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EFFECTIVENESS OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION EXERCISES IN DECREASING PAIN SEVERITY, INCREASING RANGE OF MOTION, BALANCE, PROPRIOCEPTION AND REGIONAL FUNCTION IN INDIVIDUALS WITH CHRONIC NON-SPECIFIC LOW BACK PAIN

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ABSTRACT

Purpose: The aim of the study was to identify the effectiveness of proprioceptive neuromuscular facilitation (PNF) exercises in decreasing pain severity, increasing range of motion, balance, proprioception error and regional function in individuals with chronic non-specific low back pain (CNSLBP).

Methods: A quasi-experimental study was conducted with 50 participants of both genders, aged between 18 to 50 years diagnosed as CNSLBP and are grouped into experimental (n=25) and control (n=25) group. After completing 3 weeks of interventions as per group allocation received either PNF or routine exercises. Pain severity, lumbar flexion range of motion, balance, proprioception and regional function were measured using numerical pain rating scale (NPRS), bubble inclinometer, balance postural sway system (BPSS), passive joint reposition sense (PJRS) and Roland-Morris Disability Questionnaire (RMDQ) before and after interventions.

Results: Findings revealed that PNF exercises improved all outcomes significantly in experimental group than control group with moderate to large effect sizes (Cohen's d ranges 0.6 – 0.9). Specifically, the proprioception error improved significantly among participants who practiced PNF exercises alone with large effect size (Cohen's d = 0.9). The centre of pressure displacement in antero-posterior direction with eyes opened and closed improved both within and between group in experimental group alone ($p < 0.001$).

Conclusion: Proprioceptive neuromuscular facilitation (PNF) exercises given for 3 weeks were effective in decreasing pain severity, improve balance, proprioception and function compared to routine exercises in individuals with chronic non-specific low back pain.

KEYWORDS: Health care, Low back pain, Lumbar well-being, Proprioception exercises.

INTRODUCTION

Low back pain (LBP) is a major global challenge and a quite common problem in populations worldwide. Non-specific low back pain (NSLBP) is a prevalent condition marked by pain in the lower back without a clearly identifiable anatomical cause and represents majority of the cases of LBP. The Global Burden of Disease (GBD) Study 2021 highlights the significant impact of LBP on global health that LBP is the leading cause of years lived with disability (YLDs) worldwide. The current data of 619 million people by 2020, with projections suggesting this number could rise to 843 million by 2050 due to population growth and aging (1).

Poor trunk muscle endurance and resulting fatigability of lumbar para spinal muscles are often associated with chronic low back pain (CLBP). Whereas, decreased spinal control, more trunk muscle activity, spinal stresses and strains further leads to deterioration of proprioception in CLBP category (2,3). Nonspecific low back pain is primarily characterized by dull, aching pain in the lumbar region, which may radiate to the gluteal area or thighs without neurological deficits. Psychological factors, such as fear-avoidance behaviors and anxiety, can further contribute to the chronicity.

Proprioception is a deep sensation, defined as afferent information that contributes to the detection of joint motion, limb position, muscle movement and resistance applied on the body (3). Impairment in lumbar proprioception is thought to decrease the ability to attain and maintain a neutral spinal posture and appropriately coordinate muscle activation. It has been frequently reported as a contributing factor of persistent LBP and is potentially associated with its recurrence (4).

Exercise therapy is one of the conservative treatments most frequently used in LBP either alone or in combination with other therapies. Proprioceptive Neuromuscular Facilitation (PNF) is an exercise therapy concept based on neuromuscular control it stimulates joint proprioceptors (5,6), muscle strength (7,8) and range of motion (9). Through sensory inputs from peripheral organs, it influences motor outputs of the central nervous system and promote functional activity of daily living (10,11) . The PNF utilizes the body's proprioceptive system and reflexes to inhibit or facilitate muscle contraction (12).

The principle of PNF approach for LBP was to stimulate sensory-motor control and promotes lumbar muscle proprioception (10). Several PNF training techniques have been proposed for CLBP, three commonly used techniques are rhythmic stabilization (RS), combination of isotonic (COI) and chop & lift (CL) (10). The RS technique is primarily used to improve muscle weakness and where stabilization can stimulate the agonist movement pattern. The COI technique is used to improve the ability in performing controlled movements, and to address deficiencies in strength and range of movement. The CL technique is used to promote trunk movement involving the use of bilateral limbs (10).

Lumbar proprioception has been commonly measured by passive joint repositioning sense (PJRS), active joint repositioning sense (AJRS), threshold to detect passive motion (TTDPM) and active movement extent discrimination assessment (AMEDA) (13), also findings from Shankar et al. (2023) states that functional proprioception declines with age and can impact balance and coordinated movements (14). Evaluation of lumbar proprioception in individuals with LBP could provide better clarity about presence of this impairment.

Individuals with LBP with impaired balance and proprioception tend to have greater center of pressure (COP) velocity and displacement(15).This conjoint problem poses greater difficulty in holding a posture and adapting to changing conditions(16). Hence treatment targeting proprioception and balance through trunk muscle conditioning could improve pain, function, proprioception and balance related outcomes in individuals with NSLBP.

PNF exercises have been described as a promising method for improving neuromuscular control and proprioceptive input. But limited studies have investigated the comparative efficacy of PNF versus other physiotherapy interventions in NSLBP. Among these the studies, which have consistently included proprioception as a primary outcome measure and analysed balance related outcomes are scarce. Thus, this study aims to investigate the therapeutic effect of PNF exercise in above population using specific outcome measures. Such evidence, combined with quality education could help in optimizing rehabilitation procedures to improve functional recovery among NSLBP populations.

METHODOLOGY

Materials

This study was approved by Institutional Ethical Committee for student's project (REF: CSPIII/25/JAN/15/08) and was registered in Clinical Trial Registry – India (CTRI/2025/03/081565). This quasi-experimental study recruited 50 participants with chronic low back pain of both genders, aged between 18 to 50 years referred to the outpatient physiotherapy department ensuring gender equality in the research, the written consent was collected from the participants. The sample size was estimated by G-POWER 3.0.10 based on assuming a 95% confidence level and 90% study power, with alpha error equals 0.05, a sample size of 50 with 25 samples in experimental and control group was attained. The alpha level was set at $p = 0.05$ and the assumed effect size was set at $d \approx 0.95$ which indicates a large effect and high clinical importance (17). Inclusion criteria for participation were individuals with non-specific chronic low back pain, age from 18 to 50 years, both male and female participants. Exclusion criteria for participation were previous history of spine surgery, neurological deficits, patient already received regular PNF training, cancer, specific LBP, pregnant women, as these factors could directly affect proprioception.

Data collection and Outcome measurement:

In this study, the participants were unaware of their allotted groups and the outcome assessors blinding was maintained to reduce bias. All participants are evaluated for pain severity, lumbar flexion range of motion, balance, proprioception and functional ability using numeric pain rating scale (NPRS), bubble inclinometer, balance and postural stability system (BPSS), passive joint repositioning sense (PJRS) and Rolland Morris disability questionnaire (RMDQ) respectively.

The NPRS consists of a 10 points scale, ranging from 0 to 10 where 0 indicates no pain and 10 indicates very severe pain. Participants were asked to report their current level of pain.

The lumbar flexion range of motion is measured using the bubble inclinometer on the day of assessment, placing one inclinometer at T12 and another at S2 (the PSIS level). Setting both inclinometers to zero, the participants were instructed to bend forward as much as possible while keeping the knees straight. The angles measured by both inclinometers at the end of the range are noted and the lumbar flexion range of motion is calculated by subtracting the reading between S2 and T12.

Balance was assessed using a Balance and Postural Stability System (BPSS). (Figure.1) BPSS records sway oscillations, both lateral and anteroposterior sway in both eyes open and eyes closed. COFP Xi indicates Center of Foot Pressure with lateral sway, COFP Yi indicates Center of Foot Pressure with anterior posterior sway (18).

Passive joint repositioning sense (PJRS) test in sitting was used to assess the lumbar proprioception. Each participant was moved passively into 15 degrees of trunk flexion in sitting and were instructed to remember the target positions (15^0) and then moved to the neutral position passively after maintaining the flexed position for 5 seconds. This procedure was repeated 3 times and the 4th time participant was asked to actively move to the target position and the positional error is noted (Figure 1) (13,19).

Figure 1: A. BPSS B. Passive joint reposition sense, Patient moved passively to target degree and then measured passively.

The Tamil and English version of the Roland-Morris Disability Questionnaire (RMDQ) was used to assess disability. The questionnaire consists of 24 items to assess disability specific to LBP. The participants put a tick on the blank in front of each item if they had such disability on the evaluation day. The total score ranges from 0 (no disability) and 24 (maximum disability).

Procedure

Individuals in the experimental group received PNF exercises, whereas the control group received conventional training. Participants in both groups received electrotherapy treatment at the beginning of each session for 20 minutes.

In Week one, participants received Rhythmic stabilization (RS) techniques were isometric contractions for trunk flexors and extensors against maximum resistance was performed. In Week two, participants received Combination of isotonic (COI) technique, it consists of alternating isometric, concentric, and eccentric contractions; 5-second resisted concentric trunk flexion, followed by 5-second isometric contraction in flexion, and then a 5-second resisted eccentric contraction of trunk flexion (20,21). In Week three, diagonal and spiral direction chop and lift were performed against maximum resistance generated by the physical therapist (Figure 2). All the above three exercises were performed 3 sets of 15 repetitions with rest interval of 30 seconds between the sets and 60 seconds after completing 15 repetitions (4). The participants were asked to continue previous week's exercises along with the corresponding week's activity.

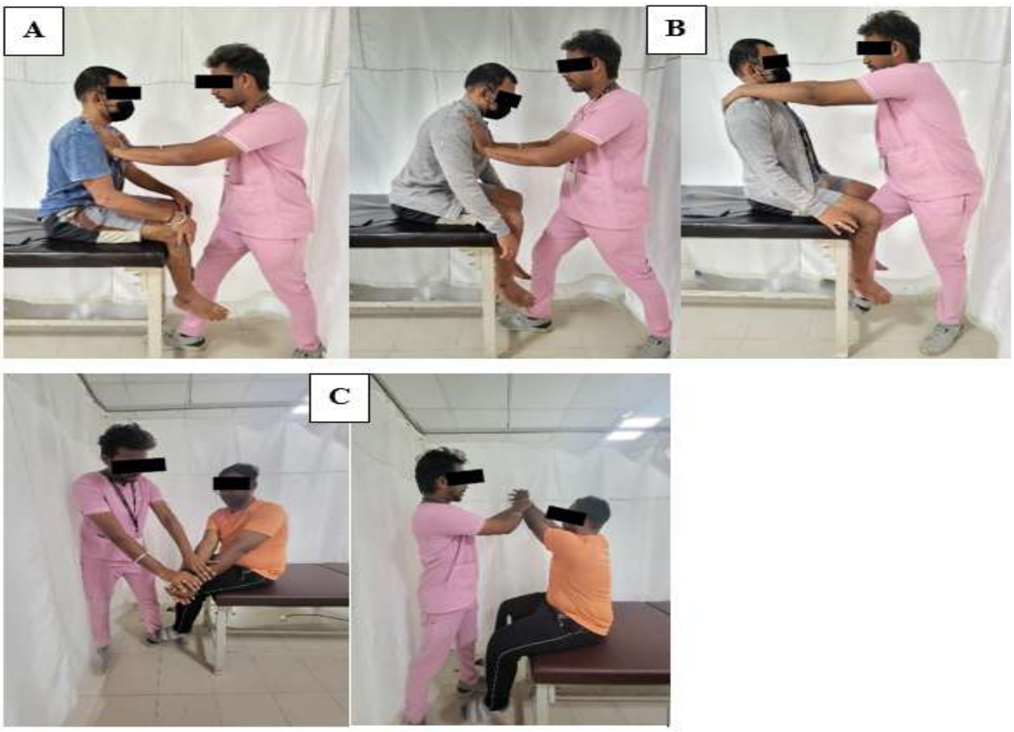

Figure 2: A. Rhythmic Stabilization, B. Combination of isotonic, C. Chop and Lift

The control group received a routine training program consisting of trunk curl-up, diagonal trunk curl, single-legged extension (Figure 3) and TA activation. Over the course of three weeks, the individuals participated in three 30-minute exercise sessions per week. All exercises were done in 3 sets of 10 repetitions, with a 30-second break between every set and a 60-second rest between sets. The participants in the experimental and control group attended each individual training session three times a week and the outcomes are measured at the baseline and the end of three weeks after 9 sessions of treatment.

Figure 3: A. Trunk Curl-up, B. Diagonal trunk curl, C. Single Leg Extension

Data analysis

Data were analysed using SPSS software version 16.0. The Shapiro-Wilk test was used to check the normality. A paired t-test was used to evaluate within-group differences (pre- and post-intervention), whereas an unpaired t-test was utilized to examine between-group differences. In addition, Cohen's d was used to determine the intervention's effect size, which was classified as small (0.2), medium (0.5), or large (0.8 and above). P-values less than 0.05 were considered significant.

RESULTS

Table 1 shows the baseline and demographic data between groups were comparable and no significant difference exists between the groups.

Table 1. Baseline and demographic data of participants in Experimental and Control group

		EXPERIMENTAL GROUP	CONTROL GROUP	UNPAIRED T TEST
AGE (years) Mean, SD	IN YEARS	39.44 (8.13)	39.48 (7.34)	0.71
GENDER (N)	MALE	14	12	
	FEMALE	11	13	
PAIN DURATION (in months) Mean, SD	BASELINE	7.56 (4.01)	7.16 (4.25)	0.73
NPRS Mean, SD	BASELINE	6.91 (.90)	6.4 (1)	0.07
LUMBAR FLEXION ROM (in degree) Mean, SD	BASELINE	48.34 (5.97)	46.48 (4.80)	0.23
RMDQ Mean, SD	BASELINE	13 (3.63)	11.52 (3.26)	0.14
PROPRIOCEPTION ERROR (in degree) Mean, SD	BASELINE	2.78(0.85)	2.84(0.98)	0.83
COFP XI IN (CM) Mean, SD	EO	1.3(0.74)	1.45 (1.54)	0.58
	EC	1.72 (1.14)	1.34 (1.06)	0.24
COFP YI IN (CM) Mean, SD	EO	15.5 (2.44)	14.43 (2.45)	0.13
	EC	13.24 (1.50)	13.43 (1.80)	0.69

(**Note:** N: number, SD: standard deviation, NPRS: numerical pain rating scale, RMDQ: Roland-Morris Disability Questionnaire, COFP: center of foot pressure, EO: eyes open, EC: eyes closed, XI: medial lateral sway, YI: anteroposterior sway)

Table 2. Shows within group analysis and their significance of the variables belonging to Experimental group and Control group (paired t test)

WITHIN GROUP DIFFERENCE								
	EXPERIMENTAL GROUP				CONTROL GROUP			
	MEAN (SD)		MEAN DIFFERENCE	p- VALUE	MEAN (SD)		MEAN DIFFERENCE	p- VALUE
	PRE	POST			PRE	POST		
NPRS	6.91 (.90)	1.95(0.877)	4.96	<0.001*	6.4 (1)	2.68 (1.14)	3.72	<0.001*
LUMBAR FLEXION ROM IN DEGREE	48.34 (5.97)	52.39 (4.32)	4.05	<0.001*	46.48 (4.80)	49.2 (3.74)	2.72	<0.001*
RMDQ	13 (3.63)	3.43(1.40)	9.57	<0.001*	11.52 (3.26)	4.56(2.06)	6.96	<0.001*
PROPRIOCEPTION ERROR	2.78(0.85)	0.95(0.70)	1.93	<0.001*	2.84(0.98)	1.64 (0.81)	1.2	<0.001*
COFP XI EO	1.3(0.74)	0.47 (0.27)	0.82	<0.001*	1.45 (1.54)	0.78 (0.52)	0.67	0.01*
COFP XI EC	1.72 (1.14)	0.65 (0.54)	1.07	<0.001*	1.34 (1.05)	1.03 (0.58)	0.31	0.06
COFP YI EO	15.5 (2.44)	18.23 (2.90)	2.73	<0.001*	14.43 (2.45)	16.55 (2.42)	2.12	<0.003*
COFP YI EC	13.24 (1.50)	15.48 (1.84)	2.24	<0.001*	13.43 (1.80)	14.03 (2.92)	0.6	0.27

(**Note:** SD: standard deviation, NPRS: numerical pain rating scale, RMDQ: Roland-Morris Disability Questionnaire, COFP: center of foot pressure, EO: eyes open, EC: eyes closed, XI: medial lateral sway, YI: anteroposterior sway, *: significant value calculated using paired t test)

Table 2 shows the within group changes in the experimental group and control group, in experimental group it shows statistically significant improvements in all the outcomes; pain severity, lumbar range of motion, Proprioception, Functional disability RMDQ score and balance following the intervention, whereas in the control group, it also exhibited statistically significant improvements across several outcome measures after the intervention. Pain severity decreased from 6.40 ± 1.00 to 2.68 ± 1.14 ($p < 0.001$). Lumbar flexion ROM improved from 46.48° ± 4.80° to 49.20° ± 3.74° ($p < 0.001$), while RMDQ scores reduced from 11.52 ± 3.26 to 4.56 ± 2.06 ($p < 0.001$). Proprioception error reduced from 2.84° ± 0.98° to 1.64° ± 0.81° ($p < 0.001$). Improvements were also noted in balance measures, with COFP XI EO reducing significantly ($p = 0.017$), Similarly, COFP YI EO showed significant improvement ($p < 0.003$). The COFP XI EC ($p = 0.062$) and COFP YI EC did not show significant change ($p = 0.27$).

Table 3- Shows between group analysis and their significance of the variables belonging to 2 groups

	BETWEEEN GROUP DIFFERENCE							
	EXPERIMENTAL GROUP			CONTROL GROUP				
	MEAN (SD)			MEAN (SD)				
	PRE	POST	MEAN DIFFERENCE	PRE	POST	MEAN DIFFERENCE	p-VALUE	Cohen's d (effect size)
NPRS	6.91 (.90)	1.95(0.877)	4.96	6.4 (1)	2.68 (1.14)	3.72	0.01*	0.71
LUMBAR FLEXION (ROM)	48.34 (5.97)	52.39 (4.32)	4.05	46.48 (4.80)	49.2 (3.74)	2.72	0.008*	0.78
RMDQ	13 (3.63)	3.43(1.40)	9.57	11.52 (3.26)	4.56 (2.06)	6.96	0.03*	0.64
PROPRIOCEPTION ERROR	2.78 (0.85)	0.95(0.70)	1.93	2.84 (0.98)	1.64 (0.81)	1.2	0.003*	0.91
COFP XI EO	1.3(0.74)	0.47 (0.27)	0.83	1.45 (1.54)	0.78 (0.52)	0.67	0.01*	0.75
COFP XI EC	1.72 (1.14)	0.65 (0.54)	1.07	1.34 (1.05)	1.03 (0.5)	0.31	0.03*	0.73
COFP YI EO	15.5 (2.44)	18.23 (2.90)	2.73	14.43 (2.45)	16.55 (2.42)	2.12	0.03*	0.63
COFP YI EC	13.24 (1.50)	15.48 (1.84)	2.24	13.43 (1.80)	14.03 (2.92)	0.6	0.04*	0.59

(**Note:** SD: standard deviation, NPRS: numerical pain rating scale, RMDQ: Roland-Morris Disability Questionnaire, COFP: center of foot pressure, EO: eyes open, EC: eyes closed, XI: medial lateral sway, YI: anteroposterior sway, *: significant value calculated using unpaired t test)

Table 3 shows the between-group comparisons revealed that the experimental group showed significantly greater improvements than the control group across all outcome measures. The experimental group showed considerably higher pain severity reduction (NPRS) than the control group ($p = 0.01$) with a moderate effect size Cohen's d = -0.71. Lumbar flexion ROM improved more significantly in the experimental group ($p = 0.008$) with a large effect size d = 0.78. Functional impairment was measured by RMDQ score, was also significantly reduced in the experimental group ($p = 0.03$) effect size of d = -0.64. Proprioception error shows considerable reduction in the experimental group than in the control group ($p = 0.003$) with a large effect size d = -0.91. Regarding balance, the experimental group was superior to the control group in COFP XI EO ($p = 0.01$) with a effect size (-0.75), COFP XI EC ($p = 0.03$) effect size (d=-0.73), COFP YI EO ($p = 0.03$) with a moderate effect size of d=0.63, and COFP YI EC ($p = 0.04$) effect size of d=0.

DISCUSSION

The purpose of this study was to investigate 3-week PNF training effects compared to routine care and individuals in the experimental group had significantly improved following PNF exercises with pain severity, lumbar flexion range and disability. The major findings of the study were PNF training significantly improved balance and proprioception error in addition to the above clinical outcomes.

The pain severity had reduced after 4 weeks of PNF training in previous studies and in the current research the pain severity had improved by 3 weeks timeline with a near large effect size (d= 0.7).The standard mean difference (SMD) observed for pain severity is 2.14 (n=965) **(2)** and in the current study the SMD for experimental and control group individuals are 4.96 & 3.72 respectively. The pain severity had improved significantly in short term as observed in a systematic review by Pourahmadi, M.,et. al 2020 (2).

The PNF exercises incorporated in the study were aimed at improving movement pattern and strength as they are performed in the direction which is like the topographical arrange of muscles used for daily functions. The lumbar flexion range of motion improved greater in experimental group (4.05degrees) than control group (2.72 degrees) this finding goes in like the observation by Areeudomwong. P. et.al., 2018 (4). The SMD for lumbar flexion is 8.5º±0.7º (Malla S et al. 2018)(22) , 1.8±0.75 cm (Hosseinifar et al.2016) (23) and 1±1.6 cm (Park and Seo 2014) (24) following PNF exercises in previous studies and in the current study the range improved by 4.05 degree by 3weeks.

Balance measured with balance postural stability system (BPSS), the center of pressure (COP) displacement with eyes closed and open improved significantly only following PNF exercises. Gao et al., 2022 in his systematic review identified PNF exercises did not improve dynamic balance in this population. RCT by Areeudomwong. P. et.al., 2018(4) observed static balance improvement following 3 weeks of PNF exercises similar to current study. The center of pressure velocity during eye opened and eye closed conditions - 6.68 mm/s, and 6.77 mm/s, respectively. Even though the method of balance evaluation and unit differs, PNF exercises had improved static balance among NLBP individuals as observed in the current research with a large effect size.

In the current study the disability improved by 9.57 and 6.96 points as measured by RMDQ in experimental and control group. Both the above improvements have crossed the MCID of 5 points in short-term following PNF exercises. Large effect size obtained following PNF training on functional disability improvement was greater than the previous research (SMD=-2.68) in population with LBP(2). The disability improvement as observed in the current study was rated low to moderate due to heterogenicity with previous researches this might improve following addition of more studies as like the current one. Certainly, PNF exercises improve function than routine care in short term and more studies is needed to establish the long-term effect. The current study was the first of its kind to measure and analyse the proprioceptive error following PNF exercises among NLBP population.

In the current study, a significant reduction in proprioception error was observed in the experimental group compared to the control group. At baseline, the proprioception error was 2.78 in the experimental group and 2.84 in the control group. Following the PNF training, the error decreased markedly to 0.95 in the experimental group, yielding a standardized mean difference (SMD) of 1.93. In contrast, participants in the control group who received general trunk exercises showed a smaller reduction in proprioception error, which decreased to 1.64, with an SMD of 1.2. These findings indicate that PNF training was more effective in improving proprioceptive accuracy than routine trunk exercises contributing to good health and overall well-being.

The possible reason for the observed benefits in experimental group could be due to stimulation of proprioceptors of joints and muscles in the lumbar area to produce a neuromuscular response that alleviates pain severity, regulation of sensory-motor system thereby improving balance and regional function.

Limitation:

To generalize the findings future studies can be conducted with more samples, LBP subgroups, long-term follow up and sensitivity analysis. More objective outcome measures for proprioception and performance test can be used to generate data. PNF exercises can be compared with other specific strategies that could improve balance, proprioception and function among LBP population.

CONCLUSION

Proprioceptive neuromuscular facilitation (PNF) exercises given for 3 weeks were effective in decreasing on pain severity, improving balance, proprioception and function compared to routine exercises in individuals with chronic non-specific low back pain.

Informed Consent: A written informed consent form was obtained from all participants.

Acknowledgement: I sincerely acknowledge all those who have supported, guided, and inspired me throughout this journey with their invaluable encouragement and blessings.

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