Advanced International Journal for Research (AIJFR)
E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

Correlation Between Physical Activity, Proprioceptive and Balance Deficits in Subjects with Chronic Mechanical Low Back Pain-An Observational Study

Mounika Akula[1], Praveen Dowle[2], Naga Sravana Kumar Jampa[3], Dr. Aluka Sundeep Kund Reddy[4]

[1] MPT (Musculoskeletal Sciences), College of Physiotherapy, Nizam's Institute of Medical Sciences (NIMS), Hyderabad, Telangana, India
[2] Physiotherapy Faculty, MPT (Musculoskeletal Sciences), College of Physiotherapy, NIMS, Hyderabad, Telangana, India
[3] Academic Incharge, MPT (Sports Medicine), College of Physiotherapy, NIMS, Hyderabad, Telangana, India
[4] Assistant Professor, Department of Orthopaedics, NIMS, Hyderabad, Telangana, India.

Abstract

Background: Low back pain (LBP) is a serious health issue that affects people of all ages. In India, the prevalence of LBP ranges from 6.2 % to 92 %, with increasing age and female predominance frequently leading to significant impairment. Non-specific Low Back Pain is on the rise due to increased sedentism People with low back pain may have decreased proprioception and motor control of deep trunk muscles, affecting postural stability.

Purpose: To investigate the association between physical activity, proprioception, and balance impairments in chronic mechanical low back pain patients (CMLBP).

Methods: 100 patients with CMLBP were selected.The outcomes measures included were Lumbar active range of motion (L-AROM), Lumbar proprioception error (Bubble inclinometer), static and dynamic balance test, Modified Oswestry disability index (MODI), Numerical Pain Rating Scale (NPRS), International Physical Activity Questionnaire Short Form (IPAQ-SF).

Results: Physical activity and proprioception error were shown to have a statistically significant correlation coefficient at 15 degrees of extension (r=27.7% with a p-value of < 0.05).Pearson correlation for physical activity and dynamic balance shows a positive correlation r=23.3% (p-value <0.05).

Conclusion: Significant correlation was seen between physical activity and proprioception error at 15 degree of lumbar extension, posterolateral reach in Y balance test.

Keywords: CLBP; MODI; NPRS; L-AROM; IPAQ-SF; Bubble Inclinometer.

1. Introduction

Low Back pain is a major health issue that affects various age groups. The majority of the population (70-85%) will have low back pain at some point in their lives(1).Low back pain arises below the costal edge and above the inferior gluteal folds(2).Mechanical factors account for 80-90 percent of the causes of lower back pain(3) and it caused by the spine, intervertebral discs, and soft tissues around the spine(4). It can also be caused by unhealthy habits including improper posture, bad sitting, and bad lifting methods(5).People who work at home put a lot of strain on their lumbar spine. Sedentary life style reduces neuromuscular efficiency, causes skeletal muscle atrophy, and decreased muscle strength, perhaps leading to NSCLBP(6).

Chronic low back pain is pain that lasts longer than the expected healing time which is more than 12 weeks(7). It also makes it difficult for the intervertebral disc to keep its water level stable, which leads to degenerative and overload lesions, which in turn causes NSLBP(8).CLBP can be caused by a lack of or inadequate motor control in the deep trunk musculature(9).Core muscle weakness has been linked to increased pain and impairment in people with low back pain(2).Physical exercise is any skeletal muscle action that results in an energy expenditure. The lack of exercise may result in diminished muscle strength and flexibility, making the spine more prone to injury(10).

Postural control is responsible for maintenance of posture, to stabilize spine and movement. Good postural control necessitates the use of an input system to gather information, as well as an integration center to receive and understand the information in order to properly prepare a response(11). While it is well established that patients with low back pain have a malfunction in the lumbo-pelvic area, there is growing evidence to suggest that proprioception is also impaired in these patients. Para spinal muscle contains abundant muscle spindles, which play a key role in generating a proprioceptive signals to monitor mid spinal motion(12).The damage in proprioception may lead to dysfunction in neuromuscular synapses in chronic low back pain. This decline in proprioception results in multiple injuries(13).

One study described the association of both sedentary type of work and heavy physical load and suggested that both had a stronger association with low back pain in women than in men(8).In another study, the researchers discovered that there is a negative relationship between physical activity and low back pain(10).

Trunk muscular dysfunction may result from proprioceptive deficiencies, which may also induce changes in the typical afferent inputs from the muscles that are impacted by the impairments. Because ligaments are under low strain in neutral posture, muscle afferents might be regarded to be the principal contributors to position awareness in this position(14).

The goal of this study is to investigate the relationship between proprioception impairment and balance impairment in individuals with persistent mechanical low back pain. Our objective was to observe the changes of postural control and repositioning error as they relate to physical activity in individuals with chronic mechanical low back pain. We hypothesized that there would be a relationship between physical activity,Proprioceptive error and postural control in CMLBP individuals.

METHODOLOGY:

STUDY DESIGN:

It is a cross-sectional study that was carried out after the approval of the Institutional Ethics Committee ,NIMS.

PARTICIPANTS:

The study included 100 individuals with persistent mechanical low back pain referred to the Physiotherapy Department,NIMS. The study comprised both male and female subjects aged between 18-45 years. The subjects were enrolled after an informed consent.

Participants with chronic mechanical low back pain for at least 3 months were included in the study.Participants with back trauma, acute low back pain, spondylolisthesis and rheumatological or neurological issues were excluded.

OUTCOME MEASURES:

The outcome measures were taken by a physiotherapist (other than the principal investigator) trained for the same.

The Y-balance test was used to determine the dynamic balance. A hundredfold increase in reach distance was estimated by dividing the total of the greatest reach distance in each direction by three times leg length, and then multiplying by 100 (4).

International Physical Activity Questionnaire-SF is used to assess the individuals physical activity level and NPRS to assess the pain.

Lumbar ROM:

Two bubble inclinometers were utilized simultaneously in conjunction with each other to measure the lumbar range of motion. The patient is instructed to assume a standing posture. The examiner then palpates and marks two reference sites on the spine: one at the 1st sacral vertebrae, and another at the 12^{th}thoracic vertebrae, both of which are used to measure lumbar flexion and extension. As reference points for side flexion, the spinous process of the T12 vertebrae is used, and for lumbar rotations, the acromion process and greater trochanter of the opposing side are used as references. Throughout the tests, the bubble inclinometer was held in a constant position on the reference points to ensure accurate results. With the lower inclinometer readings subtracted from the upper inclinometer readings, the true range of motion of the lumbar region when bending forward and backward was estimated for each individual subject. For evaluating lumbar mobility, the bubble inclinometer has excellent intrarater and interrater reliability, as well as strong concurrent validity(15).

Lumbar proprioception error:

Bubble inclinometer was used to also measure the proprioception error. The participants were in a neutral posture i,e standing erect. Three alternative starting places were used for this. Each participant was requested to hold a 45-degree lumbar flexion position for ten seconds, and then they were instructed to remember the position since they would be required to replicate it with closed eyes. After that, the participant was requested to return to the neutral position and then to duplicate the goal position as closely as possible, which was the final step. When the patient has reached the desired posture, he or she informs the therapist. The individual was instructed to maintain the final position for three seconds, after

which the therapist recorded the replicated position. The identical process was carried out for 60 degrees of lumbar flexion and 15 degrees of lumbar extension on a second occasion. A total of three trials were performed with a 30 second break between each trail, and then the average of all three trials was computed for further study. The participants were given the opportunity to practice the exam once before it was completed. During the testing process, no feedback was provided.(11)

Single limb stance test:

Patients were asked to position their contralateral leg in 45 degrees hip flexion and 90 degrees knee flexion while standing on their dominant leg with their arms crossed over their chests. While standing on each leg, the time was recorded with both eyes open and both eyes closed. The timing was halted at 60 seconds (with the eyes open) or 30 seconds (with the eyes closed). Two trails were recorded, and the best values from each of them were noted. If the participant maintains his or her position for the whole 60 seconds or 30 seconds, no second timing is performed.(9)

Dynamic balance test:

Each subject stood in the middle of intersecting lines barefoot, one leg at a time, and was asked to extend their non- dominant limb as far as possible before returning to the original standing position. The test is performed in the following order: anterior reach, 3 trails per leg, then posterolateral and posteromedial reach. Each direction included 3 trails with 1 min respite between them. On the inch tape, a notation on the touchdown spot marked the maximum reach. The trail measurements are averaged and standardized to their leg length (from ASIS to distal end of medial mallelous). The composite score was calculated by multiplying the sum of maximum reach distance by 3 times the leg length. The Y Balance Test (YBT) has strong inter-rater reliability, with intraclass correlation values of 0.99 to 1 (16).

International physical activity questionnaire:

It is a self-reported questionnaire used to determine an individual's physical activity level. This scale involves nine questions on time spent on walking, exercising moderately and strenuously, and sitting during the previous seven days. In order to determine the duration and frequency of each activity, we use minutes per day in addition to days per week. The quantity of METs-minutes/week for each category was gained by multiplying the number of minutes by 3.3 (for walking), 4 (for moderate exercise), 8 (for intense exercise), and 1.3 (for no exercise) (sitting). It is computed by adding together the METs- minutes/week= [(walk METs mindays) + (moderate METs mindays) + (vigorous METs mindays)] to get the total score. Individuals with a score of less than 600 METs are classed as inactive, while those with a score of equal to or greater than 600 METs are classified as actively exercising. A moderate concurrent validity and good test-retest reliability (ICC = 0.80) have been established for the IPAQ-SF (17).

Modified oswestry disability index:

The MODI is a disease specific disability measure used to know the level of disability. It consists of 10 questions, each question is scored from 0-5(minimum to maximum). The total score from each section is summed and then divided by the total number of questions answered and multiplied by 100 to create a percentage disability. The scores range from 0-100% with less scores meaning less disability.
MODI = (Sum of items scored/Sum of sections answered) X 100.

MODI is reliable in assessing disability in patients with low back pain (18).

Numeric pain rating scale:

NPRS is used to measure the pain intensity in the lower back region. It is a linear measurement on a straight 100 line with 10mm intervals. The score ranges from 0 to 10, where "0" indicates no pain and "10" indicates the worst pain. The NPRS has high validity and moderate reliability in pain assessment (4).

STATISTICAL ANALYSIS AND RESULTS:

The mean age of the patients was 35 years, with a standard deviation of 7.43.In the research, there were 56 females and 44 males that participated.

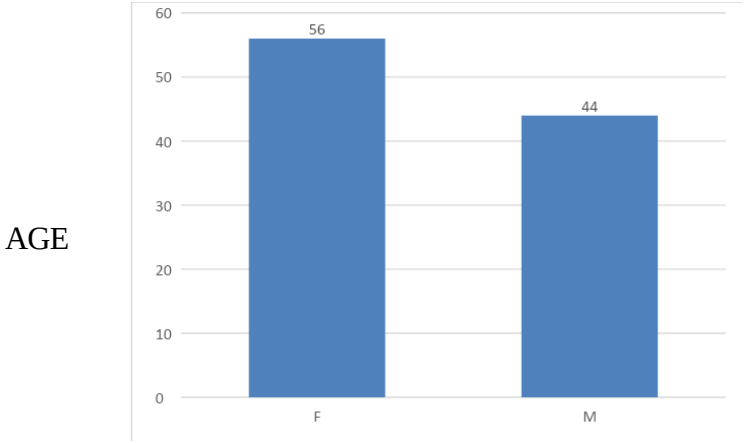

Figure 1: Representation of the demographic data of subjects

Table 1: Mean and Standard deviation of Age, MODI, NPRS.

	N	Median	Standard deviation
AGE	100	35.10	7.43
MODI	100	39.01	10.28
NPRS	100	5.43	1.42

Table 2: Mean values for physical activity, lumbar proprioception, and static and dynamic balance.

	Mean	Standard deviation
PHYSICAL ACTIVITY	629.24	452.66
PROPRIOCEPTION ERROR	At 45◦ flex- 1.68 At 60◦ flex- 1.76 At 15 ◦ext- 1.28	At 45◦ flex- 1.30 At 60◦ flex- 1.34 At 15◦ext- 0.99
STATIC BALANCE	Rt EO - 40.49 Lt EO- 35.18 Rt EC- 16.81 Lt EC- 13.64	Rt Eo - 14.03 Lt EO- 14.11 Rt EC- 9.12 Lt EC- 8.42.
DYNAMIC BALANCE	Rt Ant – 48.93 Lt Ant- 49.41 Rt PL- 52.65 Lt PL- 54.02 Rt PM- 42.92 Lt PM- 42.56	Rt Ant – 7.46 Lt Ant- 8.06 Rt PL- 8.07 Lt PL- 8.69 Rt PM- 6.14 Lt PM- 7.53

(RT EO: Right eye open, LT EO: Left eye open, RT EC: Right eye closure, LT EC: Left eye closure)

Table 3: This table shows correlation between physical activity and single leg stance test

Correlations

		IPAQ	RT_EO	LT_EO	RT_EC	LT_EC
IPAQ	Pearson Correlation	1	-.108	-.057	-.057	-.011
	Sig. (2-tailed)		.287	.572	.571	.915

(IPAQ- International physical activity questionnaire, RT EO: Right eye open, LT EO: Left eye open ,RT EC: Right eye closure, LT EC: Left eye closure)

A negative Correlation was seen between IPAQ and RT_EO (10.8% and p-value > 0.05) , IPAQ and LT_EO (5.7% and p-value > 0.05),IPAQ and RT_EC is (5.7% and p-value > 0.05),IPAQ and LT_EC (1.1%, p-value > 0.05).

Table 4: This table shows correlation between physical activity and Y balance test.

Correlations

		IPAQ	RT_Ant	LT_Ant	RT_PM	LT_PM	RT_PL	LT_PL
IPAQ	Pearson Correlation	1	.125	.097	-.050	.014	.232*	.189
	Sig. (2-tailed)		.216	.336	.624	.887	.020	.059

*Correlation is significant at the 0.05 level (2-tailed).

(RT ANT: Right anterior reach, LT ANT: left anterior reach, RT PM: Right posteromedial reach, LT PM: left posteromedial reach, RT PL: Right posterolateral reach, LT PL: Left posterolateral reach)

There was a negative Correlation seen between IPAQ and RT_Ant (12.5% and p-value> 0.05),IPAQ and LT_Ant (9.7% and p-value > 0.05),IPAQ and RT_PM (5% and p-value > 0.05), IPAQ and LT_PM (1.4% and p-value > 0.05), IPAQ and and LT_PL(18.9% and p-value >0.05).

A Positive Correlation was seen between IPAQ and RT_PL is 23.3% with a significant p-value of 0.02 <0.05).

Table 5: This table shows correlation between physical activity and proprioception error.

		IPAQ	Flex_45deg	Flex_60deg	Ext_15deg
IPAQ	Pearson Correlation	1	-.008	-.098	-.277**
	Sig. (2-tailed)		.933	.334	.005
**. Correlation is significant at the 0.01 level (2-tailed).					

Negative Correlation was found between IPAQ and Flex_45deg (0.8% with a p-value >0.05, IPAQ and Flex_60deg (9.8% with a p-value >0.05. However, there was a Positive Correlation seen between IPAQ and Ext_15deg Ext (27.7% with a significant p-value <0.05).

Table 6: This table shows correlation between NPRS and single leg stance test, Y balance test, proprioception error.

		NPRS	RT_EO	LT_EO	RT_EC	LT_EC
NPRS	Pearson Correlation	1	-.247*	-.189	-.050	.000
	Sig.(2-tailed)		.013	.060	.620	.995
		NPRS	**RT_ANT**	**LT_ANT**	**RT_PM**	**LT_PM**	**RT_PL**	**LT_PL**
NPRS	Pearson Correlation	1	-.119	-.137	-.103	-.104	-.001	-.110
	Sig.(2-tailed)		.239	.176	.308	.302	.991	.277
		NPRS	**Flex_45deg**	**Flex_60deg**	**Ext_15deg**	
NPRS	Pearson Correlation	1	.262**	.284**	.141	
	Sig. (2- tailed)		.008	.005	.161	
**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).						

There was a negative correlation seen between NPRS and RT_EO(24.7% with p-value > 0.05, NPRS and LT_EO(18.9% with p-value >0.05, NPRS and RT_EC(0.5% with p-value >0.05, NPRS and LT_EC (0% with p-value >0.05).

Negative correlation was found between NPRS and RT_ANT(11.9% with p-value >0.05, NPRS and LT_ANT(13.7% with p-value >0.05, NPRS and RT_PM(10.3% with p-value >0.05, LT_PM (10.4% with p-value >0.05, NPRS and RT_PL(0.1% with p-value >0.05, NPRS and LT-PL (11% with p-value >0.05).

Positive correlation was found between NPRS and proprioception error at flex_45deg (26.2% with a p-value < 0.05, NPRS and flex_60 deg (28.4% with a p-value < 0.05, NPRS and ext_15 deg (14.1% with p-value .161).

Table 7: This table shows correlation between MODI and Single leg stance test, Y- balance test, proprioception error.

		MODI	RT_EO	LT_EO	RT_EC	LT_EC
MODI	Pearson Correlation	1	-.278**	-.218*	-.097	-.018
	Sig.(2-tailed)		.005	.030	.335	.860
		MODI	RT_ANT	LT_ANT	RT_PM	LT_PM	RT_PL	LT_PL
MODI	Pearson Correlation	1	-.211*	-.201*	-.213*	-.214*	-.077	-.116
	Sig. (2-tailed)		.035	.045	.033	.033	.449	.251
		MODI	Flex_45deg		Flex_60deg		Ext_15deg	
MODI	Pearson Correlation	1	.150		.272**		.126	
	Sig. (2- tailed)		.136		.008		.210	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Between MODI and RT_EO there was a negative correlation with r=27.8%, p-value of <0.05.Negative correlation between MODI and LT_EO (21.8% with p-value >0.05, MODI and RT_EC (0.9% with p-value >0.05, MODI and LT_EC (1.8% with p-value >0.05).

Negative correlation was seen between MODI and RT_ANT(21.1% with p-value >0.05, MODI and LT_ANT(20.1% with p-value >0.05, MODI and RT_PM(21.3% with p-value >0.33, MODI and LT_PM(21.4% with p-value >0.05, MODI and RT_PL(7.7% with p-value >0.05, MODI and LT_PL(11.6% with p-value >0.05).

Positive correlation was found between MODI and fle_45 deg (15% with p value .136, MODI and flex_60 deg(27.2% with p-value <0.05, MODI and ext_15 deg(12.6% with p-value .210).

DISCUSSION

Our study examines the effects of physical activity, pain, disability on proprioception, static and dynamic balance, as well as their mechanical low back pain. Physical activity and posterolateral reach in the dynamic balancing test, as well as physical activity and proprioception error at 15 degrees of lumbar extension, were shown to be significantly correlated. The *p*-value for the interaction between physical activity and static balance is larger than 0.05. The current study found a link between physical activity and reach distance in the Y balance test, perhaps owing to peripheral muscle spindle changes(19), decreased or weak muscle strength(20), sedentary lifestyle.

In our study, we also found a significant correlation between NPRS and proprioception error at 45, 60 degree of lumbar flexion, it may be due to the reorganization of somatosensory cortex which compromises the proprioceptive signals or due to the inflammatory response in paraspinal muscles which causes slow muscle fibers to get transform to fast twitch fibers, altered muscle function (I,e proprioception). (21). Proprioceptive information might be disrupted as a result of tissue damage, muscle fatigue or due to nociceptive activation which interferes with motor control.(22).Reduction of lumbar muscle strength, endurance and proprioception leads to increase in lumbar disability and pain intensity.(23).

It has been reported that the mechanism of postural control has been altered in patients with chronic mechanical low back pain(24).Individuals who lead a sedentary lifestyle exhibit poor postural control as compared to those who have an active lifestyle, which may be linked to higher impairment (6).

Additionally, the findings of this study reveal a link between physical activity and proprioception errors (25). In physically inactive individuals, proprioception errors may be due to muscle atrophy and decreased strength. Our study demonstrated a link between physical exercise, proprioception, and dynamic balance. According to recent and earlier study, people with persistent mechanical low back pain have sustained discomfort for over 12 weeks(7).Chronic pain which may give rise to delayed muscle activation that decreases the ability to control the spine(24), reduced physical activity alters proprioception, which is linked to muscle spindle modifications(18),also thought to result in reduced muscle mass, decreased mobility. Regular physical activity helps in improving muscle strength which helps to control movement and enhances joint proprioception(26).

In the chronic low back patients, there was no statistical difference found in the physical activity, MODI, NPRS and static balance. A previous study found the IPAQ- SF to be extremely accurate and repeatable in people with nonspecific low back pain(6).

A positive Correlation is seen with Pearson correlation coefficient for Physical activity and proprioception error at 15 degree of lumbar extension (r =27.7%) and physical activity and posterolateral reach (r = 23.3%) which supports our hypothesis. As the age group was 18 to 45 years these results cannot be generalized to other age groups with LBA.

Multiple injuries may occur as a result of decreased joint mobility, alterations in sensory input, decreased muscular strength, and reduced proprioceptive feedback from mechanoreceptors in the trunk

and hip joint, among other factors. The effects of treatment strategies and the role of strength of hip girdle muscles on proprioception and balance in CMLBA can be focussed for future studies.

CONCLUSION:

Physical activity level was correlated with proprioception error at 15 degrees of lumbar extension and posterolateral reach in the Y balance test in individuals with CMLBA, whereas pain intensity, disability were correlated with proprioception error.

BIBLOGRAPHY:

1. Buselli P, Bosoni R, Busè G, Fasoli P, La Scala E, Mazzolari R, et al. Effectiveness evaluation of an integrated automatic termomechanic massage system (SMATH®system) in non-specific sub-acute and chronic low back pain - a randomized double-blinded controlled trial, comparing SMATH therapy versus sham therapy: Study protocol. Trials [Internet].2011;12(1):216.
2. Maas ET, Juch JN, Groeneweg JG, Ostelo RW, Koes BW, Verhagen AP, et al. Cost-effectiveness of minimal interventional procedures for chronic mechanical low back pain: Design of four randomised controlled trials with an economic evaluation. BMC MusculoskeletDisord [Internet]. 2012;13(1):1.
3. Fahmy E, Shaker H, Ragab W, Helmy H, Gaber M. Efficacy of spinal extension exercise program versus muscle energy technique in treatment of chronic mechanical low back pain. Egypt J Neurol Psychiatry Neurosurg. 2019;55(1).
4. Alsufiany MB, Lohman EB, Daher NS, Gang GR, Shallan AI, Jaber HM. Non- specific chronic low back pain and physical activity: A comparison of postural control and hip muscle isometric strength: A cross-sectional study. Medicine (Baltimore). 2020;99(5):e18544.
5. Citko A, Górski S, Marcinowicz L, Górska A. Sedentary lifestyle and nonspecific low back pain in medical personnel in North- East Poland. Biomed Res Int. 2018;2018.
6. Pengel LHM, Herbert RD, Maher CG, Refshauge KM. Acute low back pain: Systematic review of its prognosis. Br Med J. 2003;327(7410):323–5.
7. Doualla M, Aminde J, Aminde LN, Lekpa FK, Kwedi FM, Yenshu EV, et al. Factors influencing disability in patients with chronic low back pain attending a tertiary hospital in sub-Saharan Africa. BMC MusculoskeletDisord. 2019;20(1):1–11.
8. Oyarzo CA, Villagrán CR, Silvestre RE, Carpintero P, Berral FJ. Postural control and low back pain in elite athletes comparison of static balance in elite athletes with and without low back pain. J Back MusculoskeletRehabil. 2014;27(2):141–6.
9. Maribo T, Iversen E, Andersen NT, Stengaard-Pedersen K, Schiøttz-Christensen B. Intra-observer and interobserver reliability of One Leg Stand Test as a measure of postural balance in low back pain patients. Int MusculoskeletMed. 2009;31(4):172–7.
10. Alzahrani H, Mackey M, Stamatakis E, Zadro JR, Shirley D. The association between physical activity and low back pain:

a systematic review and meta-analysis of observational studies. Sci Rep. 2019;9(1):1– 10.

11. Abbasi S, HadianRasanani MR, Ghotbi N, Olyaei GR, Bozorgmehr A, Rasouli O. Short-term effect of kinesiology taping on pain, functional disability and lumbar proprioception in individuals with nonspecific chronic low back pain: a double- blinded, randomized trial. Chiropr Man Ther. 2020;28(1):1–10.
12. Sadeghi R, Mosallanezhad Z, Nodehi- Moghadam A, Nourbakhsh M, Biglarian A, Ezati K. The Reliability of Bubble Inclinometer and Tape Measure in Determining Lumbar Spine Range of Motion in Healthy Individuals and Patients. Phys Treat Specif Phys Ther. 2015;5(3):137–44.
13. Alnahdi AH, Alderaa AA, Aldali AZ, Alsobayel H. Reference values for the y balance test and the lower extremity functional scale in young healthy adults. J Phys Ther Sci. 2015;27(12):3917–21.
14. Kolber MJ, Pizzini M, Robinson A, Yanez D, Hanney WJ. The reliability and concurrent validity of measurements used to quantify lumbar spine mobility: an analysis of an iphone® application and gravity based inclinometry. Int J Sports Phys Ther [Internet]. 2013;8(2):129–37.
15. Alshehre Y, Alkhathami K, Brizzolara K, Weber M, Wang-Price S. Reliability and validity of the y-balance test in young adults with chronic low back pain. Int J Sports Phys Ther. 2021;16(3):628–35.
16. van Weering M, Vollenbroek-Hutten MMR, Kotte EM, Hermens HJ. Daily physical activities of patients with chronic pain or fatigue versus asymptomatic controls. A systematic review. Clin Rehabil. 2007;21(11):1007–23.
17. Ribeiro F, Oliveira J. Aging effects on joint proprioception: The role of physical activity in proprioception preservation. Eur Rev Aging Phys Act. 2007;4(2):71–6.
18. Lamba, D., and R. K Upadhyay. "Comparsion between modified oswestry low back pain disability questionarrie and aberdeen low back pain scale taking low back-specific version of the SF-36 physical functioning scale as a gold standard in patients with low back pain.". Asian Journal of Pharmaceutical and Clinical Research, vol. 11, no. 11, Nov. 2018, pp. 97-99,
19. Wilson BR, Robertson KE, Burnham JM, Yonz MC, Ireland ML, Noehren B. The relationship between hip strength and the Y balance test. J Sport Rehabil. 2018;27(5):445–50.
20. Freeman MD, Woodham MA, Woodham AW. The Role of the Lumbar Multifidus in Chronic Low Back Pain: A Review. PM R [Internet]. 2010;2(2):142–6.
21. Pinto SM, Cheung JPY, Samartzis D, Karppinen J, Zheng Y-p, Pang MYC and Wong AYL (2020) Differences in Proprioception Between Young and Middle- Aged Adults With and Without Chronic Low Back Pain. Front. Neurol. 11:605787.
22. Meier, Michael Lukas et al. "Low Back Pain: The Potential Contribution of Supraspinal Motor Control and Proprioception." The Neuroscientist : a review journal bringing neurobiology, neurology and psychiatry vol.25,6 (2019): 583-596.
23. Hu, Haoyu MD[a]; Zheng, Yili MD[a]; Wang, Xueqiang PhD[a,*]; Chen, Binglin MD[b]; Dong, Yulin MD[a]; Zhang, Juan MD[a]; Liu, Xiaochen MD[a]; Gong, Di MD[a] Correlations between lumbar neuromuscular function and pain, lumbar disability in patients with nonspecific low back pain, Medicine: September 2017 - Volume 96 - Issue 36 - p e7991
24. Brumagne S, Janssens L, Knapen S, Claeys K, Suuden-Johanson E. Persons with recurrent low back pain exhibit a rigid

postural control strategy. Eur Spine J. 2008;17(9):1177–84.
25. Jubany J, Danneels L, Angulo-Barroso R. The influence of fatigue and chronic low back pain on muscle recruitment patterns following an unexpected external perturbation. BMC MusculoskeletDisord. 2017;18(1):1–10.
26. Petrella RJ, Lattanzio PJ, Nelson MG. Effect of age and activity on knee joint proprioception. Am J Phys Med Rehabil. 1997 May-Jun;76(3):235-41.