางส่วน โดยใช้สิทธิ์.....

() ไม่ได้จ่ายค่ารักษา โดยใช้สิทธิ์.....

ส่วนที่ 2 ข้อมูลเกี่ยวกับโรคและการรักษาของผู้ป่วย

การวินิจฉัยโรค.....การผ่าตัด.....

วันที่ทำผ่าตัด.....

เคยได้รับการผ่าตัด เกี่ยวกับข้อ หรือกระดูกอื่น ๆ ที่ไม่ใช่ข้อเข่า

() ไม่เคย () เคย ระบุ.....

ประวัติความเจ็บป่วยอื่น ๆ

ยาระงับปวดตามแผนการรักษาที่ได้รับในการผ่าตัดครั้งนี้

.....

ยาระงับปวดที่ผู้ป่วยได้รับก่อนการทดลองในเวลาเช้า.....

ได้รับก่อนการทดลองนาน.....ชั่วโมง.....นาที

ยาระงับปวดที่ผู้ป่วยได้รับก่อนการทดลองในเวลาเย็น.....

ได้รับก่อนการทดลองนาน.....ชั่วโมง.....นาที

สัญญาณชีพ

ก่อนการทดลอง ในเวลาเช้า T.....⁰C, P..... / min, R / min, BP.....mmHg

หลังการทดลอง ในเวลาเช้า T.....⁰C, P..... / min, R / min, BP.....mmHg

ก่อนการทดลอง ในเวลาเย็น T.....⁰C, P..... / min, R / min, BP.....mmHg

หลังการทดลอง ในเวลาเย็น T.....⁰C, P..... / min, R / min, BP.....mmHg

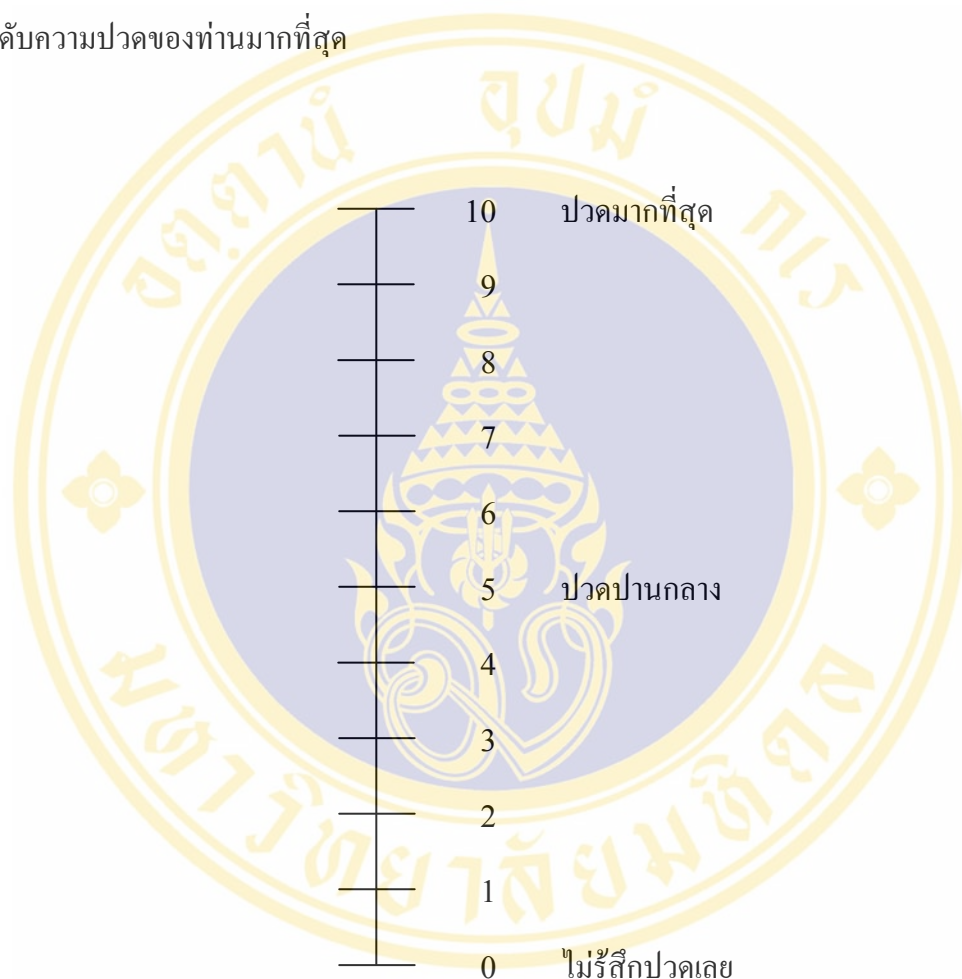
ส่วนที่ 3 ระดับความปวด

เวลาที่วัดระดับความปวด	ระดับความปวด	
	การประเมินทั้งก่อนและขณะบริหาร (วิธี เอ)	การประเมินก่อนบริหาร (วิธี บี)
ในนาทีที่ 0 (ก่อนการบริหาร)		
ในนาทีที่ 20 (เมื่อประเมินครบ 20 นาที)		
ในนาทีที่ 35 (ขณะที่มีการบริหาร)		
ในนาทีที่ 50 (เมื่อเสร็จสิ้นการบริหาร)		

มาตรวัดความปวด

คำชี้แจง

มาตรวัดความปวดนี้ เป็นมาตรวัดความปวดตามความรู้สึกของท่านตั้งแต่ไม่ปวดเลย จนกระทั่งปวดมากที่สุด โปรดกาเครื่องหมายลงบนตัวเลขระหว่าง 0 – 10 ที่ใดก็ได้ที่ตรงกับระดับความปวดของท่านมากที่สุด



ส่วนที่ 4 แบบสอบถามความคิดเห็นในการประคบเย็นเพื่อบรรเทาอาการปวด

คำชี้แจง โปรดตอบคำถามที่ตรงกับความรู้สึกหรือความคิดเห็นของท่านมากที่สุด ตามความเป็นจริง คำตอบของท่านจะเป็นประโยชน์อย่างมากต่อการปรับปรุงคุณภาพในการให้การพยาบาล โดยการประคบเย็นเพื่อช่วยลดความปวด ในผู้ป่วยที่ได้รับการฟื้นฟูสภาพข้อเข่าภายหลังการผ่าตัดเปลี่ยนข้อเข่าเทียม

1. โดยสรุป ในการบริหารข้อเข่าภายหลังการผ่าตัดเปลี่ยนข้อเข่าเทียม ท่านรู้สึกพึงพอใจที่ได้รับการประคบเย็นเพื่อลดความปวด ในแต่ละวิธี มากน้อยเพียงใด

- วิธีการประคบเย็นก่อนบริหารข้อเข่า

() พอใจมาก () พอใจปานกลาง () พอใจน้อย () ไม่พอใจ

- วิธีการประคบเย็นทั้งก่อนและขณะบริหารข้อเข่า

() พอใจมาก () พอใจปานกลาง () พอใจน้อย () ไม่พอใจ

2. เวลาที่ท่านต้องการให้ประคบเย็นเพื่อลดความปวดเข่าข้างที่ทำผ่าตัด (ตอบได้มากกว่า 1 ข้อ)

() ก่อนการฝึกบริหารข้อเข่า

() ขณะกำลังฝึกบริหารข้อเข่า

() ทั้งก่อนและขณะการฝึกบริหารข้อเข่า

() อื่น ๆ โปรดระบุ เวลาที่ต้องการ.....

3. ท่านรู้สึกอย่างไร หลังจากได้รับการประคบเย็น ในแต่ละวิธี (ตอบได้มากกว่า 1 ข้อ)

- วิธีการประคบเย็นก่อนการบริหารข้อเข่า

() ปวดมากขึ้น

() งอเข่าได้น้อยลง

() รู้สึกไม่สบาย

() รู้สึกเฉย ๆ

() รู้สึกสบายขึ้น

() งอเข่าได้ง่ายมากขึ้น

() ปวดน้อยลง

() อื่น ๆ โปรดระบุ.....

- วิธีการประเมินทั้งก่อนและขณะการบริหารข้อเข้า

- () ปวดมากขึ้น
- () งอเข้าได้น้อยลง
- () รู้สึกไม่สบาย
- () รู้สึกเฉย ๆ
- () รู้สึกสบายขึ้น
- () งอเข้าได้ง่ายมากขึ้น
- () ปวดน้อยลง
- () อื่น ๆ โปรดระบุ.....

4. หากท่านจะต้องได้รับการผ่าตัดเปลี่ยนข้อเข้าเทียมอีก 1 ข้าง ท่านต้องการให้มีการประเมินเพื่อลดความปวดในการบริหารโดยการงอและเหยียดเข้าหรือไม่

- () ต้องการ
- () ไม่ต้องการ

ข้อคิดเห็นและข้อเสนอแนะอื่น ๆ

.....

.....

.....

.....

.....

.....

APPENDIX E**Data of receiving analgesic drugs in each participant**

Case	HOUR													
	AM							PM						
	6	7	8	9	10	11	12	1	2	3	4	5	6	
1			V											
2	P						P							
3	P						P							
4	T		V				T							
5			V											
6			V											
7			V											
8			V											
9			V											
10			V											
11	P		V				P							
12	P		V				P							
13	T						T							
14			V											
15	T						T							
16	T	TM					T							
17			V											
18	T						T							
19	T						T							
20	P	PE					P							
21	T		V				T							
22	P						P							
23	T						T							
24	T		V				T							
25	P						P							
26	P						P							
27			V											
28			V											
29	T						T							
30			TC				TC							



= Method A: Cold compression before and during passive exercise



= Method B: Cold compression before passive exercise

P = Paracetamol (500mg.) 2 tablets oral

PE = Pethidine 50 mg. muscular injection

T = Tramal (50 mg.) 1 capsule oral

TE = Tramal 50 mg. muscle injection

TC = Tylenol with Codiene 1 tablet oral (Paracetamol 500 mg. + Codiene 15 mg.)

V = Vioxx (25mg.) 1 tablet oral

From data of receiving analgesic drugs in each participant, the participants were received analgesic drugs more than two hours before the experiment.

APPENDIX F**Data of pain score****Pain score of method A**

Participant	Pain score of method A				A difference of pain score between the 0 th and 50 th minute
	The 0 th minute	The 20 th minute	The 35 th minute	The 50 th minute	
1	5	2	1	0	5
2	6	3	2	2	4
3	5	2	1	0	5
4	5	2	1	1	4
5	5	2	1	1	4
6	5	2	2	1	4
7	5	3	2	2	3
8	7	5	4	4	3
9	5	3	2	1	4
10	5	2	2	1	4
11	5	3	2	1	4
12	5	2	2	1	4
13	6	3	2	1	5
14	6	3	0	0	6
15	5	2	1	1	4
16	5	2	1	1	4
17	5	2	1	1	4
18	6	5	3	1	5
19	5	3	2	2	3
20	5	2	2	1	4
21	5	2	2	1	4
22	9	4	2	2	7
23	5	3	2	0	5
24	5	3	3	1	4
25	6	3	3	2	4
26	7	4	2	0	7
27	5	3	2	0	5
28	5	3	2	1	4
29	5	3	1	0	5
30	6	4	3	1	5
Total	164	85	56	31	133

Pain score of method B

Participant	Pain score of method B				A difference of pain score between the 0 th and 50 th minute
	The 0 th minute	The 20 th minute	The 35 th minute	The 50 th minute	
1	5	3	4	5	0
2	5	4	6	6	-1
3	5	3	3	5	0
4	5	4	4	5	0
5	5	2	3	4	1
6	5	2	4	5	0
7	5	3	4	6	-1
8	5	4	6	7	-2
9	5	3	4	6	-1
10	5	3	4	5	0
11	5	3	3	4	1
12	5	2	3	4	1
13	5	3	4	5	0
14	5	3	4	5	0
15	7	3	5	7	0
16	8	4	5	6	2
17	6	4	5	7	-1
18	5	3	5	5	0
19	5	3	4	6	-1
20	6	3	4	6	0
21	6	4	5	6	0
22	5	3	4	5	0
23	8	5	6	7	1
24	6	4	5	6	0
25	5	3	4	6	-1
26	5	3	4	5	0
27	5	3	4	4	1
28	6	4	5	6	0
29	5	2	4	5	0
30	7	5	6	7	0
Total	165	98	131	166	-1

Table 8. Mean pain score of all participants in the morning and afternoon.

Time	Min	Max	Mean
Morning	5	8	5.27
Afternoon	5	9	5.65

Table 8 showed that the minimum pain score in the morning was 5, the maximum pain score was 8 and the mean pain score was 5.27. In the afternoon the minimum pain score was 5, the maximum pain score was 9 and the mean pain score was 5.65.

Table 9. Number and percentage of pain score at 0 minute (before exercise) that using both method A and method B of cold compression.

Pain score at the 0 th minute (before exercise)	Method A		Method B	
	Number	Percentage	Number	Percentage
5	21	70	21	70
6	6	20	5	16.7
7	2	6.7	2	6.7
8	0	0.00	2	6.7
9	1	3.3	0	0.00

Table 9 showed that most of the participant's pain scores at 0 minute, before exercise, both in method A (70%) and method B (70%), were 5.

Table 10. Number and percentage of pain score at the 50th minute (after exercise) that using both method A and method B of cold compression.

Pain score at the 50 th minute (after exercise)	Method A		Method B	
	Number	Percentage	Number	Percentage
0	7	23.3	0	0.00
1	17	56.7	0	0.00
2	5	16.7	0	0.00
3	0	0.00	0	0.00
4	1	3.3	4	13.3
5	0	0.00	11	36.7
6	0	0.00	10	33.3
7	0	0.00	5	16.7

Table 10 showed that most of the participant's pain scores at the 50th minute, after exercise, in method A (56.7%) were 1. Most of the participant's pain scores at the 50th minute, after exercise, in method B (36.7%) were 5.

Table 11. Number and percentage of difference pain score between the 0 and 50th minute (before exercise and after exercise) that using both method A and method B of cold compression.

A difference of pain score between the 0 th and 50 th minute (0 th – 50 th)	Method A		Method B	
	Number	Percentage	Number	Percentage
-2	0	0.00	1	3.3
-1	0	0.00	6	20
0	0	0.00	17	56.7
1	0	0.00	5	16.7
2	0	0.00	1	3.3
3	3	10.0	0	0.00
4	16	53.3	0	0.00
5	8	26.7	0	0.00
6	1	3.3	0	0.00
7	2	6.7	0	0.00

Table 11 shows that more than half of the difference pain scores between the 0 and 50th minute, before exercise and after exercise, in method A were 4 (53.3%), and can interpret that after exercise more than half of the participants have less pain than before exercise. More than half of the difference pain scores between the 0th and 50th minute, before exercise and after exercise, in method B were 0 (56.7%), and can interpret that after exercise more than half of the participants have pain equally before exercise.

Calculation of ANOVA (cross over design) of pain score

Period	Individual (case)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Morning	A	B	A	A	B	B	B	A	A	A	B	B	A	B	A
Difference of pain score	5	-1	5	4	1	0	-1	3	4	4	1	1	5	0	4
Afternoon	B	A	B	B	A	A	A	B	B	B	A	A	B	A	B
Difference of pain score	0	4	0	0	4	4	3	-2	-1	0	4	4	0	6	0
Total	5	3	5	4	5	4	2	1	3	4	5	5	5	6	4

Period	Individual (case)																Total
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
Morning	B	A	B	B	A	A	B	A	B	B	B	A	B	A	A	67	
	2	4	0	-1	4	4	0	5	0	-1	0	5	0	5	5		
Afternoon	A	B	A	A	B	B	A	B	A	A	A	B	A	B	B	65	
	4	-1	5	3	0	0	7	1	4	4	7	1	4	0	0		
Total	6	3	5	2	4	4	7	6	4	3	7	6	4	5	5	132	

Total of treatment A = 133

Total of treatment B = (-1)

$$\text{Correction term (CT)} = (132)^2 / 60 = 290.4$$

1. Total SS =

$$\begin{aligned} & (5^2+0^2+(-1)^2+4^2+5^2+0^2+4^2+0^2+1^2+4^2+0^2+4^2+(-1)^2+3^2+3^2+(-2)^2+4^2+ \\ & (-1)^2+4^2+0^2+1^2+4^2+1^2+4^2+5^2+0^2+0^2+6^2+4^2+0^2+2^2+4^2+4^2+(-1)^2+0^2 \\ & +5^2+(-1)^2+3^2+4^2+0^2+4^2+0^2+0^2+7^2+5^2+1^2+0^2+4^2+(-1)^2+4^2+0^2+7^2+ \\ & 5^2+1^2+0^2+4^2+5^2+0^2+5^2+0^2) - \text{CT} = 636 - 290.4 = 345.6 \end{aligned}$$

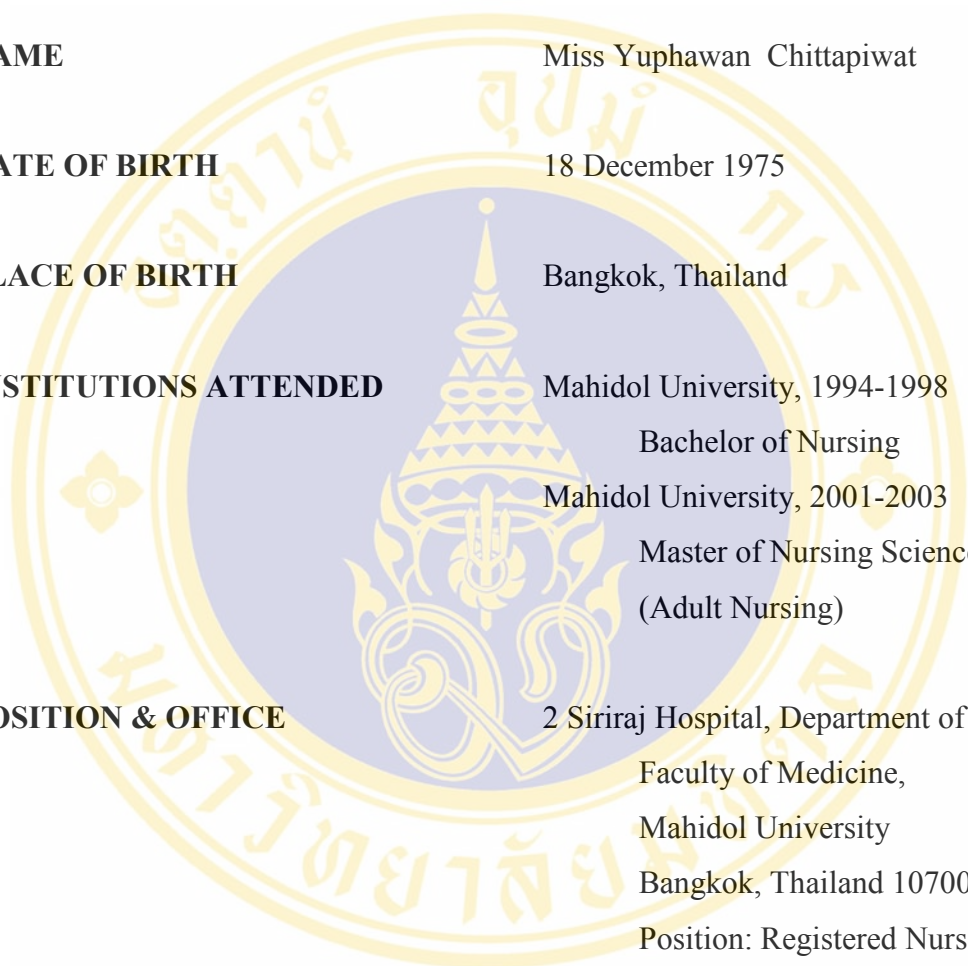
2. Individual SS =

$$\begin{aligned} & 5^2+3^2+5^2+4^2+5^2+4^2+2^2+1^2+3^2+4^2+5^2+5^2+5^2+6^2+4^2+6^2+3^2+5^2+2^2 \\ & +4^2+4^2+7^2+6^2+4^2+3^2+7^2+6^2+4^2+5^2+5^2 / 2 - \text{CT} \\ & = 320 - 290.4 = 29.6 \end{aligned}$$

$$\text{3. Period SS} = \frac{67^2 + 65^2}{30} - \text{CT} = 290.46 - 290.4 = 0.06$$

$$\text{4. Treatment SS} = \frac{133^2 + (-1)^2}{30} - \text{CT} = 589.66 - 290.4 = 299.26$$

$$\text{5. Error SS} = 1 - 2 - 3 - 4 = 345.6 - 29.6 - 0.06 - 299.26 = 16.68$$

BIOGRAPHY

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