

A COMPARATIVE STUDY TO ANALYSE THE EFFECTIVENESS OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION TECHNIQUE IN COMPARISION TO CORE STRENGTHENING EXERCISES IN CHRONIC LOW BACK PAIN WITH RADICULOPATHY

Khushboo Arora, Prof Dr Bhanwar Singh Takhar

University Of Technology Jaipur

List of Abbreviations used

LBP: Low Back Pain.

CLBP: Chronic Low Back Pain

PNF: Proprioceptive Neuromuscular Facilitation

VAS: Visual Analogue Scale.

MODQ: Modified Oswestry Disability Questionnaire

RST: Rhythmic Stabilization Training

COI: Combination of Isotonic exercises

CNLBP: Chronic Non Specific Low Back Pain

ABSTRACT

BACKGROUND: Low back pain is defined as the pain which is localized between 12thrib and inferior gluteal folds with or without leg pain.Despite the large number of pathologic conditions that can give rise to LBP, 85% of cases are without a detected pathoanatomic / radiological abnormality. This population is classified as having “nonspecific” LBP, which often develops into a chronic fluctuating problem with intermittent flares. Several therapeutic interventions are available for its treatment. From among all the interventions, many evidences are available to support Classic trunk exercises and PNF, but the short term treatment effects were not well known. So this study aims to find out a better treatment by comparing effectiveness of these two interventions in reducing pain and disability in CNSLBP patients.

OBJECTIVES: To investigate and compare the effectiveness of Core strengthening exercises and PNF in reducing pain and disability in chronic nonspecific low back pain patients **METHOD:** This was a comparative study, 30 subjects (15 in control group, 15 in experimental group) within the age group of 30 - 50 years were considered for this study by using randomised sampling procedure. Control group

underwent Classic Trunk Exercises and Experimental group underwent PNF techniques for a period of 4 weeks. Both the groups were assessed before and after the intervention to determine the extent of reduction in the level of pain and disability using VAS Scale and MODQ for low back respectively.

RESULTS: The data were analyzed by the Wilcoxon Signed Ranks Test and Mann Whitney U Test. The difference between the two groups were tested using Mann Whitney U Test. Comparison of VAS score for both experimental and control group showed $Z = 2.296$ ($p = 0.022$) and of MODQ score for both the groups showed $Z = 2.092$ ($p = 0.031$) which was significant statistically. These test result showed significant decrease in pain and disability in experimental group than the control group.

CONCLUSION: This study indicates that PNF techniques were effective in the reduction of pain and disability than the Core strengthening exercises in Chronic Low Back Pain patients.

KEY WORDS: Chronic Nonspecific Low Back Pain (CNSLBP), Proprioceptive neuromuscular facilitation, Core strengthening exercises.

INTRODUCTION

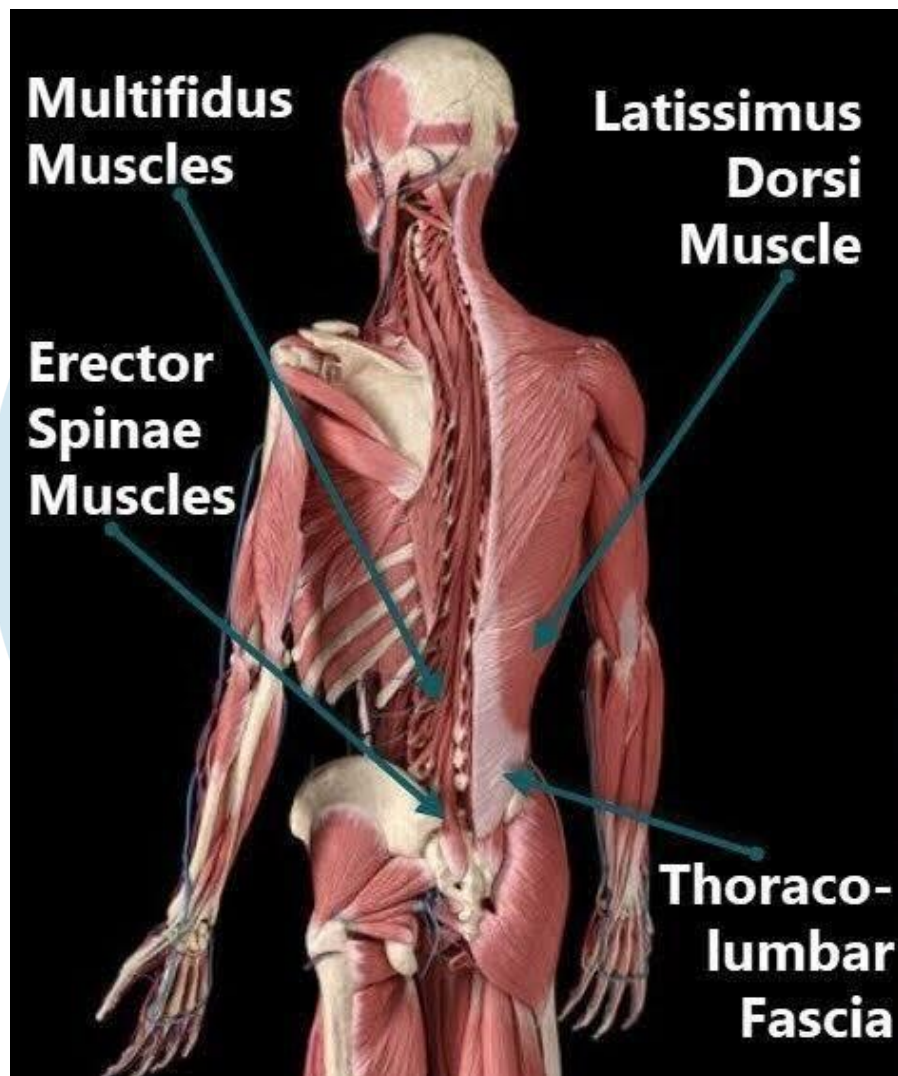
Low back pain is usually defined as pain, aching or discomfort localized in area between costal margin and gluteal folds. Low back pain is one of the most common and costly musculoskeletal pain syndromes of modern society. Low back pain can be divided into acute, sub acute and chronic types in which chronic pain is defined as pain of at least 12 weeks duration.⁽¹³⁾ Nearly all the structures of the back can cause pain most commonly muscles, tendons, ligaments or joints become sources of pain when they are irritated or overloaded. Certain movements are particularly likely to cause problems. Bending over to lift something places tremendous strain on our backs. The combination of bending and twisting can cause damage even if we don't lift anything in that position. Prolonged sitting, even in a good chair, places a great deal of strain on the muscles of the back. Risk factors that have been associated with the work related back pain. Physical work factors include heavy manual work, lifting and twisting, postural stress, whole body vibrations. Psychosocial work factors include monotonous work, lack of personal control, low job satisfaction. Physiologic factors which includes low physical fitness, inadequate trunk strength and health behaviour which includes smoking.⁽³⁶⁾

Frequently the cause of LBP is not known and our understanding of the problem is very limited. In 9 out of 10 instances LBP is transient, it is related to some posture or strain, and recovery can take place in a short time. However, chronic back pain and its associated disabilities represent a significant health problem in which physical signs are often totally lacking.⁽⁴⁴⁾

Pain in low back may originate in one or several of a number of different tissues. Due to the intricate innervations of these tissues and of the low back as a whole localizing such low back pain in a clinical setting to a particular tissue will generally prove difficult. In most back pain patient's, the specific pathophysiology or the pathoanatomic correlation with the pain remains unknown.

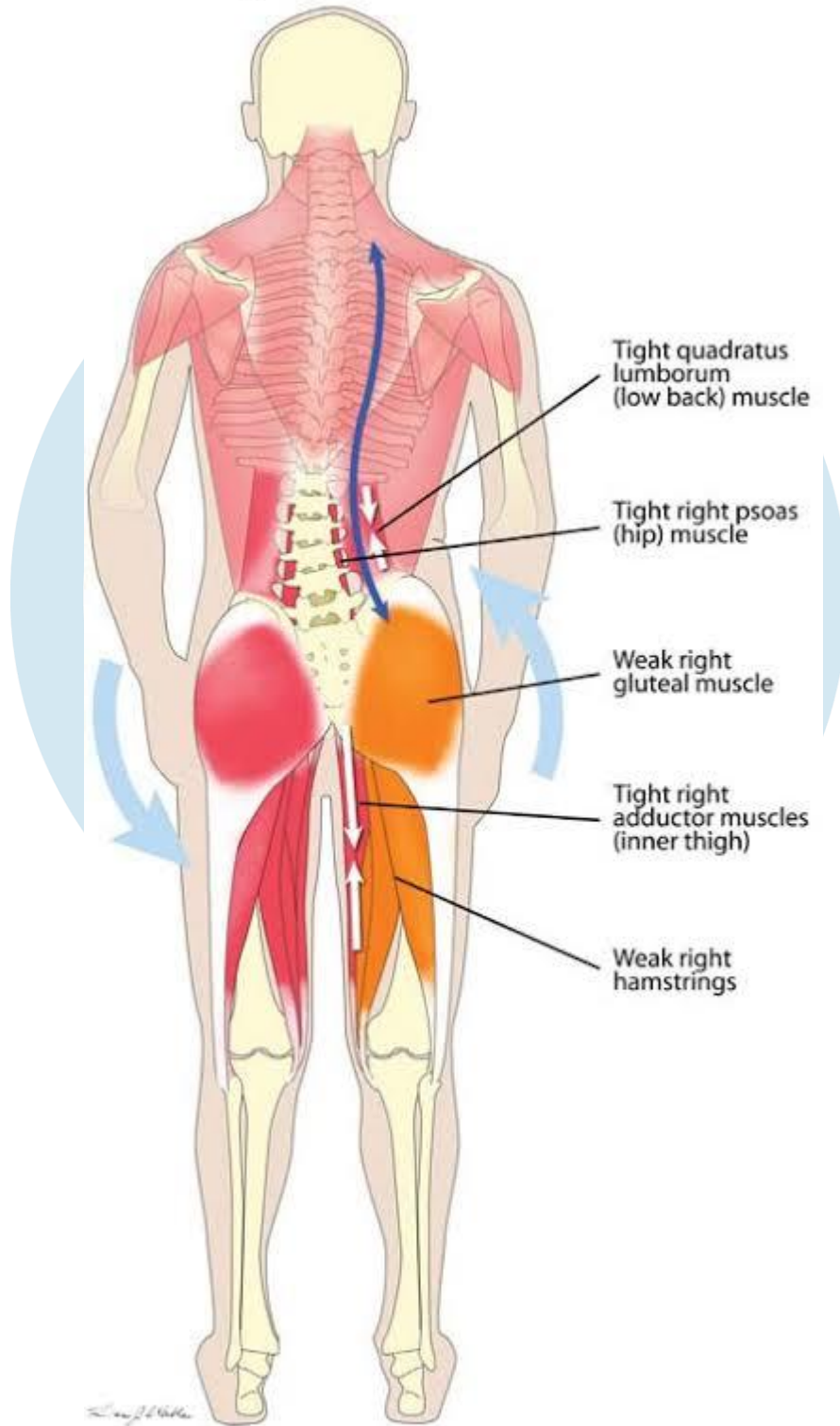
Causes of low back pain are idiopathic origin (85%), fracture (5%), spinal stenosis (4%), spondylolisthesis (2%) and neoplastic diseases, inflammatory arthritis or haematological origins (1%). In majority of patients the common causes for low back pain includes mechanical non specific causes, activity related causes, systemic disorders, neurological syndromes, referred pain and psychogenic aetiology. Nearly all the structures of the back can cause pain most commonly muscles, tendons, ligaments or joints become sources of pain when they are irritated or overloaded. Certain movements are particularly likely to cause problems. Bending over to lift something places tremendous strain on our backs.⁽³⁶⁾

Chronic low back pain can be categorized as specific as specific and non specific. Low back pain leads to pain and disability , physical and psychological dysfunction, impact on quality of life, socioeconomic problems like high cost of health care, work absenteeism and disablement.⁽¹¹⁾

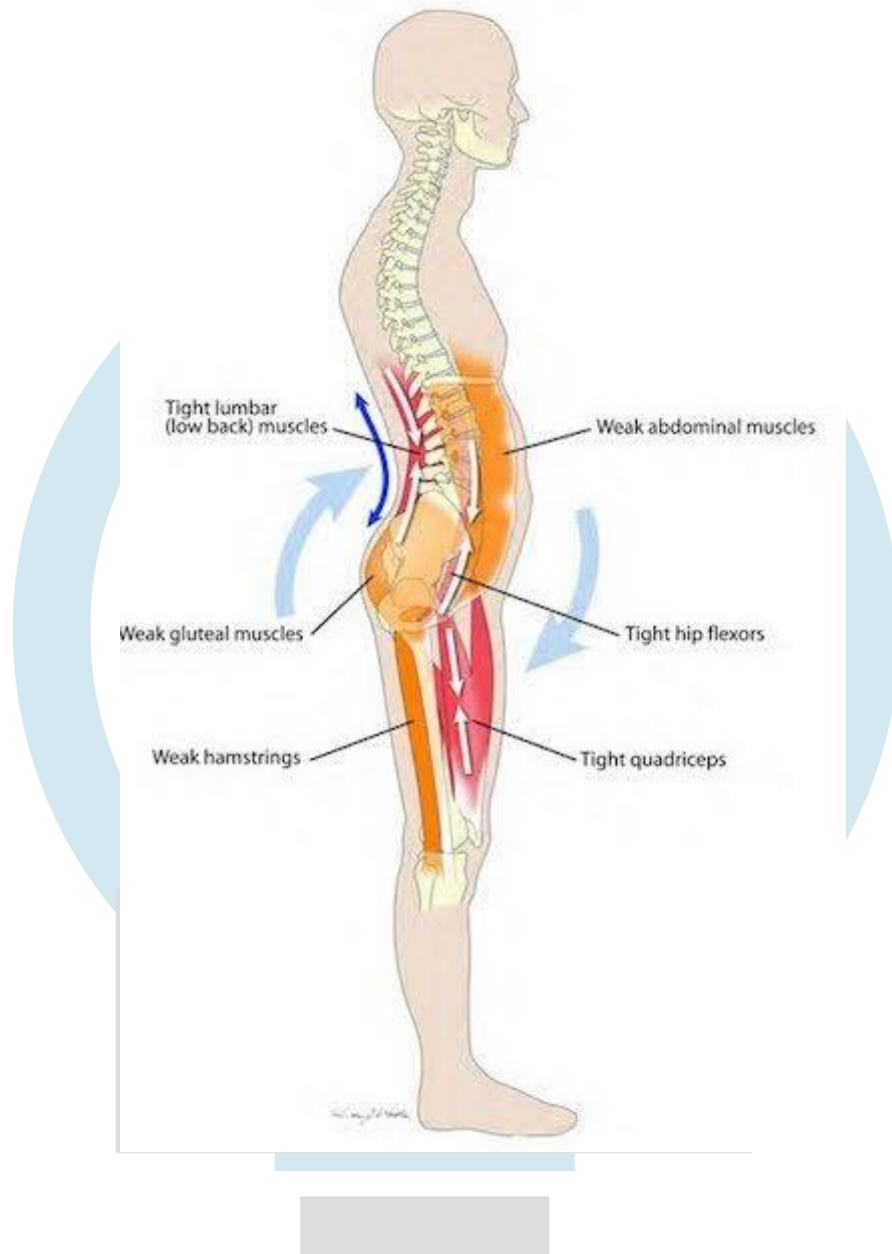


Until we learn to distinguish between improvement that occurs directly as a result of treatment and improvement that results from spontaneous healing or natural recovery, our credibility is at risk. Failure to recognize and understand the natural history and self limiting characteristics of “non-specific” spinal disorders will perpetuate the inability of so many to critically review the treatment methods and results. Physical therapy and exercises includes advice to stay active.⁽⁹⁾

High Right Pelvis



Forward Tipped Pelvis



Physical therapy and exercises includes advice to stay active. Exercise is one of the most frequently used modalities in the rehabilitation of subjects with chronic low back pain (CLBP). The primary goals of physical exercise in the management of CLBP are to gain muscle strength (force-generating capacity), flexibility to restore injured tissues, and to contribute to the ability to sustain normal life activities, such as those at work. Exercise programs for managing CLBP differ with regard to duration, training frequency, intensity, and the mode of exercise. Many different clinical trials using a wide variety of general dynamic fitness programs have produced positive clinical effects. In the chronic phases of low back pain, tailored exercise programs have been shown to have positive effects on physical impairments and limitations. However, the effects of particular types of exercise and the distinct effects of the particular components of exercise length and dosage on performance need to be determined. Some people with CLBP have benefited from long-term programs, whereas a positive short-term effect can be achieved with very intensive functional restoration programs. In our experience, patients very often ask for rapid restoration of functional ability, pain reduction, and enhancement of muscle function for financial reasons. In this respect, the application of short-term intensive exercise programs for CLBP treatment is worthwhile.⁽³⁸⁾

The exercise programs (often called "classic exercise programs" 26) are designed to enhance trunk performance through the training of long trunk muscles (erector spinae and rectus abdominis), whose primary function is to generate movement. However, the researches have shown that in most cases of CLBP, certain muscles of the back (musculi multifidi and transversus abdominis) that stabilize the spine

are reflexively inhibited after injury. These muscles do not spontaneously recover even if patients are pain-free with a return to normal activity levels. Enhancement of function of such muscles may improve trunk stability, muscle strength, endurance, and flexibility. Neurophysiologic studies have linked pain development in the lumbar spine region of the vertebral column with disturbances in the mechanoreceptors and probably with impairment of the superior proprioception centres. Therefore, exercise programs that enhance proprioception may be beneficial for managing CLBP. Proprioceptive neuromuscular facilitation (PNF) exercises are designed to enhance the response of neuromuscular mechanisms by stimulating proprioceptors. The patterns of PNF exercises have a spiral, diagonal direction, and the performance of these patterns is in line with the topographic arrangement of the muscles being used. The performance of movements in PNF patterns may permit muscles to act in ways that are close to the actions and movements found in various sports.⁽²⁸⁾

Exercise is one of the most frequently used modalities in the rehabilitation of subjects with chronic low back pain (CLBP). The primary goals of physical exercise in the management of CLBP are to gain muscle strength (force-generating capacity), flexibility to restore injured tissues, and to contribute to the ability to sustain normal life activities, such as those at work.⁽⁹⁾

Proprioception (sense of body positioning in space) is an important bodily neuromuscular sense. It falls under our "sixth sense", more commonly known as somatosensation. The term somatosensation (or somatosensory senses) is an all encompassing term which includes the sub-categories of mechanoreception (vibration, pressure, discriminatory touch), thermoreception (temperature), nociception (pain), equilibrioception (balance) and proprioception (sense of positioning and movement).^[1] The feedback from all these different sensory components arise from our peripheral nervous system (PNS), and feed information to our central nervous system (CNS), both at the level of the spinal cord (reflexive) and sent to the cerebral cortex for higher processing.^[2]

Proprioception itself can be understood as including various sub-modalities:

Joint Position Sense: Proprioception is our sense of joint / limb positioning. It is often measured through joint position sense - active joint position sense (AJPS) and passive joint position sense (PJPS). Joint position sense determines the ability of a person to perceive a presented joint angle and then, after the limb has been moved, to actively or passively reproduces the same joint angle^[3] (Clinically measured as a joint matching task).

Kinaesthesia: Kinaesthesia (kinaesthesia) is the awareness of motion of the human body (motion sense).^[4] Sense of movement refers to the ability to appreciate joint movement, including the duration, direction, amplitude, speed, acceleration and timing of movements.^[3]

Sense of Force: Sense of Force (SoF) is also known as sense of effort / heaviness / tension or the force matching sense. It is the ability to reproduce (or match) a desired level of force one or more times. Sense of force is thought to stem from the afferent feedback of the Golgi Tendon Organs (GTOs) embedded within our tendons, the muscle spindles within our muscles and proprioceptions within our skin.^[5]

Sense of Change in Velocity (SoV): SoV is our ability to detect vibration, derived from oscillating objects placed against the skin.^[6] It is believed to travel through the same type of large afferent nerve fibers ($A\alpha\beta$) as proprioception.

The neurological basis of proprioception comes primarily from sensory receptors (mechanoreceptors and proprioceptors) located in your skin, joints, and muscles (muscle spindles with a smaller component from tendon organ afferents, cutaneous receptors and minimal input from joint receptors).

These muscle afferents receptors allow for the identification of limb position and movement via neural signalling of a change in muscle, skin or joint stretch

Proprioceptive exercises are exercises which challenge and develop proprioceptive receptors. Proprioception helps to stabilise a joint during static and dynamic functional tasks. Decreased proprioception can lead to an increased risk of injury. There are many benefits of receiving a proprioceptive exercise programme

Improved joint stability

Reduced risk of injury

Helps to improve your confidence in your joint

Improved mobility

Reduced muscle compensation – muscles may become overactive if proprioception is decreased as they will compensation to stabilise the joint.

A proprioceptive exercise programme will be a graduated rehabilitation programme where the exercises become more challenging as the proprioception improves. Some of the principles and exercises which are included in proprioceptive exercise programmes include:

- Exercises within the joint range of movement just as instability is felt
- Exercises to improve muscle reaction time
- Balance exercises
- Strengthening exercises
- Functional dynamic exercises just into the range where instability is felt
- Self-management strategies close to end stage rehabilitation

The states of exercise therapy in the case of LBP with new methods such as Proprioceptive Neuromuscular Facilitation (PNF) techniques Combination of Isotonic (COI) will be more effective because it is an exercise designed to improve neuromuscular response mechanisms by stimulating proprioceptors. The exercise pattern of PNF itself has a spiral pattern, and a diagonal direction that is synergistic with the central system of muscle control, as well as the performance of the exercise patterns and the adjustment is in line with the used muscle fibers. The performance of PNF patterns movement itself can stimulate the muscles to work in a way to optimize muscle function that is used in performing a movement.

Combination of Isotonic (COI) is a form of exercise that uses the PNF techniques on the isotonic contraction with movement aimed at the agonist, which is to control / control a coordinated muscle contractions. This technique combines several types of muscle contraction such as concentric, eccentric, and maintained. In this exercise, the agonist movement patterns is not accompanied by a phase of reflex movements that can make a smoother movement, controlled, and coordinated so as to get a functional movement. The mechanism of COI for reducing pain is a response to muscle through stimulation of neural mechanisms that may result the proprioceptor facilitation or inhibition [11]. With the stress and overload received by isotonic muscle, it will result in the additional strain on the tendon; hence, the muscle spindle will receive stronger stimulus. This causes muscle stimulation to receive spindle that reaches the threshold, where the stronger the muscle is stretched, it will make contractions stronger. When the voltage muscles become stronger, the contractions suddenly stop and relax the muscle, and become involve in muscle relaxation, which occurs due to an active Golgi tendon organ. This is in

accordance with the principle of reciprocal Innervatie where reflex muscle contraction agonist activity will make relax antagonist, the relaxation effects can also be called reflex inhibition or autogenic inhibitions.

In the chronic phases of low back pain, tailored exercise programs have been shown to have positive effects on physical impairments and limitations.

Neurophysiologic studies have linked pain development in the lumbar spine region of the vertebral column with disturbances in the mechanoreceptors and probably with impairment of the superior proprioception centres. Therefore, exercise programs that enhance proprioception may be beneficial for managing CLBP. Proprioceptive neuromuscular facilitation (PNF) exercises are designed to enhance the response of neuromuscular mechanisms by stimulating proprioceptors. The patterns of PNF exercises have a spiral, diagonal direction, and the performance of these patterns is in line with the topographic arrangement of the muscles being used. The performance of movements in PNF patterns may permit muscles to act in ways that are close to the actions and movements found in various sports. Therefore, these exercises may be better suited for performance enhancement than are conventional single plane or single-direction weight-training programs. Furthermore, PNF techniques often have been used to improve the range of motion of a joint. There are different forms of PNF exercises. Two commonly used forms are rhythmic stabilization training (RST) and combination of isotonic exercises (COI). The RST technique uses isometric contraction of antagonistic patterns and results in co-contraction of the antagonists if the isometric contraction is not broken by the physical therapist. It is used mainly to manage conditions in which weakness is a primary factor and in which stabilization provides stimulation of the agonistic pattern.⁽¹⁹⁾

The exercise programs are designed to enhance trunk performance through the training of long trunk muscles (erector spinae and rectus abdominis), whose primary function is to generate movement. However, the researches have shown that in most cases of CLBP, certain muscles of the back (musculi multifidi and transversus abdominis) that stabilize the spine are reflexively inhibited after injury. These muscles do not spontaneously recover even if patients are pain-free with a return to normal activity levels. Enhancement of function of such muscles may improve trunk stability, muscle strength, endurance, and flexibility.

The core muscles are involved in maintaining spinal and pelvic stability and can be divided into two groups, according to function. The first group of muscles is the inner or deep core muscles. This group of muscles is also known as the local stabilizing muscles, it act as an anticipatory way and that these muscles are activated and fire before the global muscles are activated. The inner core muscles include – pelvic floor, transverses abdominis, internal obliques, multifidus, diaphragm. The outer core muscles or the global muscles are also refer to as the movers a, that are – rectus abdominis, external obliques, erector spinae, quadrates lumborum, hip muscle groups. Core strengthening is progressed by adding movement of arms and legs. Kibler defined core stability as “ The ability to control the position and motion of the trunk over the pelvis and legs to allow optimum production, transfer, control of force and motion to the terminal segment in integrated kinetic chain activities.”⁽²¹⁾

The influence of different types of programs on trunk muscle strength, endurance, and range of motion is unclear. If the aim of exercise programs for CLBP treatment is to improve trunk stabilization and flexibility, then examination of the effectiveness of PNF exercises for this purpose may yield useful results. Furthermore, studies on lower-extremity muscles have identified different muscle responses to concentric work and eccentric work, indicating that muscle adaptive responses vary in accordance with the specific training regimen used.

People with CLBP often demonstrate reduced muscle strength and endurance levels and altered flexibility accompanied by low-intensity pain levels and reduced functional ability. Therefore, the

effectiveness of any exercise program could be tested against the occurrence of both these symptoms. So this study aims to find out the effectiveness of PNF techniques and core strengthening exercise on pain and disability in CNSLBP patients.

NEED FOR THE STUDY

LBP causes major medical and economical problems in the industrialized countries, which is demonstrated by the high direct and indirect costs and the large variety of therapeutic interventions available for its treatment. The primary goals of physical exercise in the management of CLBP are to gain muscle strength, flexibility, and endurance, to restore injured tissues, and to contribute to the ability to sustain normal life activities. Patients very often ask for rapid restoration of functional ability, pain reduction, and enhancement of muscle function for financial reasons. As new training methods (PNF) are emerging, a better understanding of the effects of such exercises on patient's status is currently considered an important area of research. In this respect, the application of short term intensive exercise programs for CLBP treatment is worthwhile. So, the examination of the effectiveness of PNF exercises for this purpose may yield useful results. Hence this study is concentrating on to check the better effectiveness of the two modes of exercise program i.e. Core strengthening exercises versus Proprioceptive Neuromuscular Facilitation exercises in reducing pain and disability in CNSLBP (chronic nonspecific low back pain patients) patients.⁽²¹⁾

Proprioceptive neuromuscular facilitation (PNF) exercises are designed to enhance the response of neuromuscular mechanisms by stimulating proprioceptors. The patterns of PNF exercises have a spiral, diagonal direction, and the performance of these patterns is in line with the topographic arrangement of the muscles being used. The performance of movements in PNF patterns may permit muscles to act in ways that are close to the actions and movements found in various sports. Therefore, these exercises may be better suited for performance enhancement than are conventional single plane or single-direction weight-training programs. Furthermore, PNF techniques often have been used to improve the range of motion of a joint. There are different forms of PNF exercises. Two commonly used forms are rhythmic stabilization training (RST) and combination of isotonic exercises (COI) which is stated in **Strength Training Exercise**. The RST technique uses isometric contraction of antagonistic patterns and results in co-contraction of the antagonists if the isometric contraction is not broken by the physical therapist. It is used mainly to manage conditions in which weakness is a primary factor and in which stabilization provides stimulation of the agonistic pattern. The COI technique is another form of PNF exercise used to evaluate and develop the ability to perform controlled purposeful movements. It involves the performance of alternating concentric, eccentric, and isometric contractions and is used to treat deficiencies in strength and range of motion. To date, information on the effectiveness of dynamic and combined dynamic static contraction exercises for trunk muscle stabilization and strength was not sufficient. Moreover, the influence of different types of programs on trunk muscle strength, endurance, and range of motion is unclear. If the aim of exercise programs for CLBP treatment is to improve trunk stabilization and flexibility, then examination of the effectiveness of PNF exercises for this purpose may yield useful results. Furthermore, studies on lower-extremity muscles have identified different muscle responses to concentric work and eccentric work, indicating that muscle adaptive responses vary in accordance with the specific training regimen used. Whether these differences apply to trunk musculature and PNF programs is not clear. The purpose of this study was to examine the effects of 2 commonly used modified PNF techniques, RST and COI, on reducing pain and disability. People with CLBP often demonstrate reduced muscle strength and endurance levels and altered flexibility accompanied by low-intensity pain levels and reduced functional ability. Therefore, the effectiveness of any exercise program could be tested against the occurrence of both these symptoms.

This study is nearly untouched field so the work up on this topic is much needed and the study aims to find out the effectiveness of PNF techniques and Strengthening exercise on pain and disability in CNSLBP patients.

AIM OF THE STUDY –

Aim of the study is to evaluate effectiveness of strengthening exercise in comparison to neuromuscular facilitation for reducing pain and disability in chronic low back pain patients.

OBJECTIVES OF THE STUDY

- To find the effectiveness of Strengthening exercise for reducing pain and disability in chronic low back pain patients.
- To find the effectiveness of Proprioceptive Neuromuscular Facilitation for reducing pain and disability in chronic low back pain patients.
- To compare the effectiveness of Strengthening exercise versus Proprioceptive Neuromuscular Facilitation for reducing pain and disability in chronic low back pain patients.

HYPOTHESIS

ALTERNATIVE HYPOTHESIS:

There is a significant difference between Strengthening exercise and Proprioceptive Neuromuscular Facilitation technique in reducing pain and disability in chronic low back pain patients.

NULL HYPOTHESIS:

There is no significant difference between Strengthening exercise and Proprioceptive Neuromuscular Facilitation technique in reducing pain and disability in chronic low back pain patients.

REVIEW OF LITERATURE

- **Van Tulder M, et al (2013)** in the study “Effectiveness of special exercises in comparison to conventional treatment in low back pain.” concluded that exercise therapy is more effective than usual care by general practitioners, and that exercise therapy and conventional physiotherapy (consisting of a combination of hot packs, massage, traction, mobilization, shortwave diathermy, ultrasound, stretching, flexibility and coordination exercises, electrotherapy) are equally effective

for the treatment of CLBP patients. It remains unclear whether any specific type of exercises (flexion, extension, or strengthening exercises) is more effective than another.⁽¹⁶⁾

- **Kofotolis N, et al (2013)** in study “The influence of exercise on musculoskeletal disorders of the lumbar spine.” concluded that exercise is one of the most frequently used modalities in the rehabilitation of subjects with chronic low back pain (CLBP).⁽¹⁸⁾
- **Van Tulder M, et al (2014)** concluded that exercise therapy is more effective than usual care by general practitioners, and that exercise therapy and conventional physiotherapy (consisting of a combination of hot packs, massage, traction, mobilization, shortwave diathermy, ultrasound, stretching, flexibility and coordination exercises, electrotherapy) are equally effective for the treatment of CLBP patients. It remains unclear whether any specific type of exercises (flexion, extension, or strengthening exercises) is more effective than another.⁽⁴³⁾
- **Joong-San Wang , et al (2014)** The immediate effect of PNF pattern on muscle tone and muscle stiffness in chronic low back pain patient. Study concluded that both the affected and non affected muscle tone is decreased with proprioceptive neuromuscular facilitation.⁽⁸⁾
- **Nachemson AL, et al (2014)** “Effectiveness of strengthening exercise in comparison to stretching exercise in non specific LBP for patients with chronic non-specific LBP”, recommended maintenance or progressive resumption of activities of daily living, and back programs combining strength training, stretching and fitness, as an effective treatment for the reduction of disability and improvement of physical function.⁽¹⁴⁾
- **Pattanasin Areudomwong, et al (2014)** “Comparison of core stabilization exercise and proprioceptive neuromuscular facilitation training on pain-related and neuromuscular response outcomes for chronic low back pain” concluded that PNF provide long term effect in comparison to core stabilization exercise in CLBP patients.⁽²³⁾
- **Sunita Koutarapu, et al (2015)** Proprioceptive neuromuscular facilitation exercises versus lumbar stabilization exercises for chronic low back pain patients by stated that PNF exercise is more effective than lumbar stabilization exercises for chronic low back pain.⁽²⁴⁾
- **Kerstin Konietzny, Omar Chehadi, Irmgard Streitlein, Böhme, Herbert Rusche, Roland Willburger, Monika Ilona Hasenbring (2015)** Mild Depression in Low Back Pain: the Interaction of Thought Suppression and Stress Plays a Role, Especially in Female Patients. *IMedicine*. Findings support the hypothesis that thought suppression (TS) heightens depressive mood under conditions of high cognitive load especially in female patients with subacute low back pain (SLBP) indicating a special vulnerability for depressive mood in women with SLBP.
- **Vitsarut Buttogat, et al (2015)** PNF enhances the deep trunk muscle activity than Core stabilization exercise in randomized controlled trial concluded PNF techniques helps to decrease the pain threshold in low back patient. ⁽³⁾
- **Vrabas IS, et al (2015)** PNF exercises may be better suited for performance enhancement than is conventional single-plane or single-direction weight-training programs on chronic low back pain patients. ⁽⁷⁾
- **Nachemson AL, et al (2015)** for patients with chronic non-specific LBP, recommended maintenance or progressive resumption of activities of daily living, and back programs combining

strength training, stretching and fitness, as an effective treatment for the reduction of disability and improvement of physical function.(44)

- **Mayer TG, et al (2016)** concluded that in the chronic phases of low back pain, tailored exercise programs have been shown to have positive effects on physical impairments and limitations.(20)
- **Paul W. Marshall, et al (2016)** concluded that supervised exercise rehabilitation leads to more rapid improvements in self-rated disability, which were associated with greater improvement in the low back Flexion Relaxation response.(45)
- **Koumantakis, et al (2016)** found that an 8-week classic trunk exercise program reduced disability in the short term to a greater extent than did a stabilization enhanced exercise approach in patients with recurrent nonspecific low back pain. They suggested that general exercise programs provide an additional benefit in reducing pain symptoms and enhancing functional ability in patients with low back pain.(26)
- **Malkia E, et al (2016)** stated that the primary goals of physical exercise in the management of CLBP are to gain muscle strength, flexibility, and endurance, to restore injured tissues, and to contribute to the ability to sustain normal life activities ,such as those at work.(19)
- **Melzack R, et al (2017)** concluded that some people with CLBP have benefited from long-term programs, whereas a positive short-term effect can be achieved with very intensive functional restoration programs.(25)
- **Kofotolis N, et al (2017)** concluded that Static and dynamic PNF programs are appropriate for improving short-term trunk muscle endurance and trunk mobility in people with CLBP and thereby reducing pain and disability Yamashita T, et al (1990) stated that Neurophysiologic studies have linked pain development in the lumbar spine region of the vertebral column with disturbances in the mechanoreceptors and probably with impairment of the superior proprioception centres. Therefore, exercise programs that enhance proprioception may be beneficial for managing CLBP.(24)
- **Frymoyer J, et al (2017)** suggested that muscle is a potential source of low back pain.(47)
- **Matthew O. B, et al (2017)** “The influence of exercise on musculoskeletal disorders of the lumbar spine.” stated that the Visual Analogue Scale (VAS) is a widely used instrument, reliable and valid for clinical rating of low back pain.(5)
- **Seidel H, et al (2017)** in their study on chronic low back pain patients, proved that failure of muscles to protect passive structures from excessive loading results in damage to these pain sensitive structures and produces pain.(48)
- **Wilder DG, et al (2017)** proved that muscle endurance is lower for people with low back pain than for individuals without low back pain. Their findings suggest that poor trunk extensor endurance is associated with prolonged or recurrent back pain. Enhancing muscle endurance, therefore, may help to reduce low back pain. (49)
- **Bentzen L, et al (2018)** recommend trunk muscle endurance training to elevate fatigue threshold and improve performance, thus reducing disability in chronic low back pain patients.(50)
- **Manniche, et al (2018)** concluded with the improvements in functional ability (as registered by the Oswestry Index) to be seen as a direct result of flexibility and endurance improvements,

thereby providing further support for the effectiveness of PNF exercises for CLBP treatment. They also demonstrated that among patients with low back pain, intensive training had to continue for more than 2 months to achieve significant pain reduction, whereas a daily 3 week intensive treatment program was found to be equally efficient.(51)

- **Voss D, et al (2018)** concluded in their study on chronic low back pain, that Proprioceptive neuromuscular facilitation (PNF) exercises are designed to enhance the response of neuromuscular mechanisms by stimulating proprioceptors.(27)
- **Vrabas IS, et al (2018)** concluded that PNF exercises may be better suited for performance enhancement than is conventional single-plane or single-direction weight-training programs on chronic low back pain patients.(29)
- **Kalogeropoulou E, et al (2019)** stated that PNF techniques have often been used to improve the endurance as well as performance in a vertical jump. concluded that PNF provide long term effect in comparison to core stabilization exercise in CLBP patients. (28)
- **Boonstra, et al (2019)** in his study concluded that the reliability of the Visual Analogue Scale (VAS) for disability is moderate to good and has strong correlation for pain.(52)
- **Matthew O. B, et al (2019)** stated that the Visual Analogue Scale (VAS) is a widely used instrument, reliable and valid for clinical rating of low back pain.(53)
- **Irrgang JJ, et al (2020)** in their study proved that MODQ has superior measurement properties compared with the QUE in measuring LBP.(54)
- **Megan Davidson, et al (2020)** stated that one of the most reliable disability scales for people with LBP is the Oswestry Low Back Pain Disability Questionnaire.(55)
- **Robert MD, et al (2021)** in their study proved that MODQ has good responsiveness for measuring pain in patients with CNSLBP.
- **Kalogeropoulou E, et al (2021)** PNF techniques have often been used to improve the endurance as well as performance in a vertical jump concluded that PNF provide long term effect in comparison to core stabilization exercise in CLBP patients..¹³⁾
- **Boonstra, et al (2021)** The reliability of the Visual Analogue Scale (VAS) for disability is moderate to good and has strong correlation for pain. stated that the Visual Analogue Scale (VAS) is a widely used instrument, reliable and valid for clinical rating of low back pain. ⁽¹⁹⁾
- **Irrgang JJ, et al.(2021)** Study proved that MODQ has superior measurement properties compared with the QUE in measuring LBP. Study concluded that assessment is reliable on CLBP. ⁽¹⁰⁾
- **Megan Davidson, et al.(2022)** Modified Oswestry Low Back Pain Disability Questionnaire Stated that one of the most reliable disability scale. Study shows scale has high reliability and validity on CLBP. ⁽²⁰⁾
- **Dixon (2022)** concluded that in 9 out of 10 instances, LBP is transient, it is related to some posture or strain, and recovery can take place in a short time.⁽²²⁾

- **Kepes, et al.(2022)** Chronic low back pain and its associated disabilities represent a significant health problem. Study shows the effect of chronic low back pain can cause to disability. They also demonstrated that among patients with low back pain, intensive training had to continue for more than 2months to achieve significant pain reduction, whereas a daily 3 week intensive treatment program was found to be equally efficient. ⁽⁶⁾
- **Paul W. Marshall, et al.(2022)** Exercise rehabilitation leads to more rapid improvements in self-rated disability, which were associated with greater improvement in the low back Flexion Relaxation response. ⁽²¹⁾

METHODOLOGY

Study Design : Comparative study design

Sample Design : Random Sampling

Sample size : 40

Duration of study : 16 weeks

Study Center: Patients of Physiotherapy OPD were included in this study. Consent form was obtained from the Ethical Clearance Committee.

INCLUSION CRITERIA

- Back pain which exists for more than 12 weeks
- Complaint of pain increased during and after activity, during and after sitting and during stair climbing
- Age group: 31-50 years
- Both males and females
- Radiculopathy

EXCLUSION CRITERIA

- Sever postural abnormality
- Any neuromuscular disorders
- Spinal fractures
- Contraindications to exercise such as uncontrolled Hypertension, cardiovascular diseases, Peripheral vascular diseases and Respiratory disorders
- Any previous history of spinal surgery
- Any signs and symptoms of spine instability

OUTCOME TOOL USED IN THIS STUDY

Visual Analogue Scale

Modified Oswestry Low Back Pain Disability Questionnaire

PROCEDURE:

Well defined 40 patients, who were undergoing regular uniform physiotherapy modalities, were selected by using simple randomized sampling technique after fulfilling the criteria from the population and then divided in two groups. Each group was consisting of 20 patients and informed consent was obtained. The informed consent was given by ethical committee. Patients were eligible for the study if they had a history of back pain which existed for more than 12 weeks specific nature, defined as back pain complaints occurring with identifiable specific anatomical or neuro physiological positive factors.

To establish these, all patients included in the study had a prior clinical examination by their physician.

Group 1 was given Proprioceptive Neuromuscular Facilitation techniques (rhythmic stabilisation training and combined isotonic exercise) for trunk 3 sets of 15 repetitions of each set, for 45 min/day, 4 days/week for the period of 4 weeks, with 2 minutes rest between each set. Progression was made by increasing the repetitions.

Group 2 was received a Core strengthening exercise program, which included exercises activating the extensor (paraspinal) and flexor (abdominals) muscle groups was administrated for 45 min/day, 4 days/week for the period of 4 weeks, with 2 minute rest in between the repetition of each set. Progression was made by increasing the repetitions.

The intensity of low back pain was assessed by using Visual Analogue Scale (VAS) which is a responsive pain scale that yields reliable and valid data.

The degree of functional impairment was assessed by means of the Modified Oswestry Low Back Pain Disability Questionnaire (MODQ) which is having clinically acceptable reliability validity and responsiveness. It is a 10-item scale; each item has 6 ranked detractors, scored from 0 to 5, yielding a maximum score of 50. The first section is a pain-related scale, and the other sections deal with various daily activities that are relevant to low back capability. Before and after the 4 week interventions for both the group's pre and post test pain intensity and disability level score was obtained and compared statistically.

RHYTHMIC STABILIZATION – STARTING POSITION

RHYTHMIC STABILIZATION – MID POSITION

RHYTHMIC STABILIZATION – ENDING POSITION

COMBINATION OF ISOTONICS - STARTING POSITION

COMBINATION OF ISOTONICS - MID POSITION

COMBINATION OF ISOTONICS - ENDING POSITION

SPINAL EXTENSOR TRAINING

SPINAL FLEXOR TRAINING

RESULTS

The data were analyzed statistically by the by Wilcoxon Signed Ranks Test and Mann Whitney U Test for the intra group and inter group comparison of experimental and control group.

WILCOXON SIGNED RANKS TEST

$$Z = (W - \mu_w) \pm .5/\sigma_w$$

W = sum of signed ranks

$$\mu_w = 0$$

$$\sigma_w = \sqrt{N(N+1)(2N+1)/6}$$

σ_w = standard deviation of sampling distribution of w

N = sample size

Mann-Whitney U Test

$$U_1 = (n_1)(n_2) + n_1(n_1 + 1) - \Sigma R_1/2$$

$$U_2 = (n_2)(n_1) + n_2(n_2 + 1) - \Sigma R_2/2$$

$$U_1 = R_1 - n_1(n_1+1)/2$$

Where n_1 is the two sample size for sample 1, and R_1 is the sum of ranks in sample 1

$$U_2 = R_2 - n_2(n_2+1)/2$$

Where n_2 is the sample size for sample 2, & R_2 is the sum of the ranks in sample 2

The sum of the two values is then given by

$$U_1 + U_2 = R_1 - n_1(n_1+1) + R_2 - n_2(n_2+1)/2$$

Where,

n_1 = sample size for control group

n_2 = sample size for experimental group

R_1 = sum of ranks in control group

R_2 = sum of ranks in experimental group

U = Mann- Whitney U test value.

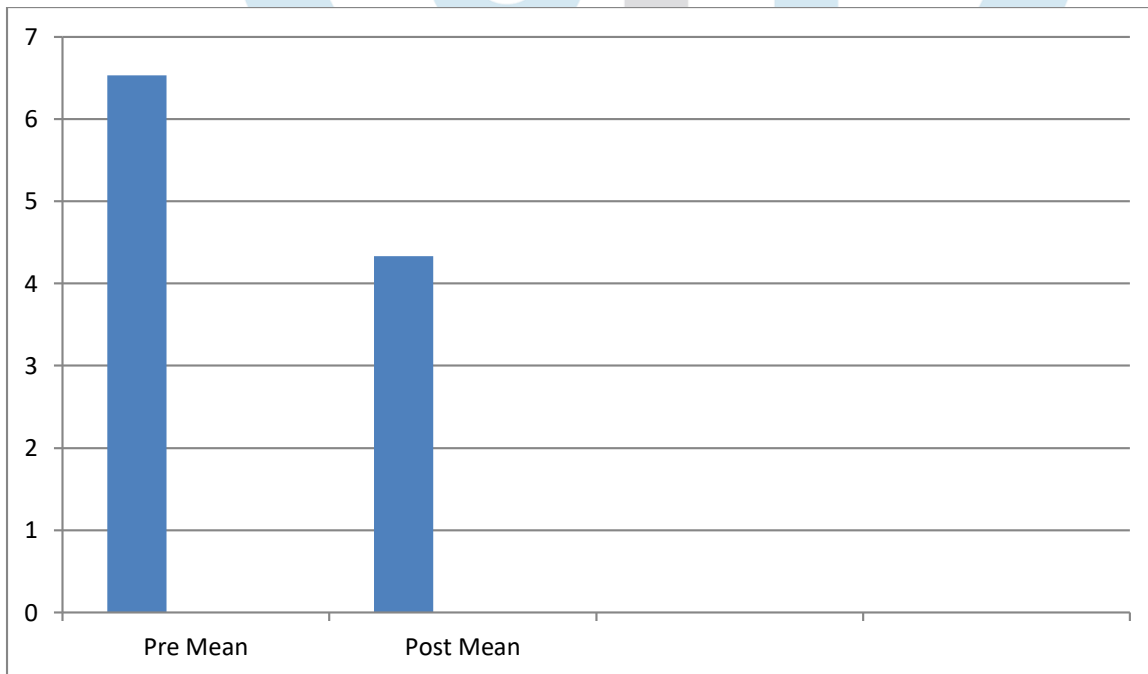
TABLE - 1

INTRA GROUP ANALYSIS OF PRE AND POST TEST PAIN LEVEL BY USING VAS SCALE FOR EXPERIMENTAL GROUP

VAS	N	PRE MEAN	POST MEAN	MEAN DIFF.	WSR Z	P VALUE
EXPERIMENTAL GROUP	20	6.53	4.33	2.2000	3.457	0.001 HS

{N = number of subjects, WSR = Wilcoxon Signed Ranks, p = probability, HS = highly significant}

Table 1 shows Intra group comparison of pain level in experimental group from day 1 to the end of 4 weeks shows the pre mean value of 6.53, post mean value of 4.33 with a mean difference of 2.2000. Z value was 3.457 and p value of 0.001 which is highly significant.



Graph -1

The values tabulated in table no. 1 shows Intra group comparison of pain level in experimental group from day 1 to the end of 4 weeks shows the pre mean value of 6.53, post mean value of 4.33 with a mean difference of 2.2000. Z value was 3.457 and p value of 0.001 which is highly significant.

It shows the intensity of pain in low back pain with radiculopathy. The subjects in the age group of 31-50 years in experimental group with irrespective of gender shows strong relationship of intensity of pain in low back pain with radiculopathy which is significant at the 0.05 and 0.01 level.

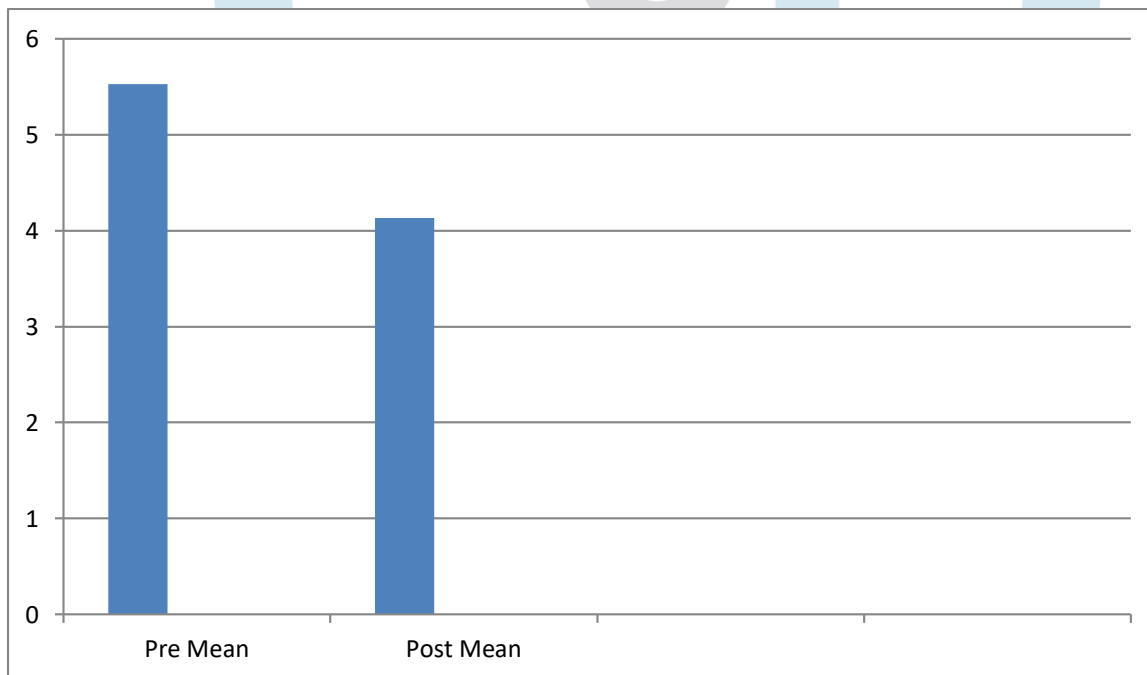
TABLE - 2

INTRA GROUP ANALYSIS OF PRE AND POST TEST PAIN LEVEL BY USING VAS SCALE FOR CONTROL GROUP

VAS	N	PRE MEAN	POST MEAN	MEAN DIFF.	WSR VALUE	Z	P VALUE
CONTROL GROUP	20	5.53	4.13	1.4000	3.535		0.000 HS

{N = number of subjects, WSR = Wilcoxon Signed Ranks, p = probability, HS = highly significant}

Table 2 shows Intra group comparison of pain level in control group on day 1 and at the end of 4 weeks shows the pre mean value of 5.53, post mean value of 4.13 with mean difference of 1.4000.Z value was 3.535 and p value of 0.000 which is highly significant.



Graph - 2

The values tabulated in Table 2 shows Intra group comparison of pain level in control group on day 1 and at the end of 4 weeks shows the pre mean value of 5.53, post mean value of 4.13 with mean difference of 1.4000.Z value was 3.535 and p value of 0.000 which is highly significant.

It shows the intensity of pain in low back pain with radiculopathy. The subjects in the age group of 31-50 years in control group with irrespective of gender shows strong relationship of intensity of pain in low back pain with radiculopathy which is significant at the 0.05 and 0.01 level.

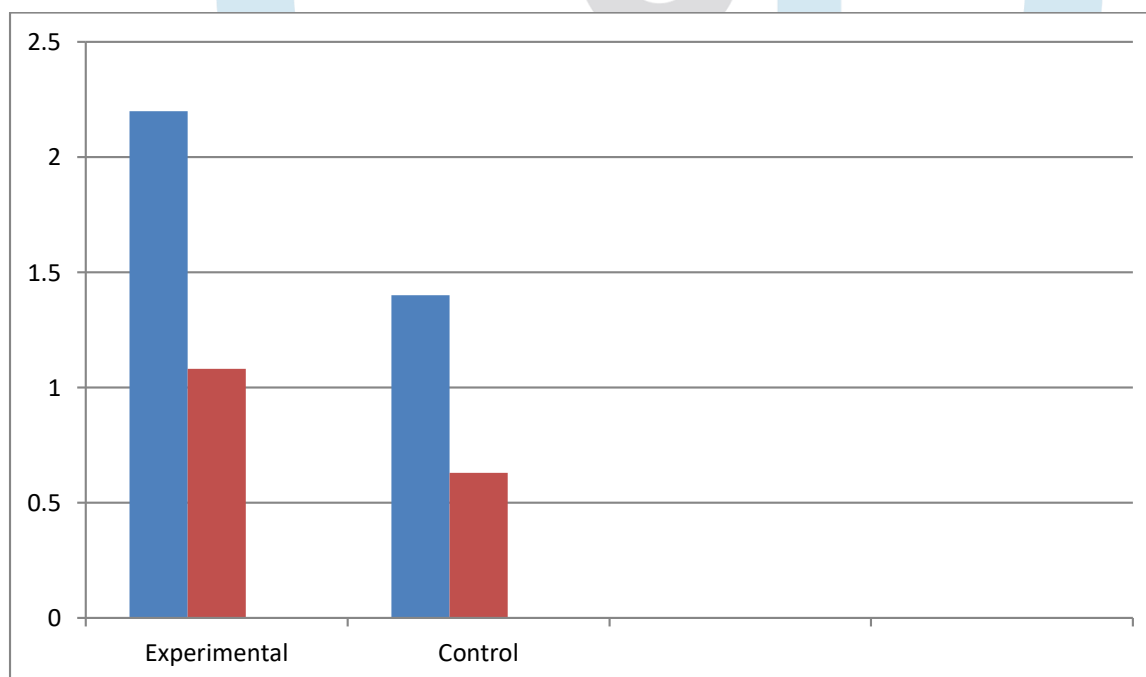
TABLE - 3

INTER GROUP ANALYSIS OF PAIN LEVEL OF EXPERIMENTAL AND CONTROL GROUP BY USING VAS SCALE.

	GROUP	N	MEAN DIFF.	SD	MWUT Z VALUE	P VALUE
CHANGE IN VAS	EXPERIMENTAL	20	2.2000	1.08233	2.296	0.022 Sig
	CONTROL	20	1.4000	0.63246		

{p = probability, sig = significant, Z = Mann Whitney U Test, N = number of subjects}

In VAS Scale, Experimental group showed a mean of 2.2000 and standard deviation 1.08233. Control group showed a mean of 1.4000 and standard deviation 0.63246. The difference between the two groups were tested using Mann Whitney U Test with a Z = 2.296 (p = 0.022) which was significant statistically.



Graph - 3

The values tabulated in table 3 In VAS Scale, Experimental group showed a mean of 2.2000 and standard deviation 1.08233. Control group showed a mean of 1.4000 and standard deviation 0.63246. The difference between the two groups were tested using Mann Whitney U Test with a Z = 2.296 (p = 0.022) which was significant statistically.

It shows the intensity of pain in low back pain. The subjects in the age group of 31- 50 years in control group and experimental group with irrespective of gender shows strong relationship of intensity of pain in low back pain which is significant at the 0.05 and 0.01 level.

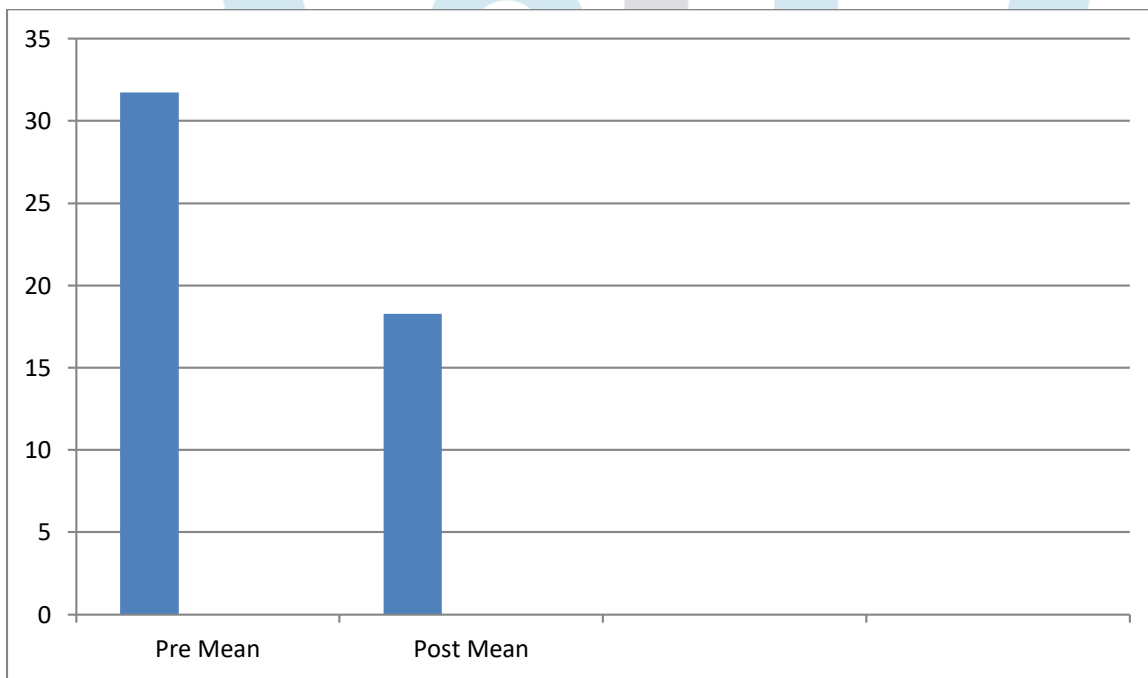
TABLE - 4

INTRA GROUP ANALYSIS OF PRE AND POST TEST RATE OF DISABILITY BY USING MODIFIED OSWESTRY DISABILITY PAIN QUESTIONNAIRE FOR EXPERIMENTAL GROUP

MODQ	N	PRE MEAN	POST MEAN	MEAN DIFF.	WSR VALUE	Z	P VALUE
EXPERIMENTAL GROUP	20	31.73	18.27	13.47	3.413		0.001 HS

{p = probability, HS = highly significant, Z = Wilcoxon Signed Ranks Test, N = number of subjects}

Table 4 shows Intra group comparison of rate of disability in experimental group on day 1 and at the end of 4 weeks shows the pre mean value of 31.73, post mean value of 18.27 with a mean difference of 13.47. Z value was 3.413 and p value of 0.001 which is highly significant.



Graph - 4

The values tabulated in Table 4 shows Intra group comparison of rate of disability in experimental group on day 1 and at the end of 4 weeks shows the pre mean value of 31.73, post mean value of 18.27 with a mean difference of 13.47. Z value was 3.413 and p value of 0.001 which is highly significant.

It shows the intensity of pain and inability to perform ADLs by using Oswestry Disability Pain Questionnaire in low back pain. The subjects in the age group of 31- 50 years in experimental group with irrespective of gender shows strong relationship of intensity of pain in low back pain which is significant at the 0.05 and 0.01 level.

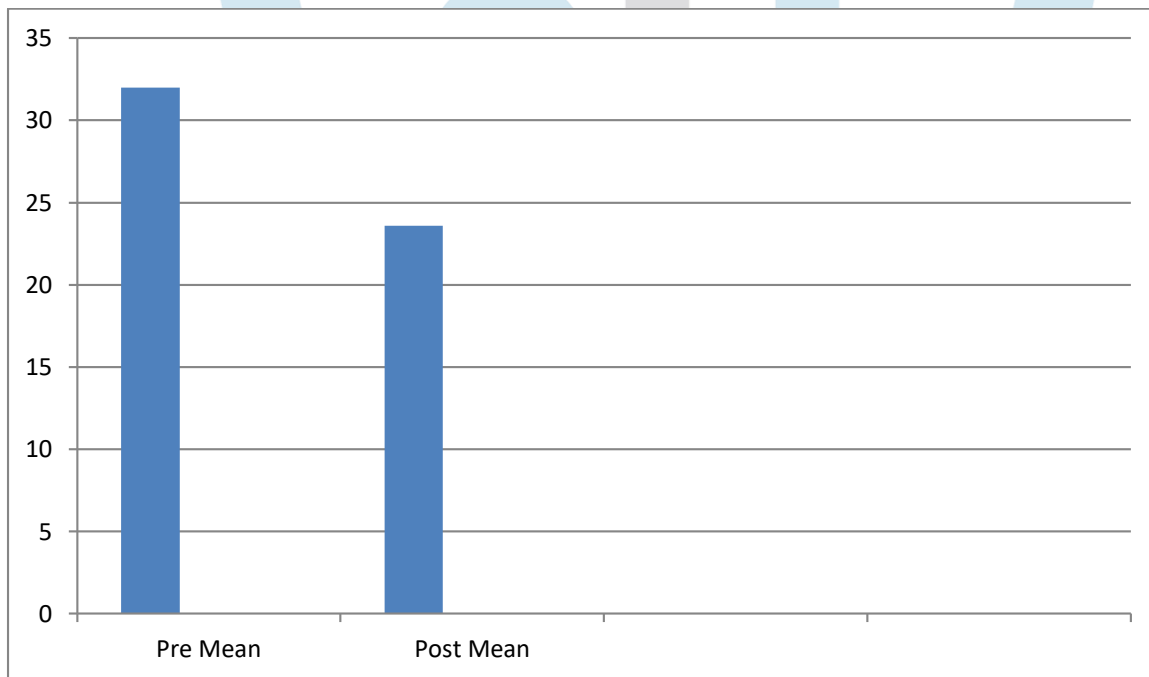
TABLE - 5

INTRA GROUP ANALYSIS OF PRE AND POST TEST RATE OF DISABILITY BY USING MODIFIED OSWESTRY DISABILITY PAIN QUESTIONNAIRE OR THE CONTROL GROUP

MODQ	N	PRE MEAN	POST MEAN	MEAN DIFF.	WSR VALUE	Z	P VALUE
CONTROL GROUP	20	32.00	23.60	8.40	3.423		0.001 HS

{p = probability, HS = highly significant, Z = Wilcoxon Signed Ranks Test, N = number of subjects}

Table 5 shows intra group comparison of rate of disability in control group on day 1 and at the end of 4 weeks shows the pre mean value of 32.00, post mean value of 23.60 with a mean difference of 8.40. Z value was 3.423 and p value of 0.001 which is highly significant.



Graph - 5

The values tabulated in Table 5 shows intra group comparison of rate of disability in control group on day 1 and at the end of 4 weeks shows the pre mean value of 32.00, post mean value of 23.60 with a mean difference of 8.40. Z value was 3.423 and p value of 0.001 which is highly significant.

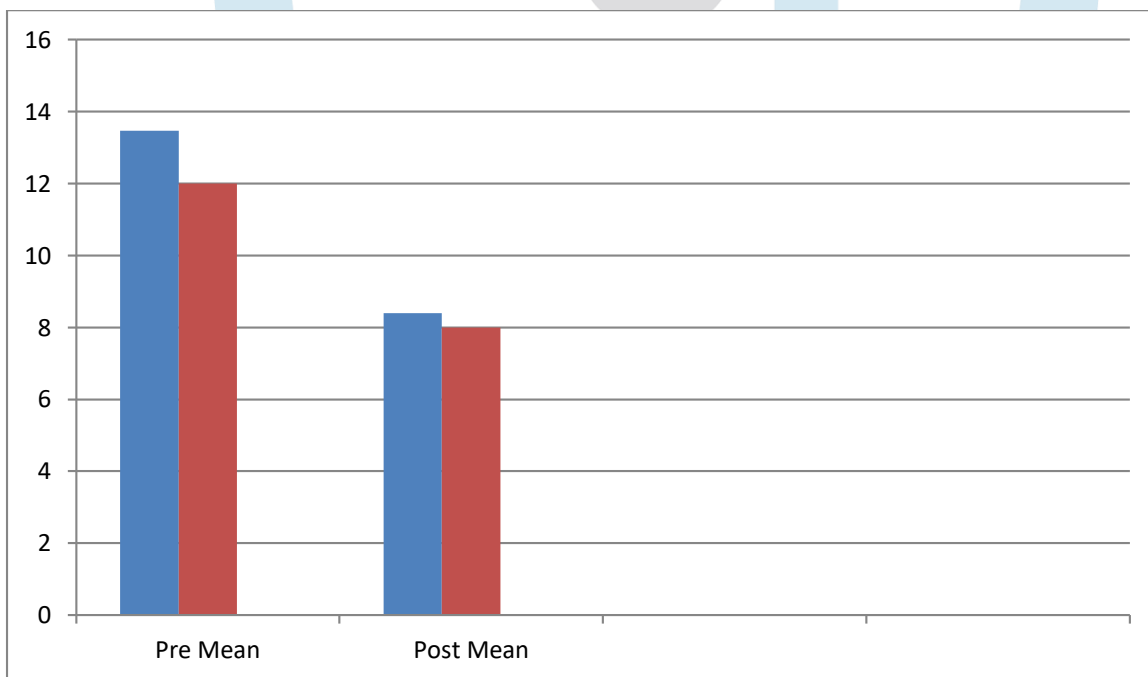
It shows the intensity of pain and inability to perform ADLs by using Oswestry Disability Pain Questionnaire in low back pain. The subjects in the age group of 31- 50 years in control group with irrespective of gender shows strong relationship of intensity of pain in low back pain which is significant at the 0.05 and 0.01 level.

TABLE- 6

INTER GROUP ANALYSIS OF PRE AND POST TEST RATE OF DISABILITY OF THE EXPERIMENTAL AND THE CONTROL GROUP BY USING MODIFIED OSWESTRY DISABILITY PAIN QUESTIONNAIRE

	GROUP	N	MEAN DIFF	SD	MWUT Z VALUE	P VALUE
CHANGE IN MODQ	EXPERIMENTAL	20	13.47	12.00	2.092	0.031 Sig
	CONTROL	20	8.40	8.00		

{p = probability, sig = significant, Z = Mann Whitney U Test, N = number of subjects} In MODQ, Experimental group showed a mean of 13.47 and standard deviation 7.539. Control group showed a mean of 8.4 and standard deviation 6.642. The difference between the two groups were tested using Mann Whitney U Test with a Z = 2.092 (p = 0.031) which was significant statistically.



Graph - 6

The values tabulated in Table 6 Is MODQ, Experimental group showed a mean of 13.47 and standard deviation 7.539. Control group showed a mean of 8.4 and standard deviation 6.642. The difference between the two groups were tested using Mann Whitney U Test with a Z = 2.092 (p = 0.031) which was significant statistically.

It shows the intensity of pain and inability to perform ADLs by using oswestry disability pain questionnaire in low back pain. The subjects in the age group of 31- 50 years in control group and experimental group with irrespective of gender shows strong relationship of intensity of pain in low back pain which is significant at the 0.05 and 0.01 level.

DISCUSSION

This study was designed to investigate and compare the effectiveness of Strengthening exercise and PNF in reducing pain and disability in chronic nonspecific low back pain patients. The purpose of study was to find out which of these exercise programs will be more effective in reducing the level of pain and disability in chronic low back pain patients.

The study consists of 40 patients who were randomly assigned into two groups. Both the groups underwent conventional physiotherapy treatment, then Control group underwent Strengthening Exercises and Experimental group underwent PNF. Both the groups were assessed before and after the intervention to determine the extent of reduction in the level of pain and disability by using Visual Analogue Scale (VAS) and Modified Oswestry Disability Questionnaire (MODQ) for low back respectively.

The experimental group showed the mean difference value 2.2 in VAS scale with the Z value of 3.457 and p value of 0.001 which is highly significant. Also this group showed the mean difference value of 13.47 in MODQ with Z value of 3.413 at p value 0.001 which was highly significant. These results were mentioned in Table.1 and 4. These scores proved that there was significant reduction in pain and disability in LBA patients after proprioceptive training. These findings are in agreement with the previous findings of Yamashita T and Melzack R in their Neurophysiologic studies have linked pain development in the lumbar spine region of the vertebral column with disturbances in the mechanoreceptors and probably with impairment of the superior proprioception centers. Therefore, exercise programs that enhance proprioception maybe beneficial for managing CLBP. It may be due to the stimulation of mechanoreceptors that increases the efficacy of PNF in reducing pain and alleviating disability in CNSLBP.

The control group showed the mean difference value 1.4 in VAS scale with the Z Value of 3.535 and p value of 0.000 which is highly significant. Also this group showed The mean difference value 8.4 in MODQ with Z value of 3.423 at p value 0.001 which Was highly significant. These results were mentioned in Table.2 and 5. These results Proved that Strengthening exercises were effective to reduce pain and disability on CLBP Patients. These study findings are supported by George Koumantakis et al, who found that a strengthening exercise program reduced the disability by improving multifidus muscle Stabilization functions in patients with recurrent nonspecific low back pain.

In the Intragroup analysis both the groups showed effectiveness in reducing the Pain and disability on LBP patients. When these groups were compared together by using Mann Whitney U Test, it showed the mean difference improvement in VAS score 2.2 for The experimental group and 1.4 for the control group. The Z value of 2.296 with p value 0.022 was highly significant. Also it showed the mean difference improvement in MODQ Score 13.47 for the experimental group and 8.4 for the control group. The Z value of 2.092 with p value 0.031 was highly significant. These results were mentioned in Table.3 And 6. This indicates that PNF techniques have greater improvement in pain and Disability than the strengthening exercises on LBP patients. This finding supported by Kofotolis et al. indicating the effectiveness of PNF on CNSLBP patients using rhythmic stabilization and combined isotonic technique. They found PNF exercises took advantage of the body's inhibitory reflexes to improve muscle relaxation. This muscle relaxation allowed a greater stretch magnitude during stretch training, which should result in superior gains in flexibility. This finding could be attributed to the fact that both exercise techniques involve muscle work at significant intensity levels that result in muscle strength and endurance improvements. The improvements in functional ability (as registered by the Oswestry Questionnaire) and reduction in the pain intensity could be seen as a direct result of flexibility and endurance improvements, thereby providing further supportfor the effectiveness of PNF exercises for CLBP treatment.

The result of the study supports the experimental hypothesis. So this study concludes that the PNF technique is more effective than Strengthening Exercises in reducing pain level and disability in CNSLBP.

Limitations:

1. This study used only Rhythmic Stabilisation and Combined Isotonic exercises.
2. The sample size of this study is too small to generalize the intervention effect.
3. Our study did not monitor the long-term effects of the exercise programs; therefore, the long-term effects of PNF exercises on CLBP are not clear.

Scope for the future study

1. The effectiveness of PNF techniques in managing acute or sub acute LBP problems is unclear and deserves further investigation.
2. Further studies are needed to examine the long-term effects of both the exercises on CLBP.
3. Further studies are recommended to find the effectiveness of both the techniques on specific LBP problems.
4. Studies can be carried out by combining other PNF techniques and investigating their effectiveness on CLBP.

Conclusion

The result of this study shows:-

1. Both the treatment groups, Strengthening exercises and PNF techniques, showed effectiveness in reducing the pain and disability on LBP patients.
2. Compared to Strengthening exercises, PNF techniques are more effective in reducing pain and disability in Chronic Non Specific Low Back Pain patients.

Summary:

This study was designed to investigate and compare the effectiveness of Strengthening exercises and PNF in reducing pain and disability in chronic nonspecific low back pain patients.

This was a comparative study, 40 subjects (20 - control group, 20 - experimental group) within the age group of 30 - 50 years were considered for this study by using randomised sampling procedure. Control group underwent Strengthening exercises and Experimental group underwent PNF techniques for a period of 4 weeks. Both the groups were assessed before and after the intervention to determine the extent of reduction in the level of pain and disability using VAS Scale and MODQ for low back respectively.

The data were analyzed by the Wilcoxon Signed Ranks Test. The difference between the two groups was tested using Mann Whitney U Test. The test results show that both the groups show significant decrease in pain. But test shows that decrease is significantly higher among experimental group compared to

control group. This study indicates that PNF techniques are effective in management of CNSLBP by reducing the level of pain and rate of disability.

Exercise therapy in the case of LBP with new methods such as Proprioceptive Neuromuscular Facilitation (PNF) techniques Combination of Isotonic (COI) is more effective because it is an exercise designed to improve neuromuscular response mechanisms by stimulating proprioceptors. The exercise pattern of PNF itself has a spiral pattern, and a diagonal direction that is synergistic with the central system of muscle control, as well as the performance of the exercise patterns and the adjustment is in line with the used muscle fibers. The performance of PNF patterns movement itself can stimulate the muscles to work in a way to optimize muscle function that is used in performing a movement.

Combination of Isotonic (COI) is a form of exercise that uses the PNF techniques on the isotonic contraction with movement aimed at the agonist, which is to control / control a coordinated muscle contractions. This technique combines several types of muscle contraction such as concentric, eccentric, and maintained. In this exercise, the agonist movement patterns is not accompanied by a phase of reflex movements that can make a smoother movement, controlled, and coordinated so as to get a functional movement. The mechanism of COI for reducing pain is a response to muscle through stimulation of neural mechanisms that may result the proprioceptor facilitation or inhibition

BIBLIOGRAPHY

1. Van Tulder, M. European guidelines for the management of acute nonspecific low back pain in primary care. 2003: 1-52.
2. Van Tulder M, Koes B, Bombardier C. Low back pain. *Best Pract Res Clin Rheumatol* 2002; 16:761–75.
3. Wolf AD, Pflieger B. Burden of major musculoskeletal conditions. *Bull World Health Organ* 2003; 81:646–56.
- 4 Frymoyer, J. W. (1988) Back pain and sciatica. *N. Engl. J. Med.*, 318, 291 – 300.
- 5 Dixon, A. St. (1976) Diagnosis of low back pain- sorting the complainers. In *The Lumbar Spine and Back Pain* (M Jayson, Ed.) Sector Publishing, London, pp.77-92.
- 6 Kepes, E.R. and Duncalf, D. (1985) Treatment of Backache with spinal injections of local anaesthetics, spinal and systemic steroids. A review. *Pain*, 22, 33-47.
- 7 Wyke, B. (1982) Receptor systems in lumbosacral tissues in relation to the production of low back pain. In *American Academy of Orthopaedic Surgeons Symposium on Idiopathic Low Back Pain*. Mosby, St Louis, pp. 97 – 107.
- 8 Gillette, R. G., Kramis, R.C. and Roberts, W.J. (1994) Sympathetic activation of cat spinal neurons responsive to noxious stimulation of deep tissues in low back Pain, 56, 31 – 42.
- 9 Frymoyer, J. W. (1992) Predicting disability from low back pain. *Clin. Orthop*, 279, 101 – 109.
- 10 Deyo RA, Weinstein JN.; Low back pain; *N Engl J Med.*; 2001 feb 1;344(5): 363-70.
- 11 S. Brent Brotzman, MD and Kevin E. Wilk, *Clinical Orthopaedic Rehabilitation*, 2nd Edition, Low Back Injuries, 2001, Pg. 559.
- 12 Craig Liebenson, *Rehabilitation Of The Spine: A Practitioner’s Manual*, 1996, pg. 171.
- 13 Gordon Waddell, *The Back Pain Revolution*, 1998, pg. 85

- 14 Koes BW, van Tulder MW, Thomas S. Diagnosis and treatment of low back pain. *BMJ*. 2006 Jun 17;332(7555):1430-4
- 15 Frymoyer JW, Cats Baril WL. An overview of incidences and causes of low back pain. *OrthopClin North Am*.1991. Apr; 22(2):263-71.
- 16 Van Tulder MW, Koes BW, Bouter LM. A cost of illness study of back pain in The Netherlands. *Pain*. 1995 Aug; 62(2):233-40.
- 17 Stuge B, Hilde G, Vollestad N. physical therapy for pregnancy-related low back and pelvic pain: a systematic review. *ActaObstetGynaecol Scand*. 2003Nov;82(11):983-90.
- 18 Kofotolis N, Sambanis M. The influence of exercise on musculoskeletal disorders of the lumbar spine. *J Sports Med Phys Fitness*. 2005; 45:84–92.
- 19 Malkia E, Ljunggren AE. Exercise programs for subjects with low back disorders. *Scand J Med Sci Sports*. 1996; 6:73–81.
- 20 Mayer TG, Gatchel RJ, Kishino N, et al. Objective assessment of spine function following industrial injury: a prospective study with comparison group and oneyear follow-up. *Spine*. 1985; 10:482–493.
- 21 Manniche C, Lundberg E, and Christensen I, et al. Intensive dynamic back exercises for chronic low back pain: a clinical trial. *Pain*. 1991; 47:53–63.
- 22 Hultman G, Nordin M, Saraste H, Ohisen H. Composition, endurance, strength, cross-sectional area, and density of MM erector spinae in men with and without low back pain. *J Spinal Dis*. 1993; 2:114–123.
- 23 Grindrod S, Tofts P, Edwards R. Investigation of human skeletal muscle structure and composition by X-ray computerized tomography. *Eur J Clin Invest*. 1983; 13:465–468.
- 24 Yamashita T, Cavanaugh JM, el-Bohy AA, et al. Mechanosensitive afferent units in the lumbar facet joint. *J Bone Joint Surg Am*. 1990; 72:865–870.
- 25 Loeser JD, Melzack R. Pain: an overview. *Lancet*. 1999;353:1607–1609
- 26 Koumantakis AG, Watson JP, Oldham AJ. Trunk muscle stabilization training plus general exercise versus general exercise only: randomized controlled trial of patients with recurrent low back pain. *PhysTher*. 2005; 85:209–225.
- 27 Voss D, Ionta M, Meyers B. *Proprioceptive Neuromuscular Facilitation: Patterns and Techniques*. 3rd Ed. New York, NY: Harper & Row; 1985:298–307.
- 28 Kofotolis N, Vrabas I, Kalogeropoulou E, et al. Proprioceptive neuromuscular facilitation versus Isokinetic training for strength endurance and jumping performance. *Journal of Human Movement Studies*. 2002; 42:155–165.
- 29 Kofotolis N, Vrabas IS, Vamvakoudis E, et al. Proprioceptive neuromuscular facilitation training induced alterations in muscle fiber type and cross sectional area. *Br J Sports Med*. 2005; 39:e11.
- 30 Lusting A, Ball E, Looney M. A comparison of two proprioceptive neuromuscular facilitation techniques for improving range of motion and muscular strength. *Isokinetic Exerc Sci*. 1992; 2:154–159.
- 31 Cornelius WL, Hands MR. The effects of a warm-up on acute hip joint flexibility using a modified PNF stretching technique. *Journal of Athletic Training*. 1992; 27:112–114.

- 32 Lucas RC, Koslow R. Comparative study of static, dynamic, and proprioceptive neuromuscular facilitation stretching techniques on flexibility. *Percept Mot Skills*. 1984; 58:615–618.
- 33 Osternig LR, Robertson R, Troxel R, Hansen P. Muscle activation during proprioceptive neuromuscular facilitation (PNF) stretching techniques. *Am J PhysMed*. 1987; 66:298–307.
- 34 Osternig LR, Robertson RN, Troxel RK, Hansen P. Differential responses to proprioceptive neuromuscular facilitation (PNF) stretch techniques. *Med SciSports Exerc*. 1990; 22:106–111.
- 35 Saliba V, Johnson GS, Wardlaw C. Proprioceptive neuromuscular facilitation. In: Basmajian JV, Nyberg RE, eds. *Rational Manual Therapies*. Baltimore, Md: Williams & Wilkins; 1992:243–284.
- 36 O’Sullivan PB, Twomey LT, Allison GT. Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radio logic diagnosis of spondylolysis or spondylolisthesis. *Spine*. 1997; 22:2959–2967.
- 37 Hather B, Tesch P, Buchanan P, et al. Influence of eccentric actions on skeletal muscle adaptations to resistance training. *ActaPhysiol Scand*. 1991; 143: 177–185.
- 38 Andersson G. The epidemiology of spinal disorders. In: Frymoyer JW, Ed. *The Adult Spine: Principles and Practice*. New York, NY: Raven Press; 1991: 107–146.
- 39 Keller A, Johansen J, Hellesnes J, et al. Predictors of Isokinetic back muscle strength in patients with low back pain. *Spine*. 1999; 24:575–580.
- 40 Flicker P, Fleckenstein J, Ferry K, et al. Lumbar muscle usage in chronic low back pain: magnetic resonance image evaluation. *Spine*. 1993;18:582–586
- 41 Kroll P, Machado L, Happy C, et al. The relationship between five measures of trunk strength. *J Back Musculoskeletal Rehab*. 2000; 14:89–97.
- 42 Craig Liebenson, *Rehabilitation of the Spine: A Practitioner’s Manual*, 1996, pg. 58.
- 43 Van Tulder M, Malmivaara A, Esmail R, Koes B. Exercise therapy for low back pain: a systematic review within the framework of the Cochrane collaboration back review group. *Spine*. 2000; 25:2784-96.
- 44 Nachemson AL, et al. *Back Pain, Neck Pain. An Evidence Based Review*. The Swedish Council on Technology Assessment in Health Care. Report Number 145 Ed. Stockholm, Sweden: 2000.
- 45 Paul W. Marshall and Bernadette A. Murphy: “Muscle activation changes after exercise rehabilitation for chronic low back pain.” June 2008.
- 46 Kofotolis N, Kellis E. Effects of two 4-week proprioceptive neuromuscular facilitation programs on muscle endurance, flexibility, and functional performance in women with chronic low back pain. *PhysTher*. 2006; 86:1001–1012.
- 47 Frymoyer J, Carr D, Gilbertson L, et al. Lumbar paraspinal compartment syndrome: a case report with physiologic and anatomic studies. *Spine*. 1985; 10:816–820.
- 48 Seidel H, Beyer H, Brauer D. Electromyographic evaluation of back muscle fatigue with repeated sustained contractions of different strengths. *Eur J ApplPhysiol*. 1987; 56:592–602.
- 49 Wilder DG, Aleksiev AR, Magnusson ML, et al. Muscular response to sudden load: a tool to evaluate fatigue and rehabilitation. *Spine*. 1996; 21:2628–2639.

- 50 Bentzen L, Manniche C, Hesselsoe G, et al. Clinical trial of intensive muscle training for chronic low back pain. *Lancet*.1988; 2:1473–1476.
- 51 Manniche C, Asmussen K, Lauritsen B, et al. Intensive dynamic back exercises with or without hyperextension in chronic back pain after surgery for lumbar disc protrusion: a clinical trial. *Spine*. 1993; 18:560–567.
- 52 Boonstra, Anne M., Posthumus, Jitze B.; Stewart, Roy E. *International Journal of Rehabilitation Research*: June 2008 - Volume 31 - Issue 2 - pp 165-169
- 53 Matthew O. B. Olaogun; *Anifaloba Physiotherapy Theory and Practice*, Volume 20, Issue 2, June 2004 , pages 135 – 142.
- 54 Fritz JM, Irrgang JJ. A comparison of a modified Oswestry Low Back Pain Disability Questionnaire and the Quebec Back Pain Disability Scale. *PhysTher*. 2001 Feb; 81(2):776-88.
- 55 Megan Davidson and Jennifer L Keating. A Comparison of Five Low Back Disability Questionnaires: Reliability and Responsiveness. *PhysTher* Vol. 82, No. 1, January 2002, pp. 8-24.
- 56 Ferrari, Robert MD. Responsiveness of the Short – Form 36 and Oswestry Disability Questionnaire in Chronic Nonspecific low back and lower limb customized foot orthotics. *Journal of Manipulative & Physiological Therapeutics*. 30(6):456-458, July/August 2007.
- 57 FAIRBANK JC, PYNSENT PB (2000): The Oswestry Disability Index. *Spine*: 25(22): 2940 – 2952.
- 58 KAREN GRIMMER, BRENTON DANSIE (2002): Adolescent standing postural response to backpack loads : a randomized controlled experimental study. *BMC Musculoskeletal disorders*. Vol.3 : 10.doi : 10.1186/1471 – 2474 –3 – 10.
- 59 KATHLEEN PRENDEVILLE, SARA DOCKRELL (1998): A pilot survey to investigate the incidence of low back pain in school children. *Physiotherapy Ireland*. Vol. 19, No.1.
- 60 BURTON A.KIM, CLARKE ROBERT D (1996): The Natural history of low back pain in Adolescents. *Spine* : Vol.21 – Issue 20 – pp 2323 – 2328.
- 61 GARETH T. JONES et al (2003): Predictors of low back pain in British school children : A population based prospective cohort study. *Paediatrics* Vol.111 No. 4 pp 822 – 828.
- 62 G KRISTJANSDOTTIR, H RHEE (2007): Risk factors of back pain frequency in school children. *Acta Paediatrica*, Vol. 91 Issue 7, Pages 849 – 854.
- 63 G. KRISTJANSDOTTIR (1996): Prevalence of self-reported back pain in school children: a study of socio demographic differences, *European Journal Pediatrics*. 155 : 984 – 986.
- 64 MA JONES, G STRATTON (2005): Biological risk indicators for recurrent non-specific low back pain in adolescents. *British Journal of sports medicine* 2005. 39: 137 – 140.
- 65 SMITH A, O SULLIVAN P, STRAKER L (2008): Classification of sagittal thoraco – lumbo – pelvic alignment of the adolescent spine in standing and its relationship to low back pain. *Spine*. 33 (19): 2101 – 7.
- 66 ROBERT J DAUL (2005): Easy exercise program for low back pain relief. *Spine – health*.