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Lumbar Multifidus Muscles Function Among Patients with Low Back Pain: Virtual Reality Versus Stabilization Exercises

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ABSTRACT

Background: The multifidus muscle, the most medially located back muscle and the largest muscle that spans the lumbosacral junction provides dynamic stability to the spinal column. Virtual reality and core stabilization exercises are commonly used for balance training in musculoskeletal conditions. The knowledge regarding the effective implementation of these training protocols in patients suffering from chronic low back pain (LBP) is insufficient.

Objective: The purpose of the present study is to investigate the efficacy of virtual reality versus stabilization exercises on lumbar multifidus muscle function among patients with low back pain.

Design: Randomized, double-blind controlled study.

Participants: Sixty LBP participants were divided into three groups in a 1:1:1 ratio, 20 in each group (control group, stabilizing exercises, and virtual reality rehabilitation system). All three groups received training three days per week throughout the Six-week treatment session.

Outcome Measures: Pain evaluation by the visual analog scale (VAS), Level of functional impairments by Oswestry Disability Index and Accuracy of lumbar repositioning measurement by Biodex system were measured at baseline and after Six weeks.

Results: Six weeks following treatment, pain severity, functional limitations and discomfort levels significantly decreased in both the VRG and STG groups. The STG group and the VRG group showed a noticeably greater improvement in their capacity to precisely realign the lumbar region (p<.001)

Conclusion: Mixing stability exercises and virtual reality into training regimens is a more successful approach than conventional exercise programs for enhancing pain management and functional impairments. Additionally, virtual reality improved lumbar repositioning accuracy slightly more for people with persistent low back pain than stability training.

Keywords: Chronic Low Back Pain; Core Stabilization Exercise; Virtual Reality Exercises; Biodex System; Oswestry Disability Index

Abbreviations: LBP: Low Back Pain; VAS: Visual Analog Scale; VRG: Virtual Reality Game; ODI: Oswestry Disability Index

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Introduction

Low back pain (LBP) is still a significant concern for the public. Health concerns in affluent nations despite advances in our understanding of spinal illnesses. The issue is significant because of its socioeconomic and psychological implications and the shortcomings of many suggested preventive or cure measures (Almazrou [1,2]). Up to 75% of people will experience low back discomfort at some point with some extent of functional difficulties (De Souza, et al. [3]). With its distinct stabilizing function, the multifidus muscle, which spans the lumbosacral junction and is medially in the back, gives the spinal column dynamic stability (Zwambag [4]). It is crucial to remember that people with low back pain may have a multifidus muscle problem, which includes critical structural alterations such as atrophy and the replacement of muscular tissue with fatty infiltrates (Shahidi, et al. [5]). A lack of proprioception and abnormal recruitment patterns are two further motor control deficiencies noted (Chua, et al. [6,7]). Several studies have linked Multifidus muscle atrophy to LBP in both acute and chronic stages (Maas [8]). This muscle loss is not due to atrophy from lack of usage; multifidus activity is reflexively inhibited (Masse-Alarie [9]). Atrophy of the spinal muscles can lead to instability and recurrent back problems (Masse-Alarie [10]). Appropriate lumbosacral position sensing depends on the multifidus muscles' muscle spindles. Lower back pain (LBP) sufferers typically have a less accurate and exact sense of their position than healthy individuals.

Multifidus muscle atrophy may result in muscle spindle dysfunction, which can limit muscle spindle input and impair STG mental stability and spinal proprioception (Crawford, et al. [11,12]). Computer technology, virtual reality (VR), employs sensory feedback to provide users with an experience that mimics real-life activities and events. People can improve their motor abilities in a fashion that mimics the real world by using a three-dimensional virtual environment (Park, et al. [13]). Virtual reality systems are well known for their distinctive qualities of interactivity and immersion. Utilizing several sense channels, such as sight, hearing, and touch, requires interaction. The degree of interaction with the virtual environment, on the other hand, is related to immersion (Coburn, [14,15]). To influence the cognitive processes involved in motor control, one needs a sense of "degree of presence," or awareness of one's existence in a certain scenario. Virtual reality technology makes the development of interactive training regimens that target various muscles, joints, coordinated movements, or the complete body easier (Levac, et al. [16,17]). There is currently a dearth of research on how VR affects the function of the multifidus muscles in people with LBP. Even though much research has been done, the best course of action for treating persistent LBP and the value of different physical therapy are still debatable. A various physical therapy methods for treating LBP have also been conducted without the superior of one technique on the others (Ahmed [18-20]). This study compares the effects of lumbar stabilizing exercises and virtual reality on the multifidus muscles and the lumbar spine's ability to accurately realign pain levels, and functional limitations in people with chronic lower back pain.

Methods

Design of the Trial

Using a computer random table method, the study divided the participants evenly among the three groups in a 1:1:1 ratio. The research was randomized, controlled, and double-blinded. There were 60 participants, 20 in each of the three groups (control group, stabilizing exercises, and virtual reality rehabilitation system). Study participants were selected from the University of Hail physical therapy Clinics. The research underwent approval from the Departmental Scientific Ethics Committee. Additionally, it adhered to the comprehensive reporting standards of the unified standards for reporting trials (CONSORT), ensuring full transparency. A physical therapist from the department evaluated to determine participant eligibility.

Participants

Participants had to provide their consent and sign an informed consent form authorized by an ethics committee to be eligible for the study. The selection criteria comprised those between the ages of 30 and 50 who had been dealing with persistent lower back pain for more than three months and who graded their pain on a visual analog scale (VAS) as being between four and eight. A person was not considered eligible for the study if they had severe musculoskeletal, neural, somatic, or psychiatric disorders, was recovering from spinal surgery, was abusing alcohol or drugs, was taking part in other weight and balance-training programs, had deformities or other soft tissue injuries or bone fractures.

Patient Participation

Through a study information form, the researchers sent the 60 patients who were initially chosen thorough instructions and information regarding the trial's goals, design, intervention techniques, outcome metrics, length, and potential risks and benefits.

Interventions

With The Ethics Committee's Approval, the VRG, STG, and control groups will undergo Six- week rehabilitation programs. A physiotherapist with five years of expertise and a good skill set completed the recovery process. The study excluded ten people who chose not to participate, eleven with joint problems, four who applied for surgery, and seven who reported significant pain (VAS score greater than 8). Participants in the study utilized a device that encouraged balance exercises to strengthen their core muscles and increase their stability. They were given one-on-one instructions while seated on how to use the virtual reality game (VRG). The participants' balance was tested in this position, which also helped them become accustomed to the game's rules. A shooting game was present in the recent study. The game was played on a display screen while participants sat on a vir-

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tual platform. Following the signs, they moved their trunks forward, backward, and left to right to control the game. Participants were urged to move their spines as much as possible while staying within their discomfort thresholds. The actions in the game were rated, and as they progressed in complexity, They have become increasingly challenging. Throughout gameplay, the difficulty level is influenced by five key factors: To increase or decrease the difficulty level of the game, you can adjust several parameters like the number of opponents, the throws angle, the shooting frequency, the flashing enemies occurrence, and the number of balls encircling the player. A training session lasts 30 minutes (Wi [21]).

The STG group will perform lumbar stabilization exercises. The participants watched training films and were given time to practice the exercises before starting the workout. Students completed 15 reps in three sets with a 30-second. Break between each set and a 60-sec. Break between rounds under the supervision of a monitor (O'Sullivan [22,23]). The control group, under observation, received traditional training for their abdominal muscles. This required aggressively working the deep abdominal muscles. The back muscles (Erector Spinae, Transverses Spinalis, and inter-spinal muscles) were also exercised. 10-15 repetitions of these workouts were done each day. They also performed stretching exercises that targeted specific muscle groups, including the lumbar extensors, hip flexors, and hamstrings. Each of these 10-second stretching sessions was done three times. All three groups received training three days per week throughout the Six-week treatment session. Each participant received a comforting 20-minute hot pack therapy, followed by a 5- minute continuous ultrasound treatment at a frequency of 1 Mhz and 1.5 W/cm^2. This effective treatment will surely enhance your recovery journey. The supervising therapist decided upon exercises that went beyond the established protocol and noted in a logbook (Shahbandar [24]).

Measures of Results

The outcome measures were assessed at baseline and again Six weeks later.

a) Evaluation of Pain

The visual analog scale (VAS) is a 10 cm line with 0 representing no pain and 10 representing the worst pain. It was used to ask patients to rate how much pain they perceived. They were told to draw a mark on the line where their level of pain was.

b) Level of Functional Impairments

To assess functional disability, we employed the Oswestry Disability Index. Ten multiple- choice questions about back discomfort and everyday activities are included. Each question has six potential answers and a maximum score of 5. Based on a few chosen statements, the ultimate score is determined. Score overall: (5 questions answered) x 100%. The degree of disability is determined using a scale from 0 to 50. The score reflects the severity of the condition, with higher scores indicating more profound impairment. Scores between 20% and 40% indicate significant disability, whereas those between 0 and 20% suggest mild disability. Scores between 40% and 60% indicate severe disability, and those between 60% and 80% indicate crippling disability. Lastly, an 80% to 100% score denotes bed rest for the patient (Fairbank [25,26]).

c) Accuracy of Lumbar Repositioning Measurement

Knee blocks, leg pads, thigh straps, pelvic brace, lumbar pad, and force application straps were used to position the person in the Biodex system. The head was supported on a flexible rest while straps restrained the torso. The spinal range of motion created a neutral spinal posture at 30 degrees of lumbar flexion. We asked participants to bend their backs as far as possible to determine the range of motion. For consistency, the dynamometer was adjusted at zero degrees. Participants were instructed to recall and replicate a 30° position in a practice trial. We ran this test thrice and calculated the mean deviation each time (Wilson [27]).

Statistic Evaluation

We used Levene's test to measure the participant's demographics to confirm the study's consistency. We showed the mean and standard deviation for the outcome data. We used SPSS software to conduct repeated measures and one-way ANOVA tests to determine significant changes within groups, with a statistical significance level of P 0.05. (IBM SPSS Statistics, V 23).

Results

Participants

Thirty-two people were dropped from the initial pool of 82 volunteers, leaving 60 who were qualified for the study. Each set of 20 participants in the VRG, STG, and control groups was evenly divided. One study participant withdrew from the VRG and control groups, preventing the study from using the "intention to treat" analysis strategy. All participants' data, including age, height, weight, and BMI, were assessed and recorded before the study. One-way ANOVA was used to calculate and compare the mean and standard deviation data. The study's homogeneity was validated as no significant changes ($p > 0.05$) were found in the studied traits across the three groups (Table 1).

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Table 1: Information about the VRG, STG, and control groups' demographics.

Items	Group (CG)		Group (STG)		Group (VRG)		Comparison		
	Mean	±SD	Mean	±SD	Mean	±SD	F-value	P-value	S
Age (yrs)	43.65	± 4.9	42.8	±5.64	42.35	±4.51	0.34	0.71	NS
Weight (Kg)	78.3	± 7.75	80.2	±11.56	79.4	±10.87	0.17	0.84	NS
Height (cm)	167.7	± 6.97	169.4	±8.53	168.4	±6.56	0.26	0.76	NS

Pain Rating Scale (VAS)

The VRG, STG, and control groups did not significantly differ in pain severity during the resting period, according to the VAS analysis ($p > 0.05$). However, all three groups experienced significantly less pain after six weeks of training with various procedures (p 0.001) (Tables 2 & 3). According to the Bonferroni post hoc test and graphical display, VRG & STG pain levels were less severe than the CG's (Figure 1). The research also showed a tendency for gains in the VRG and STG categories.

Table 2: The results of the ANOVA for the three groups.

Variable	Treatment		SS	MS	F	P- value	S
Pain intensity	Pre-Treatment	Between	1.43	0.71			
		Groups					
		Within Groups	101.5	1.78	0.4	0.67	NS
		Total	102.93				
	Post Treatment	Between	319.43	159.71			
		Groups					
		Within Groups	92.5	1.62	98.42	0.0003	S
		Total	411.93				
Functional	Pre-Treatment	Between	24.45	12.22			
disabilities		Groups					
level		Within Groups	8447.45	148.2	0.08	0.92	NS
		Total	8471.9				
	Post Treatment	Between	12154.64	6077.32			
		Groups					
		Within Groups	4595.99	80.63	75.37	0.0004	S
		Total	16750.63				
lumbar	Pre-Treatment	Between	.184	.092			
repositioning		Groups					
accuracy		Within Groups	131.703	2.311	0.04	0.96	NS
		Total	131.887				

Note: SS to The sum of Squares, MS to Mean Square, P to Probability, S to Significance, and NS to Non-Significant are abbreviations used in statistics.

Table 3: Post hoc analysis of the three groups.

Post Treatment		Mean difference	P value	S
Pain intensity	CG compared with Group STG	4.35	0.0004	S
	Group CG compared with Group VRG	5.3	0.0002	S
	Group STG compared with Group VRG	0.95	0.02	S

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Functional disabilities level	Group CG compared with Group STG	23.44	0.0003	S
	Group CG compared with Group VRG	34.06	0.0002	S
	Group STG compared with Group VRG	10.62	0.0004	S
lumbar repositioning accuracy	Group CG compared with Group STG	3.01	0.0001	S
	Group CG compared with Group VRG	1.56	0.0004	S
	Group STG compared with Group VRG	1.45	0.0004	S

Note: P refers to probability, and S to significance.

Level of Functional Disabilities

Using the Oswestry Disability Index (ODI), we looked at the severity of functional limitations experienced during movement for the VRG, STG, and control groups (Tables 2 & 3). After the 6-week interventions, however, we saw substantial statistical differences (p 0.001) between the groups that were not present in the baseline data (p > 0.05). For the VRG and STG groups, we discovered stronger evidence of improvement in the level of functional limitations in the post hoc Bonferroni test (Figure 2).

Precision of Lumbar Repositioning

An examination of the effectiveness of lumbar repositioning before and after a 6-week intervention is presented in (Tables 2 & 3). The initial data did not show any differences between the three groups that were statistically significant (p > 0.05). However, from the pre- intervention to the post-intervention, all groups significantly improved in every area (p 0.001). The post hoc Bonferroni test confirmed that the VRG group showed a larger tendency toward improvement (Figure 3).

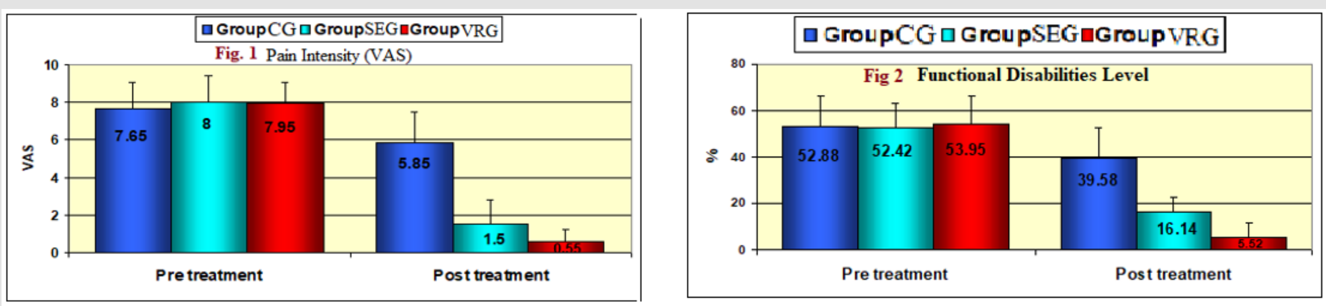

Figure 2.

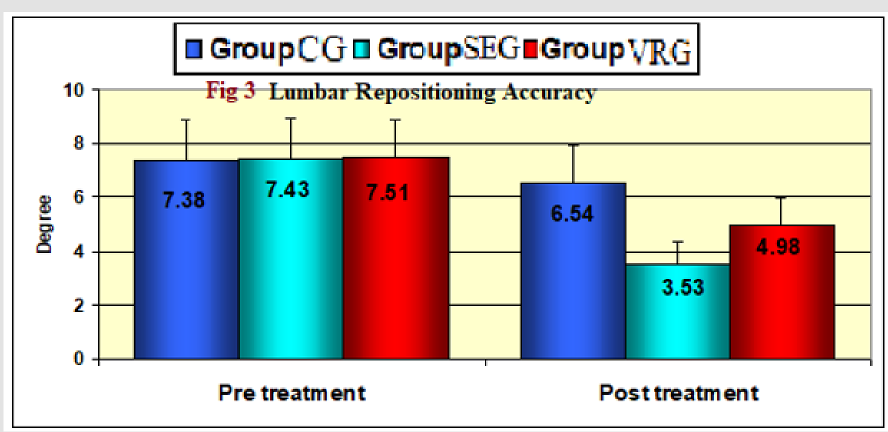

Figure 3: Lumbar Repositioning Accuracy.

Discussion

This study examined the effects of classical training, VRG, STG, and functional limitations in individuals with persistent LBP. The study measured pain severity and functional limitations using VAS and ODI, and the results were reliable and consistent. Prior investigations suggested tissue damage or injury was the reason also found that participants reported higher degrees of pain intensity and functional impairments before training (Bozorgmehr, et al. [28,29]). The paraspinal muscles become less active, the spine becomes unstable, and the trunk becomes unbalanced. Additionally, the role of biological plasticity showed the link between pain and functional limitations in those with CLBP (Hodges, et al. [30]). This study found that functional limitations and discomfort levels significantly decreased in both the VRG and STG groups. The paravertebral muscles were given priority during the exercises to accomplish this improvement. Muscle weakness is typical in people with spinal pain and lumbar disc herniation, making it difficult to maintain stability while moving or in still situations. The central nervous system may overcompensate for this deficit by inducing paraspinal muscular spasms to improve strength (Masse-Alarie, et al. [9,10]). Unfortunately, as stated by Fryer [31], this spasm can result in nociceptor stimulation, impaired muscle circulation, and metabolite accumulation, leading to increased pain and more disruption of microcirculation. It has been demonstrated that VR stimulates the sensory system and improves motor function, Improving the strength of muscle groups (Wi [21]).

This may lessen discomfort and functional limitations. VR can hasten motor learning using real-time feedback to guide players through activities and swiftly advance to the next level in games (Tieri [17]). Additionally, by modifying the environment, VR games can adjust how painful they seem (Papadopoulos, et al. [15]). Gamers' attention, concentration, memory, and working ability can all be improved, as well as their fear of movement (Jung [32,33]). These results differ from the study by Danneels, et al. [34], but are in line with other investigations. Compared to the control group, the group who underwent lumbar stabilization exercises, or STG, showed a considerable improvement in their capacity to precisely realign their lumbar spine. The exercises' impact on the lumbar spine's neuromuscular control system, resolving multifidus muscle dysfunction, and addressing proprioceptive deficits are responsible for this improvement. Exercises for lumbar stabilization are designed to retrain the muscles that support the spine, improving motor abilities and spinal STG mental support and control. These exercises are crucial for enhancing the precision of lumbar positioning and resolving position sense impairments in the proprioception system's peripheral and central components by treating multifidus muscle dysfunction. These exercises, which target the multifidus muscle specifically, cause it to contract independently from other trunk muscles, increasing its mass and cross-sectional area, which enhances the accuracy of the lumbar position and sensory units (Ahmed [18-20]).

Deficits in lumbar position sensation may result from changes in the lumbosacral spine's posture, frequently seen in people with lower back pain. Such modifications may impair muscular coordination, resulting in inaccurate body position perception. Muscle atrophy can also result in morphological alterations that have an additional negative effect on the sensorimotor cortex. Fortunately, lumbar stability exercises and skilled motor training can improve lumbar position accuracy. In patients with deficiencies, these activities improve proprioception because they cause a higher plastic change in the motor cortex than strength training does. Therefore, in patients with proprioception impairments, the remodeling of the motor cortex through skilled motor training may be related to improved lumbar position accuracy (Hlaing [35-37]). Compared to the STG group, the VRG group showed a noticeably greater improvement in their capacity to precisely realign the lumbar region. The benefits of VR therapy are credited for this improvement. VR-induced biomechanical modifications are hypothesized to physiologically affect how sensory information enters the central nervous system. The signaling capabilities of neurons in paraspinal tissues responsive to mechanical or chemical stimuli can also be impacted by changes in biomechanics between vertebral STG ments. These changes in sensory input can alter neural integration by directly changing reflex activity or impacting central neural integration within motor neuronal pools.

Ultimately, modifications to sensory input may result in modifications to efferent somatomotor function. VR alters how paraspinal tissues send sensory impulses into the brain to improve physiological function (Levac [13,16,17,21,33]). This study has the advantage of providing real-time, accurate clinical analysis for people with CLBP. However, it is crucial to consider some restrictions. First, the results were difficult to extrapolate due to the small sample size. The data interpretation did not consider other measurements like the range of motion and muscle strength. Lastly, follow-up measurements that could have offered insightful information over a long period were not carried out. Recent studies have shown that using VRE and STG in clinical settings has been quite helpful in treating CLBP, demonstrating their potency in identifying and reducing pain. However, further investigation is required to identify the neurochemical pathways and physical mechanisms behind the beneficial effects of virtual reality and stability exercises on CLBP.

Conclusion

The findings of this study suggest that mixing stability exercises and virtual reality into training regimens is a more successful approach than conventional exercise programs for enhancing pain management and functional impairments. Additionally, virtual reality improved lumbar repositioning accuracy slightly more for people with persistent low back pain than stability training.

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References

1. Almazrou SH, Elliott RA, Knaggs RD, Alaujan SS (2020) Cost-effectiveness of pain management services for chronic low back pain: A systematic review of published studies. BMC Health Services Research 20(1): 1-11.
2. Schmidt AM, Schiøttz-Christensen B, Foster NE, Laurberg TB, Maribo T, et al. (2020) The effect of an integrated multidisciplinary rehabilitation programme alternating inpatient interventions with home-based activities for patients with chronic low back pain: a randomized controlled trial. Clinical Rehabilitation 34(3): 382-393.
3. De Souza IMB, Sakaguchi TF, Yuan SLK, Matsutani LA, do Espírito Santo A de S, et al. (2019) Prevalence of low back pain in the elderly population: a systematic review. Clinics 74: e789.
4. Zwambag DP, Gsell KY, Brown SHM (2019) Characterization of the passive mechanical properties of spine muscles across species. Journal of Biomechanics 88: 173-179.
5. Shahidi B, Parra CL, Berry DB, Hubbard JC, Gombatto S, et al. (2017) Contribution of Lumbar Spine Pathology and Age to Paraspinal Muscle Size and Fatty Infiltration. Spine 42(8): 616-623.
6. Chua M, Salame K, Khashan M, Ofir D, Hochberg U, et al. (2022) Facet overhang: A novel parameter in the pathophysiology of multifidus muscle atrophy. Clinical Anatomy 35(8): 1123-1129.
7. Shahidi B, Padwal JA, Su JJ, Regev G, Zlomislic V, et al. (2023) The effect of fatty infiltration, revision surgery, and sex on lumbar multifidus passive mechanical properties. JOR Spine 6(3): e1266.
8. Maas H, Noort W, Hodges PW, Van Dieën J (2018) Effects of intervertebral disc lesion and multifidus muscle resection on the structure of the lumbar intervertebral discs and paraspinal musculature of the rat. Journal of Biomechanics 70: 228-234.
9. Massé Alarie H, Beaulieu LD, Preuss R, Schneider C (2016a) Corticomotor control of lumbar multifidus muscles is impaired in chronic low back pain: concurrent evidence from ultrasound imaging and double-pulse transcranial magnetic stimulation. Experimental Brain Research 234(4): 1033-1045.
10. Masse Alarie H, Elgueta Cancino E, Schneider C, Hodges P (2016b) Paired-pulse TMS and fine-wire recordings reveal short-interval intracortical inhibition and facilitation of deep multifidus muscle fascicles. PLoS One 11(8): e0159391.
11. Crawford RJ, Volken T, Mhuiris ÁN, Bow CC, Elliott JM, et al. (2019) Geography of lumbar paravertebral muscle fatty infiltration: the influence of demographics, low back pain, and disability. Spine 44(18): 1294-1302.
12. Gabel CP, Mokhtarinia HR, Melloh M (2021) The politics of chronic LBP: can we rely on a proxy-vote? Linking multifidus intra-Myo-cellular lipid (IMCL) fatty infiltration with Arthrogenic muscle inhibition (AMI)-induced chronic nonspecific low Back pain. Spine 46(2): 129-130.
13. Park E, Yun B-J, Min Y-S, Lee Y-S, Moon S-J, et al. (2019) Effects of a mixed reality-based cognitive training system compared to a conventional computer-assisted cognitive training system on mild cognitive impairment: a pilot study. Cognitive and Behavioral Neurology 32(3): 172-178.
14. Coburn JQ, Freeman I, Salmon JL (2017) A Review of the Capabilities of Current Low-Cost Virtual Reality Technology and Its Potential to Enhance the Design Process. Journal of Computing and Information Science in Engineering 17(3): 031013.
15. Papadopoulos T, Evangelidis K, Kaskalis TH, Evangelidis G, Sylaiou S, et al. (2021) Interactions in Augmented and Mixed Reality: An Overview. Applied Sciences 11(18): 8752.
16. Levac DE, Huber ME, Sternad D (2019) Learning and transfer of complex motor skills in virtual reality: a perspective review. Journal of Neuroengineering and Rehabilitation 16: 1-15.
17. Tieri G, Morone G, Paolucci S, Iosa M (2018) Virtual reality in cognitive and motor rehabilitation: facts, fiction and fallacies. Expert Review of Medical Devices 15(2): 107-117.
18. Ahmed UA, Maharaj SS, Van Oosterwijck J (2021) Effects of dynamic stabilization exercises and muscle energy technique on selected biopsychosocial outcomes for patients with chronic non-specific low back pain: a double-blind randomized controlled trial. Scandinavian Journal of Pain 21(3): 495-511.
19. Ahmed UA, Nadasan T, Van Oosterwijck J, Maharaj SS (2021) Effect of dynamic stabilisation exercise therapy enhanced with muscles energy technique on some selected patients outcomes and trunk muscles function in patients with chronic non-specific low back pain: a study protocol. European Journal of Physiotherapy 23(6): 344-354.
20. Mohamed Kamel E, Salah Eldin Mahmoud W, Raafat Mohamed Atteya M, Maher Gabr A, Abdelmoniem Ibrahim A, et al. (2019) Effect of core training exercises versus Lumbo- Pelvic-Hip complex strength training on the balance in mechanical low back pain patients: comparative study 16(4): 3364-3371.
21. Wi S, Kang J (2012) The effects of virtual reality interactive games on the balance ability of elderly women with knee osteoarthritis. Journal of Korean Society of Physical Medicine 7(3): 387-393.
22. O Sullivan PB, Phyty GDM, Twomey LT, Allison GT (1997) Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis. Spine 22(24): 2959-2967.
23. Richardson C, Jull G, Hides J, Hodges P (1999) Therapeutic exercise for spinal STGmental stabilization in low back pain. Churchill Livingstone London.
24. Shahbandar L, Press J (2005) Diagnosis and Nonoperative Management of Lumbar Disk Herniation. Operative Techniques in Sports Medicine 13(2): 114-121.
25. Fairbank JCT, Pynsent PB (2000) The Oswestry disability index. Spine 25(22): 2940-2953.
26. Monticone M, Baiardi P, Vanti C, Ferrari S, Pillastrini P, et al. (2012) Responsiveness of the Oswestry Disability Index and the Roland Morris Disability Questionnaire in Italian subjects with sub-acute and chronic low back pain. European Spine Journal 21(1): 122-129.
27. Wilson SE, Granata KP (2003) Reposition Sense of Lumbar Curvature with Flexed and Asymmetric Lifting Postures. Spine 8(5): 513-518.
28. Bozorgmehr A, Zahednejad S, Salehi R, Ansar NN, Abbasi S, et al. (2018) Relationships between muscular impairments, pain, and disability in patients with chronic nonspecific low back pain: a cross sectional study. Journal of Exercise Rehabilitation 14(6): 1041-1047.
29. Emami F, Yoosefinejad AK, Razeghi M (2018) Correlations between core muscle geometry, pain intensity, functional disability and postural balance in patients with nonspecific mechanical low back pain. Medical Engineering & Physics 60: 39-46.

30. Hodges PW, Barbe MF, Loggia ML, Nijs J, Stone LS, et al. (2019) Diverse role of biological plasticity in low back pain and its impact on sensorimotor control of the spine. Journal of Orthopaedic & Sports Physical Therapy 49(6): 389-401.

31. Fryer G, Morris T, Gibbons P (2004) Paraspinal Muscles and Intervertebral Dysfunction: Part One. Journal of Manipulative and Physiological Therapeutics 27(4): 267-274.

32. Jung Y, Li KJ, Janissa NS, Gladys WLC, Lee KM (2009) Games for a better life: effects of playing Wii games on the well-being of seniors in a long-term care facility. Proceedings of the Sixth Australasian Conference on Interactive Entertainment, p. 1-6.

33. Smirni D, Garufo E, Di Falco L, Lavanco G (2021) The Playing Brain. The Impact of Video Games on Cognition and Behavior in Pediatric Age at the Time of Lockdown: A Systematic Review. Pediatric Reports 13(3): 401-415.

34. Danneels LA, Vanderstraeten GG, Cambier DC, Witvrouw EE, De Cuyper HJ, et al. (2000) CT imaging of trunk muscles in chronic low back pain patients and healthy control subjects. European Spine Journal 9: 266-272.

35. Hlaing SS, Puntumetakul R, Khine EE, Boucaut R (2021) Effects of core stabilization exercise and strengthening exercise on proprioception, balance, muscle thickness and pain related outcomes in patients with subacute nonspecific low back pain: a randomized controlled trial. BMC Musculoskeletal Disorders 22(1): 1-13.

36. James G, Stecco C, Blomster L, Hall L, Schmid AB, et al. (2022) Muscle spindles of the multifidus muscle undergo structural change after intervertebral disc degeneration. European Spine Journal 31(7): 1879-1888.

37. MY Dambele, Yamsat NA, Raheem S, Akindele MO (2021) Influence of physical activity level and body adiposity on lumbar multifidus muscle fat infiltration of low back pain individuals. Bayero Journal of Pure and Applied Sciences 13(2): 13-21.

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