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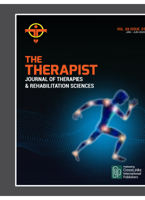

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The Role of the Spine in Posture and Movement

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Spine is one of the most vital parts of human body, plays an integral role in movement, posture and overall well-being. It works as a central axis for human skeleton, supporting the head, ribs and pelvis. Spinal health has evolved over time. This editorial explores the role of spine in maintaining proper posture and enabling movement.

Spine, also called vertebral column, consists of 33 vertebrae that are categorized into five regions. These vertebrae are separated by intervertebral discs which act as a shock absorber and allow for flexibility. The spine also serve as a protector for bundles of nerves that transmits signals between the brain and the rest of the body.

From a functional standpoint, the spine provides the stability and structure, facilitating key movements like, twisting, bending and extending. When the spine is aligned properly it provides a solid foundation. Spine also maintains the body posture which is crucial for performing daily tasks.

Posture refers to the positioning and alignment of the body while standing, sitting or lying down. When spine is properly aligned, it helps distribute weight evenly across the body. Also reduce stress on specific muscles and joints. Conversely, being in poor posture and sedentary lifestyle for a prolonged period of time, often the result of prolonged slouching, and can lead to spinal misalignments that may increase the pressure on the nerves, muscles and discs cause pain, discomfort and long-term musculoskeletal pain.

Over the past few years, research has developed the link between sedentary lifestyle and overall health. Sedentary lifestyle can lead to various health issues such as chronic back pain, digestive problems, and even mood swings.

Common issues associated with spine are degenerative disc disease, weakness in muscles and osteoarthritis which results in chronic pain, reduced mobility and leads to overall effecting quality of life. Considering these spinal issues, it is important to raise awareness and also encourage to take preventive measures such as regular physical activity and strengthening exercises.

New solutions for prevention, diagnosis and treatment of spinal cord are offered by advancement in medical sciences and technology. With, increasing awareness regarding spinal issues, it is also important to do exercise on daily basis and posture exercise as well, to prevent spinal problems. More accurate diagnosis can be provided by innovation in imaging technology, such as 3D spine modelling and high-resolution MRI.

Advancement in technology and medical research provides promising solutions for spinal health such advancement includes early diagnosis, prevention and also improved treatment of spinal issues. Regenerative medicine is an innovative approach, that is used for repairing damaged spinal disc, and it may become a standard for the treatment of spinal cord in the future.

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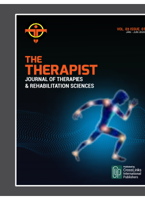

Review Article

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Emerging Paradigms in Exercise-Based Neuro-Physiotherapy for Holistic Motor and Cognitive Rehabilitation in Parkinson's Disease

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ABSTRACT

Parkinson's Disease (PD) is a progressive neurodegenerative disorder that affects motor and non-motor functions, including cognitive, emotional and autonomic systems, severely impacting quality of life. The motor symptoms of PD are successfully treated by traditional physiotherapy, but such treatments often fail to address the complexity and variety of PD. Advancements in exercise-based neuro-physiotherapy are reviewed, with a focus on innovative and multimodal approaches combining motor and cognitive rehabilitation. Technology-driven interventions like virtual reality, robotics and AI add real-time feedback and personalized care to therapy, while cognitive strategies like dual-task training and mindfulness practice address cognitive impairments. Comprehensive benefits of multimodal exercise programs that include aerobic, strength and flexibility exercises are targeted to achieve both physical and mental health. Comparative analysis of traditional, emerging and multimodal approaches shows their strengths and weaknesses and highlights the need for tailored interventions. Future directions are directed at longitudinal research, a combination of pharmacological and surgical treatments, and the use of biomarkers and AI to design personalized therapy to enhance outcomes and quality of life of PD patients.

INTRODUCTION

Parkinson's Disease (PD) is a slowly progressive neurodegenerative disorder with motor symptoms including tremor, rigidity, bradykinesia and postural instability resulting from the loss of dopamine-producing neurons in the brain. In addition to these motor symptoms, PD also has a range of non-motor symptoms including cognitive impairment, depression, anxiety, sleep disorders and autonomic dysfunction [1]. Non-motor symptoms present so severely that they significantly impair patients' quality of life and complicate disease management, and therefore require holistic and adaptable therapeutic approaches [2, 3]. Innovative, technology-driven and multimodal approaches to address the complex nature of PD have been emerging trends in neuro-physiotherapy. Balanced training and cognitive stimulation are being done with the use of virtual reality and gaming technologies, while dual-task training combines motor and cognitive exercises to improve overall functionality [4]. A more robust approach to rehabilitation is multimodal exercise programs, that include aerobic, strength, and flexibility exercises. Also, AI-powered tools are adding a layer of personalized therapy plans, making it possible for therapists to consider individual patient's needs for their treatment [5]. The purpose of this review is to explore new neuro-physiotherapy approaches in PD that may enhance motor and cognitive rehabilitation. This paper reviews the state of the science of PD rehabilitation, with a discussion of the limitations of traditional therapies and the benefits

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of innovative solutions. It is anticipated that it will demonstrate how these advances can address the PD problem and improve patient outcomes.

Pathophysiology Basis of Parkinson's Disease

Parkinson's disease (PD) is a progressive neurodegenerative disorder of the motor system characterized by a progressive degeneration of dopamine-producing neurons in the substantia nigra. PD is a complex pathology that consists of several interrelated mechanisms leading to motor and non-motor symptoms [6].

Neurodegenerative Mechanism

The loss of dopaminergic neurons in the substantia nigra pars compacta of the basal ganglia is the hallmark feature of PD. Deficiency of dopamine is essential for smooth, coordinated movement and results in the characteristic motor symptoms of PD, including bradykinesia (slowness of movement), rigidity, resting tremor, and postural instability [7]. This loss of dopamine arises because the neurons that release dopamine into the striatum, the brain's main motor control center, undergo progressive degeneration[8].

Lewy Bodies and Protein Mis-folding

Another significant component of PD pathology is the appearance of additional Lewy bodies and abnormally formed protein lumps found in neurons. Primarily, they are made up of alpha-synuclein, a protein that functions in normal synaptic vesicle function and regular dopamine release. PD involves a mis-folding and aggregation of alpha-synuclein, which ultimately characterizes the formation of Lewy bodies [9]. Deposition of alpha-synuclein in other brain regions is thought to interfere with neuronal function and contribute to neuronal death or degeneration. Cognitive decline and psychiatric symptoms in PD patients result, over time, from the spread of these aggregates from the substantia nigra to other parts of the brain, including the cortex[10].

Mitochondrial Dysfunction and Oxidative Stress

Dysfunction of the mitochondria is critical to PD pathogenesis. The cells release energy for their host cell, and mitochondrial dysfunction implies reduced energy delivery to neurons, demanding high-energy neurons of the substantia nigra. Oxidative stress contributes by accumulating reactive oxygen species (ROS), which damage cellular components (lipids, proteins, and DNA). One reason neurons die or degenerate in PD cases is the inability of neurons to repair oxidative damage[11].

Neuro-Inflammation

Neuro-inflammation is another important pathological feature in PD. Exacerbation of neuronal damage is due to activated microglia (brain immune cells) and the release of pro-inflammatory cytokines. These neuro-inflammatory responses can be the cause as well as the consequence of neurodegeneration, constituting a vicious cycle of cellular damage. Neuro-inflammation has been associated with the progression of both motor and non-motor symptoms [12, 13].

Genetic and Environmental Factors

Most PD cases are sporadic, but genetic mutations in specific genes, including LRRK2, PARK7, PINK1, and SNCA (encoding for alpha-synuclein), make one more prone to PD [14]. PD is also reported to be triggered by environmental factors like exposure to toxins like pesticides. The age of onset and severity of the disease may be influenced by genetic and environmental factors[1].

Neuroplasticity and Compensatory Mechanisms

One of the most important features in the progression of PD is the brain's attempt to compensate for dopaminergic neuron loss. Neuroplasticity is how the brain recruits other brain regions to take over lost functions [15]. However, these compensatory mechanisms stop working overtime as the disease progresses, and more severe symptoms become more apparent. Exercise enhances the formation of new neural connections and may slow down the progression of the disease[16].

Non-motor symptoms and Systemic Involvement

Although motor symptoms are the defining feature of PD, non-motor symptoms are often more associated with inducing disabling symptoms. Non-motor symptoms generally include cognitive decline, sleep disturbance, autonomic dysfunction (e.g., orthostatic hypotension), and psychiatric symptoms such as depression and anxiety. They are believed to involve widespread brain areas, including the cortex, the limbic system, and the brainstem [17]. Cognitive decline in PD is usually expressed as executive dysfunction (problems with planning and decision-making) and later dementia (problems with memory and reasoning)[18].

Motor Rehabilitation Through Exercise-Based Neuro-Physiotherapy

Management and improvement of movement require exercise-based motor rehabilitation. Body weight-supported treadmill training (BWSTT) is helpful for patients to train in walking, correct abnormal gait patterns, and increase walking speed and balance[19]. Doing these types of resistance exercises, such as with elastic bands or weights, will strengthen muscles and might slow the progression of PD when done regularly [20]. The methods increase motor skills like precision and strength, but they must be continued long-term to retain that benefit. Other therapies can be combined with these exercises to make them more effective. However, each patient's best intensity and duration still require more research [16, 21]. Using robotic aids and virtual reality (VR), people with PD are being helped with improving movement and balance using technology-assisted physiotherapy. VR creates interactive environments for balance and coordination training, while robotic devices, such as exoskeletons and treadmills, help with walking and good posture. However, these technologies are expensive or unsuitable for some patients, making therapy more engaging and effective. However, it is important to remember that traditional

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exercises such as knee extensions, sit-to-stand, and backward walking remain important to improving strength, balance, and stability. Combined, these methods present a better approach to managing PD and a better quality of life for patients [16, 19]. It overviews key techniques such as body weight, body-supported treadmill training (BWSTT), resistance training, robotic assistance, virtual reality (VR) therapy, and dance therapy and describes their features, benefits, and limitations. Studies have been conducted that were intended to enhance PD patients' strength, balance, gait, coordination, and flexibility, thereby contributing to perhaps achieving mobility and/or better quality of life. The table further addresses the challenges these therapies can encounter, for example, its cost, patient-specific, and others, and uses insights from recent research sources on these issues. A summary of various motor rehabilitation strategies for PD patients is shown (Table 10.

Table 1: Motor Rehabilitation Techniques in Parkinson's Disease

Technique	Key Features	Benefits	Limitations	Sources
Physical Therapy (PT)	Involves exercises to improve strength, flexibility, balance, and gait. Tailored to individual needs based on PD stage	Improves motor function, reduces rigidity,increases mobility, enhances balance and posture	May require frequent sessions for long-term improvement. Limited by physical space or resources	[20,21]
Gait Training	Focuses on walking improvements, including cadence, stride length, and reducing freezing of gait (FOG). Can use auditory or visual cues to aid movement	Reduces FOG episodes, improves walking speed and stability, decreases fall risk	May require continuous practice to maintain gains. Some patients may not respond to cues	[22,23]
Strength Training	Involves resistance exercises designed to build muscle mass and strength, often using weights or resistance bands	Enhances muscle strength, reduces rigidity, improves overall mobility, and reduces falls	Potential for overexertion or injury if not properly managed. Requires supervision	[24,25]
Dance and Rhythm Therapy	Dance styles (e.g., tango, ballet) or rhythmic exercises (e.g., drumming) that focus on coordination, posture, and rhythm	Improves coordination, balance, flexibility, and motor planning.Reduces motor symptoms and boosts mood	May be difficult for patients with advanced PD or severe rigidity. Accessibility issues	[26,27]
LSVT BIG Therapy	Amplitude-based therapy with exercises emphasizing large, exaggerated movements to overcome rigidity and bradykinesia	Increases motor amplitude, improves gait, reduces bradykinesia, enhances balance and overall mobility	Requires intensive and sustained effort over weeks/months. May be tiring for some patients	[28]
Cueing Techniques	Use of external auditory, visual, or tactile cues to help patients initiate and perform movements, especially during freezing episodes	Reduces freezing episodes,improves movement initiation and execution, enhances motor control	Not all patients respond equally to cues. May not be effective in severe PD cases	[29]
Aquatic Therapy	Exercises performed in a pool, using water resistance and buoyancy to reduce joint impact while enhancing strength, flexibility, and motor coordination	Enhances strength, balance,and flexibility. Provides a low-impact alternative to land-based exercises	Limited availability of facilities. May be challenging for those with severe mobility issues	[30]
Robotic-assisted Gait Training	Use of robotic devices or exoskeletons that assist in walking, helping patients relearn gait patterns through repetitive movements and support	Promotes neuroplasticity, improves gait, walking speed, reduces bradykinesia and fall risk	High cost, limited availability in clinics, may require training to use effectively	[31]
Treadmill Training	Walking exercises performed on a treadmill with or without body support. Often includes high-speed walking to improve gait and cardiovascular endurance	Improves cardiovascular fitness, walking speed, gait, and endurance. Reduces fall risk	May cause discomfort or fatigue, especially in advanced stages of PD.Requires careful monitoring	[32]

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Neurofeedback	A technique that trains patients to self-regulate brain activity using real-time feedback on brainwave patterns. Often used to reduce tremors and improve focus	Reduces tremors, improves motor function, enhances focus and attention,potentially improves cognitive functions	Expensive, may require specialized equipment and trained clinicians. Limited long-term data	[33]

Cognitive Rehabilitation: Neuro-Physiotherapy's Dual Role

These cognitive problems memory loss, or trouble planning or multitasking in PD can make daily life harder and make movement worse [34]. Many cognitive challenges like focus, planning movements and remembering motor patterns can reduce the success of therapy [35]. This neuro-physiotherapy addresses the cognitive as well as the motor problems together. Often, it uses exercises that increase attention, memory, problem-solving, and movement tasks. Patients can work on both thinking and movement at the same time via techniques such as dual-tasking training or virtual reality. The combination of approaches improves independence and quality of life for people with PD [33, 36]. Advanced neuro-physiotherapy techniques for PD address both motor and non-motor symptoms (Table 2). Dual-task training involves movement and thinking tasks, and patients learn to multitask, pay attention, and become more independent [4, 37, 38]. Meditation and yoga are mindfulness practices that reduce anxiety and depression and increase emotional stability and movement [39-42]. In addition, these methods may also produce positive brain changes, such as increased grey matter in important areas. Although a promising but new method, neuro-feedback, which uses brain activity feedback to improve control has been used [43-46]. But these techniques look promising and further research is needed to validate their long-term benefits and develop effective treatment plans.

Table 2: Summary of cognitive rehabilitation strategies and their neurophysiological targets.

Technique	Key Features	Benefits	Limitations	Sources
Dual-task Training	Combines cognitive and motor tasks to improve overall function	Improves multitasking ability Enhances attention and executive functionPromotes independence in daily activities	Optimal protocolsstill under research Challenging for advanced cognitivedecline patients	[4, 37, 38]
Mindfulness Interventions	Incorporates mindfulness meditation and yoga to address psychological and motor symptoms	Reduces anxiety and depressionImproves emotional stability and cognitive performance Enhances motor symptom management	Efficacy varies among individuals Long-term effects need more study	[39,41]
Neuro-feedback	Uses real-time brain activity feedback to improve self-regulation of neural processes	May improve motor control and reduce tremors Enhances cognitive and emotional regulation	Research in early stages Long-term effectiveness remains unclear	[43,44]

Role of Multimodal Exercise Programs

PD holistic rehabilitation combines exercises to assist in movement and general health. These programs combine aerobic exercises (heart disease, brain protection), strength training (muscle building and balance), and flexibility exercises (reduce stiffness and improve motion). Group-based or individualized programs are also available to patients. Social interaction and motivation are significant in group sessions, while an individual can focus on his needs and specific symptoms in the case of personalized plans. It is a case of some centers using both approaches. The best results come together. This combined method helps manage PD symptoms and improves quality of life [47]. Multimodal exercise programs have shown significant benefits for managing various conditions, including PD and cancer. In a randomized trial in Hong Kong, 138 PD patients were assigned to mindfulness yoga or stretching and resistance exercises. The yoga group had significant improvements in depression, anxiety, motor function (MDS-UPDRS III scores reduced from 34.9 to 21.1), and quality of life [40]. For pancreatic cancer patients, a study of six older individuals undergoing chemotherapy found that five completed the program, showing increases or maintenance in lean mass (0.1%-4.4%), reduced fat mass (0.4%-8.6% in four patients), improved muscle strength (7.1%-75% in four to five patients), and better physical abilities like sit-to-stand and backward walking [48]. A trial in Spain with 44 cancer patients (mean age 63.46 years) also showed that those in a multimodal exercise program experienced lower fatigue, better functional capacity (SPPB scores), and reduced dependency (Barthel Index) over the control group [49]. These experiments reveal that both physical and mental health are enhanced by multimodal exercise programs for diverse patient populations.

Technology and Innovation in Neuro-Physiotherapy

The field of neuro-physiotherapy has begun to transform its approach to the rehabilitation of Parkinson's Disease

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(PD) patients concerning technology. Technology offers personalized, engaging, adaptive therapies that improve motor and cognitive rehabilitation. Specific technologies applied directly include virtual reality (VR), rehabilitation robotics, wearable devices and sensors, artificial intelligence (AI) and machine learning, brain-computer interfaces (BCIs), and neuro-feedback, as well as integrating technology with traditional therapies[50-52].

Virtual Reality (VR)

VR is a valuable tool for PD patient's motor and cognitive rehabilitation. VR systems provide immersive environments where patients can practice movements, balance, and coordination tasks in a controlled and safe space. For example, on virtual trails or obstacle courses, walking will also improve gait and decrease the frequency of PD freezing episodes, a typical motor symptom of PD. Furthermore, VR systems include cognitive challenges, such as dual tasking (e.g., walking and solving puzzles), to train executive functioning and multi-tasking [4]. Studies have demonstrated that VR-based therapies can improve motor symptoms such as stride length, walking speed, and balance, as well as non-motor symptoms such as apathy and depression. VR also provides immediate feedback and engaging exercises, thus increasing patient motivation and adherence to therapy. In the advanced stages of PD, however, VR is likely to have difficulties in sensory integration and cognitive overload, so the effectiveness of VR at this stage of PD needs to be investigated[49].

Robotics in PD Rehabilitation

One of the significant roles played by robotic devices such as exoskeletons, robotic arms, and treadmills is to help PD patients regain functional independence. For example, robotic-assisted gait training (RAGT) assists patients in learning walking patterns again by simulating natural gait mechanics. These devices provide a form of high-intensity training that is also consistent, which helps improve postural control, decrease tremors, and reduce bradykinesia (slow movement) [52]. Additionally, robotic systems can enable genuine time assistance and resistance oriented to the patient's abilities to promote neuroplasticity and muscle strengthening. Biofeedback systems have also been integrated with robotic therapies, allowing PD patients to see their movements and chronic their progress. Although these devices are quite effective, their high cost and limited accessibility hinder their widespread use[53].

Wearable Devices and Sensors

Accelerometers, gyroscopes, and smartwatches have become wearable technologies that can help monitor and treat symptoms of PD. In real-time, these devices track movement and tremors as well as gait patterns so that the therapists can track the progression of symptoms and the effectiveness of their interventions. For instance, wearables can pick up on the freezing of gait episodes to deliver auditory or vibratory cues to patients to make it through. Furthermore, wearable devices allow for ongoing monitoring in a nonclinical setting, providing important information about daily motor fluctuations and non-motor symptoms such as sleep disturbance and fatigue. Therefore, this data supports the customization of therapy plans and precision of care for PD patients[54].

Artificial Intelligence (AI) and Machine Learning

Analysis of patient data opens the doors of AI as a game changer in PD rehabilitation to personalize therapy plans. Machine learning algorithms can predict PD symptoms' progression, determine what works best for different individuals, and help select the most effective interventions. Therefore, AI-driven systems can analyze gait patterns based on the treadmill settings or determine the proper robotics assistance levels for specific therapy sessions. AI also helps make early diagnoses by analyzing imaging and biomarker data so early interventions can be started sooner. Additionally, it enables remote care via virtual coaching systems, which enable AI to provide real-time feedback on how exercise performance can be improved and thus recommend an adjustment, ensuring consistency and quality of therapy provided to PD patients in the home[52, 53].

Brain-Computer Interfaces (BCIs) and Neuro-feedback

The solutions to PD symptoms are promising solutions given by BCIs and neuro-feedback systems. PD patients can, with BCIs, use brain signals to control assistive devices like robotic arms, giving independence to people who are severely motor impaired. Instead, Neuro-feedback trains patients to control brain activity that could reduce tremors, mood, and cognitive functioning. Specifically, these systems are helpful for non-motor symptoms in PD, depression, and anxiety, which are very common in PD. In addition to modulating brain activity, neuro-feedback may also improve executive functions, including attention and memory, which are impaired in PD patients[43].

Combining Technology with Traditional Therapies

Although technological innovations may bring many benefits, their combination with mainstream physiotherapy practice provides the best results for PD patients. For example, with strength training exercises, VR and robotics can be combined, or wearables can provide biofeedback to a person during yoga or mindfulness sessions. The hybrid approach guarantees that motor and non-motor symptoms are treated holistically[55].

Comparative Analysis of Approaches

Each traditional, emerging, and multimodal approach has strengths and challenges (Table 3). It is simple, cost-effective, and easy to use but not flexible and scalable. In addition to VR and AI, other emerging approaches offer personalized treatments, real-time feedback, and greater engagement, but are expensive, complex, and have limited long-term efficacy data. Combining different methods in multimodal approaches can improve accuracy and engagement but is resource-intensive, more challenging

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to implement, and may be overwhelming for some patients. The high costs of diagnosis and treatment, limited access, and patient compliance are challenges that call for a balanced approach that combines traditional and innovative methods and is appropriate for the patient and resources[56].

Table 3: Comparative Analysis of Neuro-Physiotherapy Paradigms Based On Key Parameters

Variables	Traditional Approaches	Emerging Approaches	Multimodal Approaches
Efficacy	Effective for specific tasks but lacks contextual adaptability	Highly effective with personalized treatments but limited long-term data	Comprehensive and robust but may overwhelm some patients
Cost	Low Cost	High cost due to advanced technology	Very high cost
Accessibility	Widely accessible in most settings	Limited accessibility in resource-constrained settings	Variable accessibility depending on resources and expertise
Engagement	Limited patient engagement	High patient engagement with real-time feedback	Enhanced engagement through diverse methods
Flexibility	Low flexibility	Moderate flexibility	Highly flexible for various needs
Resource Requirements	Minimal resource requirements	High resource requirements	Very high resource requirements

CONCLUSIONS

Parkinson's disease (PD) is a complex motor and non-motor challenge that requires holistic and creative rehabilitation. Motor symptoms respond well to traditional physiotherapy, but the need remains for more adaptive physiotherapy for cognitive impairments and the progressive nature of the disease. Among emerging technologies, virtual reality, robotics, artificial intelligence, and multimodal exercise programs promise personalized, engaging, and complete care. These advancements combine motor and cognitive rehabilitation to provide physical and mental health. Nevertheless, resource demands and accessibility remain intractable. Longitudinal research, integrating therapies with pharmacologic and surgical treatments, and using biomarkers and AI to personalize interventions are the future directions for this work. A balanced, patient-centred approach to PD can significantly improve outcomes and the quality of life of PD patients.

Authors Contribution

Conceptualization: SI
Methodology: SI, ZZ
Formal analysis: SI, ZZ
Writing, review and editing: SI, ZZ

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Conflicts of Interest

The authors declare no conflict of interest.

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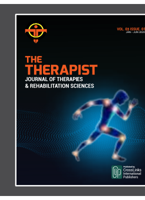

Review Article

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Impact of Core Stability Training on Football-Specific Performance and Injury Prevention: A Review

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ABSTRACT

Enhancing agility, balance, strength, and injury prevention are all made possible by core training, which is essential for football players. This review assesses the efficacy of football players' core training regimens. Both general and sport-specific core training considerably enhances athletic performance and lower the risk of injury, according to the analysis by positively impacting the agility, balance, and speed. The risks of injury are also prevented by such trainings by increased neuromuscular efficiency of athletes, the strength of stabilizing muscles augments, improved body alignment, appropriate load distribution and shock absorption and reduction in compensatory movements. Different exercises are incorporated in the core stability trainings of footballs including plank variations (front, side, reverse), bird-dog, dead bug, glute bridges, medicine ball rotational throws, Russian twists, cable woodchoppers, mountain climbers, single-leg balance exercises and lateral band walks. Variations in training methods and study designs, however, point to a lack of standardization in procedures. The review emphasizes the necessity of specialized core training interventions as well as additional study into their long-term effects on football players of various ages and abilities. Practitioners can more effectively create core training plans to maximize player performance and well-being by filling in these gaps.

INTRODUCTION

Football players' development of power is largely dependent on their level of physical fitness, which includes their strength, speed, and endurance. Soccer is a high-intensity sport that requires both anaerobic power and aerobic endurance because it mixes constant movement with intense activity bursts [1]. A player's performance is greatly impacted by these variables, with VO2 max being essential for facilitating recovery from repeated anaerobic efforts during a game. Core training has become more well-known in recent years because of its beneficial effects on everyday tasks and sports recovery [2]. Because they serve as the basis for stability and mobility, the core muscles are crucial for achieving peak athletic performance. Often referred to as the "proximal stability for distal mobility," the core is the central structure that connects the body and includes the hips, pelvis, and waist [3]. The diaphragm, rectus abdominis, erector spinae, internal and external obliques, multifidus, pelvic floor, and transverse abdominis are important core muscles. Core strength is also influenced by supporting muscles like the cervical, lumbar, deep rotator, and quadratus lumborum [4]. Football players can perform at their best for the full 90 minutes of a game or even for up to 120 minutes during extra time thanks to the balance, strength, and endurance these muscles provide [5]. For effective force generation and transfer during dynamic movements, core stability which is the capacity to regulate the trunk's position and motion over the pelvis and legs is essential. While a weak or unstable core can hinder performance and raise the risk of injury [6], a strong core improves energy transfer from the ground through the lower body, trunk, and upper body. In addition to helping athletes perform at their peak while

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lowering their risk of injury, core stability is essential for controlling spinal loads and transferring force between the upper and lower bodies [7]. Planks, side planks, bridges, side-lying hip abductions, oblique crunches, straight leg raises, cycling motions, windshield wipers, squats, glute bridges, superman variations, and hip extensions are among the exercises that football players frequently include in their training regimens to increase their core stability[8].

The purpose of this study is to investigate how core stability training exercises affect football players' overall performance.

The hips, lower back, and abdomen make up the core region. Furthermore, the core area is defined as the space between the knees and the ribs. According to another description, lumbopelvic hip complex is regarded as the core. A more recent method defines the core idea as a training program specifically created to promote the integrity and activity of the muscle groups that make up the body, support and wrap the spine, and actively participate in strength transitions in the upper extremities [9]. The most popular training technique used by football players to improve their strength performance is core training [10]. In this regard, core training has become a popular and successful approach in training programs in recent years which impacts an athletic body in several ways.

Impact on Agility, Balance, and Speed

Athletic performance receives fundamental enhancement from core stability training since football demands high agility, balance, and fast movements. Football players need to perform various complex movements, such as rapid changes of direction and sprinting, along with controlled slowing down of their motion when faced with different physical obstacles. Essential strength training activates positive physical effects through a solid movement base and protects players from injuries. The quick and effective direction modifications that football players must demonstrate depend on agility. The ability to perform agility depends directly on neuromuscular control and strength, together with balance, which requires a robust core structure. Scientific evidence shows that core conditioning improves neural coordination, which results in enhanced athletic agility during acceleration and deceleration functions [11]. When lower and upper body forces link properly through core training, it leads to enhanced movement quality and lowered expenses from quickly changing directions [12]. Agility performance improved significantly among athletes who took part in core stability training during eight weeks, according to results measured through the T-test and 5-10-5 shuttle run against a control group, as described in former research [13]. Core stability exercises provide sports competitors advantages when playing football because they perform well in sports that need constant directional changes.

Core stability training enhances balance requirements to a critical level. Football players who maintain balance through their training sessions have better control of their bodies while performing demanding dynamic movements when they are tackling, jumping, and landing [14]. Stability exercises that use unsteady equipment, such as balance boards and Swiss balls, help improve body comprehension, thus enhancing overall balance control. Because they target core stability as well as leg balance, single-leg exercises boost the stability of ankle and knee joints. Such training proves valuable for football players since it minimizes the occurrence of non-contact injuries. Athletes who maintain superior balance have better control of their bodies and avoid losing ball control during raging situations with competitors. Postural adjustments are made to realign the centre of gravity inside the support base to prevent loss of balance and falls. In order to maintain the lumbar spine, these postural changes require the activation of core muscles. The postural control capability of players improves through core stability because it allows them to execute technical moves with precision during challenging situations[15].

Football success in defensive plays depends equally on speed, and both elements connect directly to strength in the core region [16]. The core functions as a transmission that connects the upper body segments to the lower body segments, thus enabling effective force transfer during sprinting movements. The ability to sprint depends on stride length and frequency together with ground reaction force, but all these elements strengthen when the core remains stable. The force that is generated in the internal abdominal pressure by the contraction of the core muscles is known as core strength. The spine is strengthened when the core muscles are activated and stabilize the core. Athletes who have developed core muscles are better able to handle the demands of training and execute technical motions with higher efficiency Core weakness causes energy wastage that diminishes the total sprint speed capability while making athletes susceptible to injuries from imbalanced movement patterns [18]. The research conducted by Stanton et al. (2004) demonstrates how core stability assesses sprint performance. Research proved that athletes who performed core stability exercises experienced substantial progress during their 20-meter sprint distances. Training core stability aims at making deep trunk muscles strong enough to properly align the pelvis and minimize trunk rotation while sprinting. A more efficient running gait occurs together with speed improvements[19, 20].

Impact on Football-Specific Skills

Performance of football-specific actions like kicking along with dribbling, passing, and shooting demands proper technical skills, strength abilities, and reasonable coordination control [21]. The skills improve through core stability training since it enhances movement efficiency together with postural control for better precision and power execution. Kicking requires precise movement coordination, beginning at the core and moving force

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between the hip and the knee, then ending in the ankle. An efficient core base enables an athlete to produce their peak power output while they strike accurately without losing stability. The core's weakness or instability determines that kicking performance will decrease and lead to increased injury risk through compensatory movements [22]. Multiple studies have confirmed that planks and rotational medicine ball throw as stability exercises boost kicking power together with accuracy improvement. For successful dribbling, players need to demonstrate excellent control, agility, and balance skills. The training of core stability enables athletes to develop the necessary coordination and stability required when handling the ball past opposition players. The performance of dribbling becomes better when players perform exercises that build their lateral stabilizing abilities, including side planks and lateral band walks [23, 24]. Balance security during quick direction modifications is enhanced due to improved stability, which allows players to hold onto the ball in demanding situations. Russian twists, along with cable woodchoppers, help athletes develop rotational strength capabilities, which leads to better force production efficiency. The critical combination of power balance and coordination in shooting benefits directly from an efficient core [25]. Competent core stability allows athletes to produce higher force outputs that simultaneously preserve their accuracy in their plays. It has been demonstrated through their study that core stability training during six weeks led participants to achieve quicker kicking speeds than the control group maintained no core training. Laboratory tests show that core training enhances more than injury prevention as it promotes specific improvements in football performance outcomes [26].

The development of defensive capabilities, including tackling and body positioning, becomes more effective when core stability improves. Athletes who defend the field need to stay balanced during physical encounters with opponents Multi-directional force transmission in athletes becomes compromised when core stabilizing muscles are weak, which results in a higher risk of opponents evading them or destabilizing their position. The improvement of trunk strength through stability exercises enables defenders to position their bodies effectively and control their movements against external resistance. The performance context benefits from core stability training, which decreases performance-related injuries. The key function of core stability training exceeds performance enhancement since it serves as an essential tool for injury prevention. Football athletes sustain frequent injuries to their hamstrings along with groin issues and lower back pain mainly because of inadequate core strength and stability. A properly designed core stability exercise regimen fixes muscle inequality while identifying asymmetrical patterns to improve neuromuscular command for decreased athletic injuries [27].

Targeted core exercises help prevent hamstring strains since poor pelvic control usually causes them. The deep abdominal muscles, together with poor lumbopelvic stability, lead to groin injuries [28]. Core stability training builds up muscle strength, which leads to a decrease in sports-related injuries in athletes. The prevention of injuries strongly depends on functional performance abilities. Dynamic training of core stability enables athletes to improve their athletic qualities and decrease their risk of suffering football-related injuries. Core training delivers a double advantage as it stands vital for every football conditioning program [29].

Core Stability and Injury Prevention

Current football practice requires an equal emphasis on guarding against injuries as it does on performance improvement. The practice of core stability training represents an essential preventive measure against lower limb injuries, which include anterior cruciate ligament (ACL) tears alongside hamstring strains and groin injuries. The core muscles build athlete capabilities to maintain posture while distributing natural body weight evenly across the joints to stabilize the lumbopelvic area in active movements. Such factors both reduce sports-related injuries and sustain athlete performance across an extended period [30]. Core stability stands as a fundamental factor for injury prevention because it performs two vital tasks, including neuromuscular control and joint stability, together with the elimination of movement compensations.

Neuromuscular Control and Postural Stability

Neuromuscular control represents a body system's natural response to external forces as it prevents instability during stability-maintaining movements. The neuromuscular efficiency of athletes increases simultaneously with improved proprioceptive feedback when they have a strong core since this allows them to react swiftly to various movements or directions. Firm core control decreases accidental uncontrolled movements,which limit the occurrence of injuries [31, 32].

Joint Stabilization

The deep stabilizing core muscles comprising transversus abdominis and multifidus and pelvic floor muscles around the spine and pelvis serve to give support. Weak activation of these muscles or their improper function leads to high-stress levels in the hips along with knees and ankles, thus heightening the chances of getting injured. Training the core stability system enhances the strength of stabilizing muscles, therefore improving body alignment and reducing pressure on outer body parts [33].

Load Distribution and Shock Absorption

The proper activation of core muscles allows athletic forces to spread out evenly through the whole body structure. Such training distributes physical stress evenly throughout the body because it avoids placing excessive pressure on key locations such as knees and lower back. Athletes with weak core muscles tend to develop lower

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back pain along with hamstring injuries because their running movement causes excessive lumbar flexion and pelvic tilt. Training the core helps maintain proper body movement patterns while decreasing the risk of developing headaches from repeated wear and tear[34].

Reduction in Compensatory Movements

Body compensation leads to inefficient movement patterns when core muscles remain weak because it forces other muscle groups to take over, thus creating higher risks of injury. Excessive internal hip rotation, together with adduction because of core weakness, leads to ACL injuries in cutting movements. The re-establishment of muscle balance by core exercises helps prevent non-optimal body mechanics and enhances every aspect of one's movement quality[35].

Reduction in the risk of Common Football Injuries

ACL injury is one of the most severe and widespread problems that affect football players. Since the core region's muscles are found in the middle of the body, they actively participate in most bodily motions. Sudden change or pivoting motions combined with cutting activities lead to most of these injuries. Scientific studies demonstrate that weak core muscles create poor pelvic and trunk control, which increases valgus knee collapse occurrence during ACL injury events. Valgus knee collapse acts as one of the main contributors to ACL injuries. The performance of core stability exercises improves trunk stability, which minimizes knee valgus motion and reduces

It has been established that individuals who possessed weak core stability demonstrated a substantially elevated chance of sustaining ACL tears compared to those exhibiting adequate core strength and control abilities. The integration of balance-oriented core exercises as part of training helps substantially decrease injury risks[36, 37].

Hamstring strains affect many football athletes when they perform sprinting or rapid acceleration movements. The ability to maintain core stability functions as a preventive measure for hamstring strains by supporting pelvic stability maintenance throughout the body. When core control is weak, it causes an anterior pelvic tilt, which creates excessive tension in the hamstrings when athletes move at high speeds[38].

The deep abdominal muscle strengthening exercises that support neutral pelvic positioning contribute to protecting hamstrings from potential injuries. Several studies validate the efficiency of Nordic hamstring exercises alongside core stability training protocols to stop these types of injuries[39].

Football athletes commonly endure groin injuries, specifically involving adductor strains, when performing kicking actions together with lateral movements. Weak core muscles increase the risk of groin injuries since they fail to properly stabilize the pelvis during energetic movements. Training the core stability system, which includes both adductors and lower abdominals, will diminish the risk of groin damage. One should perform side planks with adduction together with resisted leg lifts as these exercises bring the most benefit[40].

Training Protocols and Approaches

Core stability exercises include static, dynamic, and functional movements as subclasses (Table 1). A successful core stability training program needs to incorporate various exercises from different groups to enhance stability and performance results.

Table 1: Core Stability Exercises

Subclasses	Characteristics	Examples
Static	Endurance building and activation of deep core muscles are the main objectives of these exercise protocols	Plank Variations (front, side, reverse), Bird-Dog, Dead Bug, Glute Bridges[41]
Dynamic	These exercises are with movement because they enhance functional strength while establishing stability	Medicine Ball Rotational Throws,Russian Twists, Cable Woodchoppers, Mountain Climbers[41]
Functional Core Exercises	The exercises replicate movements from football, which helps athletes connect their core strength to actual performance in the game	Single-Leg Balance Exercises, Lateral Band Walks,Unilateral Kettlebell Carries, Agility Drills with Core Activation[42]

Numbered periods under periodization enable core stability training to achieve its maximum benefits by preventing athlete overload. Structured programming allows core strength to advance through multiple phases, which helps athletes adequately recover during development[42]. The training program is split into three distinct phases as part of the periodization system: the preparatory phase and the competition phase, with a separate recovery phase(Table 2)[43].

Table 2: Three Distinct Phases as Part of The Periodization System

Phase	Focus	Duration
Preparatory Phase	Focus on building foundational strength and endurance.Emphasize static and dynamic core exercises.	Train 2–3 times per week.
Competition Phase	Shift focus to sport-specific and functional core exercises. Sports movements that replicate those in football should be included in exercises	The number of workouts should decrease to 1-2 sessions weekly since overexertion is possible.
Recovery Phase	Exercise training should concentrate on movements that enhance flexibility alongside the prevention of injuries.Reduce the intensity and volume of core	2–3 times per week.

Integration into Football Training

Proficient football training must include core stability exercises as integral components that should be implemented during every regular training session. The

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first stage of core stability training includes dynamic core activation exercises in usual warm-up period and static core exercises along with flexibility work completed through the cool-down period. Coaches must make physical practice include multisegmental movements that replicate fundamental football athletic requirements [26].

Core stability research has expanded significantly during the last twenty years because it affects injury prevention and athletic performance. Research methodology issues create barriers to the standardization of experimental findings, which prevents their practical usage. The research challenges in core stability originate mainly from inconsistent definitions, dissimilar training methods, and divergent assessment instruments and performance evaluation measures used by different studies [44]. The reliability and validity of core stability research depend on resolving these fundamental problems. Core stability research faces its main obstacle due to the absence of clearly accepted definitions regarding core stability. Secondary sources create two distinct definitions of core stability: first, it describes movement ability to hold stable spinal and pelvic alignment, and second, it defines force capacity between upper and lower body segments. The absence of a clear definition of core stability prevents proper comparison of research findings and standardization of training approaches between studies. Multiple training methods differ for core stability protocols through their exercise choices and their parameters of intensity and frequency along with duration. Research investigations either concentrate on non-dynamic strength work via planks and bridges or target functional movements matching sports conditions. The heterogeneity of core training intervention design methodologies creates challenges for researchers when they process data and prevents the effective implementation of study results [45]. Researchers who examine static core exercises in their investigation generate dissimilar results from researchers performing dynamic intensity-based core training, although they use equivalent performance metrics. Research findings become complicated because scientists analyzed different populations, from recreational athletes to elite football players. Core stability requirements, together with their associated training responses, display substantial variability between different groups of participants. Studies that do not take into consideration population variables risk forming universal conclusions that might not apply to entire population groups.

Future studies should concentrate on creating standardized core training regimens specifically designed for football in order to overcome these constraints. Particularly needed are longitudinal studies examining the long-term impacts of core training on performance and injury prevention across various age groups and skill levels. Additionally, combining core training with other conditioning regimens like resistance training and plyometrics may offer a more comprehensive strategy for improving performance.

CONCLUSIONS

To conclude, core training is an essential part of contemporary football training plans. Beyond just improving physical performance, it also helps players become more resilient and healthier overall. Coaches and practitioners can use core training to help football players at all levels reach their full potential by filling in the gaps in current research and practice.

Authors Contribution

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Methodology: LB
Formal analysis: HFT
Writing review and editing: SS

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Review Article

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Biomechanical Changes in Football Players Post Functional Strength Training: A Review paper

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ABSTRACT

The assessment of how functional strength training (FST) influences movement efficiency alongside core stability together with sprint mechanics and agility and injury prevention forms the foundation of this review. The data demonstrates how better posture, reduced energy costs together with enhanced movements result in noticeable improvements. Functional strength training allowed neuromuscular adaptations such as increased excitatory drive that can lead to an elevated jumping frequency and higher number of activated motor units. Further, neuromuscular adaptations enhance dynamic postural stability and core stabilizing capacities and prove effective for improving hip movements and stride efficiency in sprinting and running techniques. The effectiveness of FST is further supported by increased agility, which is shown by better cutting and pivoting mechanics. The injury risk protection offered by FST stems from its ability to fix muscular weaknesses along with provision of balance between different areas. Functional training also significantly enhances athletes' cardiorespiratory endurance performance. Various data points including joint angles alongside ground reaction forces together with muscle activation levels have also been documented in the literature. Future research should focus on the training protocols tailored to the specific capabilities required for improving athletics' performance because the positions in which the player is playing are different, and the training protocol should be specified accordingly.

INTRODUCTION

Athletes participating in football need to develop strength as well as agility, endurance, and power because the sport always demands high-intensity performance. High-intensity movements that involve sprinting along with jumping, multidirectional changes and tackling form the critical foundation for field success in football. The sequence of intense movements happens back-to-back during games [1]. Running intensity in football depends strongly on the variables between positions and team strategies but also competition strength. Top-tier players execute more high-intensity movements when compared to average players in their playing field [2]. Successful football performance requires highly specialized strength and conditioning for athletes. The intense physical nature of football also raises the risks of developing injuries which most commonly affect the lower body areas. The knees and ankles make up 61.2% of all reported injuries based on analysis [3]. The strength capability of player joints and muscles needs to sustain these forces. Different combinations of weak muscles along with insufficient endurance and muscle flexibility together with physical weaknesses create potential risk for knee injuries [4]. Traditional strength training receives less attention among football players because researchers advocate functional strength training as a superior method. The main goal of FST is to build athletic performance through strengthened movements along with improved body mechanics for better functionality [5]. The combination of strength training boosts athletic performance as well as minimizes risks of harm during complicated high-intensity athletic

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activities. By correcting muscle imbalances and improving knee joint stability in professional football players, individualized resistance training may provide further advantages [6]. This review explores how FST benefits football players by improving running mechanics, core stability, and movement efficiency while also playing a significant role in injury prevention. Participation in football sports demands a combination of powerful force input with outstanding balance and movement coordination from players [7]. The strength ability by itself proves insufficient since athletes also need training that allows them to apply this strength through dynamic movements required in their respective sports. Lower-body power synergizes with neuromuscular control to perform sprinting and lateral movements and rapid decelerations. Both jumping moves and ball heading activities need powered force together with stability during positions in the mid-air [8]. A sudden and quick response in the field demands not only the strength of lower body parts but also necessitates an appropriate and coordinated movement of upper body. Football matches exceed usually ninety minutes and thus require players to maintain their energy levels throughout the entire game duration [9]. Weightlifting alone does not suffice for this purpose, so training needs to include movements which can simulate authentic on-field situations together with performance-enhancing features. The core concept of functional strength training is to enhance movement efficiency above everything else because it meets the biomechanical specifications [10]. The approach provides training benefits which directly translate into real-life performance making it an optimal choice specifically for athletes. FST delivers different benefits than weightlifting since it uses multi-joint, multi-plane movements that optimize coordination besides neuromuscular function. Athletes who perform exercises that include kettlebell swings in combination with sled pushes and resistance band drills and squats and lunges improve their performance-related strength [11]. During FST training people engage with unstable surfaces and perform balance exercises and exercises which demand proprioceptive exercises to make muscles operate together while enhancing total coordination and stability [12]. The most crucial component of functional training enables the individual to work independently of any machine, utilizing the limitations of his own body. The individual can accomplish his aim by using the four fundamental movements in this program. These motions include rotation, level shifting, pushing and pulling, and pausing and switching [13, 14]. Success in sports rises in tandem with the renewal of sports records and training techniques through scientific study and approaches, as well as with the aid of science and technology that are developing daily. Long-term, methodical implementation of a well-designed functional training program is crucial to lowering injury risk and enhancing athletes' performance [15]. Extensive research demonstrates that FST provides valuable advantages to football players, leading to progress in running methods and body movement quality and core control development [13]. The performance of specific running techniques serves as essential for attaining speed and accelerated speed while preventing injuries. The muscular strength obtained through FST makes foot and ankle movements more efficient during sprinting by improving hamstring power and activation with gluteal and hip flexor strength [16]. Placing the feet properly while exercising with ground reaction force components helps athletes sustain proper posture as it reduces energy drains during their high-speed movements. Athletes can shift in all directions with speed and preserve their stability through increased movement efficiency during high-intensity football moments. The strengthening of a person's core represents a primary advantage of FST [17]. A powerful and stable core functions as a power conduit that distributes energy between lower and upper body segments to execute essential abilities such as shooting, passing along with ball protection. The performance-based exercises including plank variations and rotational medicine ball throws and stability ball drills increase core strength aspects which help football-specific movements Planks increase core strength by engaging multiple muscles in the abdominal region such as rectus abdominis, external oblique and erector spinae and transverse abdominis, that is a deep core muscle capable of stabilizing the spine, thus improving overall trunk stability and posture when held in a contracted position; essentially, by isometrically contracting these muscles for a sustained period, you build strength throughout the core [18], (Table 1). Among all FST benefits, injury prevention represents a crucial advantage that stands as the most vital point. Professional football athletes face high risks of sustaining knee and ankle injuries together with hamstring injuries during their matches since the sport demands repetitive sprints and quick turns and frequent physical collisions [19]. Weak stabilizer muscles together with muscle imbalances serve as common causes behind most injuries. The major muscles get stronger through traditional training yet smaller muscles that sustain joints receive insufficient attention. The approach of functional training solves this issue because it combines exercises which train the major muscle groups alongside their stabilizing counterparts [20]. Wrestlers can enhance knee protection by performing squats and lateral band walks which build strength in the crucial gluteus medius muscle The Bulgarian split squat is a unilateral exercise that increases

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the demand on the glutes while also enhancing stability and coordination. Research has shown that unilateral exercises like the Bulgarian split squat are highly effective for targeting the gluteus medius, a crucial muscle for hip stability [21]. Lateral band walks are a simple but effective exercise for targeting the gluteus medius. A study in the Journal of Orthopaedic & Sports Physical Therapy found that lateral band walks significantly activate the gluteus medius, an often-underdeveloped muscle that plays a key role in hip stability. Joint stability improves from performing proprioceptive exercises which include balance board drills and eccentric hamstring curls leading to diminished risks of ligament injuries such as ACL tears [22]. Specific FST training routines created for individual athletes lead to improved athletic performance together with better resistance against injuries. A football team requires specific physical qualities in their positions which must be addressed through individually designed training programs [23]. The ability of strikers to accelerate and jump improves with explosive sprint training while midfielders need endurance alongside dynamic strength exercises for maintaining their game performance. To succeed in defensive situations players must train their upper body and conduct reaction-based agility workouts against approaching attackers [24]. The training focus of goalkeepers includes reaction-based instruction as well as core stability exercises and explosive lower-body movements that enhance diving performance and speed of movement shifts. A correctly designed functional training system takes into account the specific needs of different positions and features activities that replicate actual gameplay movements. Numerous scientific studies show that FST produces effective results for football athletes [25]. Athletes who use functional strength programs perform their movements better while making fewer injuries happen and achieving better nerve-muscle control than athletes who train their strength according to traditional methods. Scientists analyzed FST effects on elite footballers by monitoring players who did functional exercises that led to better sprinting and improved balance, enhanced agility skills. Research showed that neuromuscular training exercises reduce knee and ankle injuries during football matches when performed by players [26]. At the molecular level, the total force-generating capacity is determined by the size and contractile characteristics of the muscle fibers, the frequency of operation, and the number of activated motor units. Increased excitatory drive-in trained individuals can result in a higher frequency of jumping and a greater number of activated motor units, among other brain changes. Additionally, the increased force output following training is a result of decreased antagonist coactivation and increased agonist, synergist, and stabilizer activation [27–30]. But the only information available for many of these neuromuscular adaptations comes from rodent models [31]. Currently professional football teams are using FST training as part of their programs because coaches and sports scientists are demonstrating its benefits for extending player careers and reducing injury-related time off [32]. Furthermore, some research has shown a strong positive correlation between balance, muscle strength, and flexibility [33]. One plausible explanation for this finding is that functional training strengthens the subjects' core muscles, which enhances their ability to control their spine and pelvis, coordinates their shift in center of gravity and posture adjustment during movement, and improves their ability to balance [34](Figure 1).

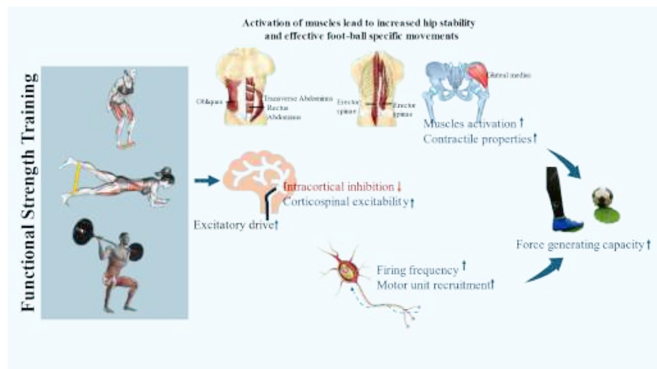

Figure 1: Different Exercises in FST lead to improvements in Football-Related Movements

Table 1: Exercises and their Intended Improvement

Exercise	Targeted Biomechanical Improvement
Single-Leg Squats	glute activation, stability of knee, maintenance of balance
Bulgarian Split Squats	mobility of hip, strength in lower-body parts
Sled Pushes	Acceleration of sprints, explosive force production
Medicine Ball Throws	Core rotation strength, power transfer
Lateral Band Walks	Preventing injury, activating Hip abductor

Additional research has shown that functional training greatly improved athletes' cardiorespiratory endurance performance; yet one study found no discernible variation in the group's postintervention results. These findings might be explained by the fact that long-term elite athletes or those who have been a part of regularly scheduled exercise programs for longer than three years have significantly altered their bodies [35], and improvements in cardiorespiratory endurance directly affect athletic performance [36]. FST provides athletes with a game-changing method to enhance their performance while building resilience because it applies biomechanical football requirements to its training strategies [37]. FST functions as a valuable contemporary football conditioning technique because it provides specific movement strength

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with core stability and joint protective support. Functional training principles spread throughout professional and grassroots football now allow all footballers from different developmental levels to obtain benefits from training methods which emphasize functional movements before isolated strength gain. Research data proves FST has vital importance for football training because it delivers optimal performance and injury protection for professional athletes from beginning to end of their careers [38]. The study review highlights how important functional strength training (FST) is for improving football performance and lowering injury risks. To effectively execute high-intensity movements, football players need a blend of strength, agility, and endurance. Improved running mechanics, core stability, and movement efficiency are just a few of the well-established biomechanical advantages of FST. Furthermore, by correcting muscle imbalances and improving joint stability, the incorporation of customized training regimens reduces the risk of injuries, especially in the knees and ankles. Despite the encouraging outcomes, the findings' generalizability is constrained by the variations in study designs and short-term interventions. Implementing thorough FST programs is further hampered by practical issues in professional football, such as player workloads and match schedules. The long-term effects of FST, the creation of standardized training regimens, and the requirements of various playing positions should be the focus of future studies. The field can advance toward optimizing training methods that protect players' health and improve performance by closing these gaps. Evidence-based strategies like FST will be essential in addressing the physical demands of the game while putting an emphasis on injury prevention as the sport develops. Additionally, programs of training must concentrate on the particular skills needed to enhance performance. The player plays a variety of roles, just like in soccer, so the training regimen should be tailored to each position.

CONCLUSIONS

Football athletes achieve better biomechanical performance through functional strength training that enhances their patterned movements together with stability and neuromuscular coordination system. Training with specific sports engagements allows an improved generation of force while enhancing balance and agility during performance. The players gain better joint stability, low risk of injuries together with stronger sprinting power output, better jumping abilities and improved directional control. The activation of core muscles together with better postural alignment during functional strength training creates better energy transfer between body segments while decreasing additional body movements. Future research must concentrate on duration-based biomechanical changes, injury-preventative training solutions and the most reliable training plans for distinct positions in the field. Post-training movement analysis alongside muscle activation evaluation gives complete insight regarding both performance boost approaches and prevention of athletic injuries.

Authors Contribution

Conceptualization: LB
Methodology: HFT, LB, SS
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Writing review and editing: HFT, LB, SS

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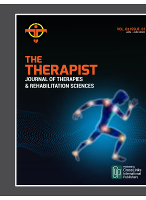

Original Article

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Fall Prevention Knowledge and Practice Patterns in Home Health Physical Therapists

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ABSTRACT

Physical therapists play a vital role in fall risk assessment and prevention due to their focus on modifiable physical risk factors. **Objectives:** To assess home health physical therapists' knowledge of evidence-based fall prevention guidelines and fall risk assessment tools. **Methods:** A cross-sectional study was conducted using both online and handwritten questionnaires. Data were collected from therapists working with elderly patients in home-based care using purposive sampling. The sample size was determined based on an estimated 25% prevalence of key practice patterns from prior studies, which would provide ±7% precision at a 95% confidence level for our primary outcomes. Informed consent was obtained before data collection. Data were analyzed using SPSS version 23.0. **Results:** A total of 151 physiotherapists participated. Among them, 30.5% reported that most of their patients were aged 50 or above. Regarding screening, 80.8% agreed that all clients aged 50+ should be assessed for fall risk. However, only 31.8% conducted regular fall risk assessments, while 21.2% did not assess at all. Tools commonly used included the Berg Balance Test (39.1%) and the Timed Up and Go Test (TUG)(13.9%). Most therapists (75.5%) followed standard assessment flow charts, though 24.5% did not. Preventive measures were used by 90.7% of low-risk and 64.2% of high-risk patients. **Conclusions:** While awareness of fall risk screening is high among physiotherapists, assessment practices vary widely. Many do not use standardized protocols or assess consistently. There is a need for targeted training and standardized guidelines to improve fall prevention in older adults.

INTRODUCTION

For older persons, falls are a prevalent concern that frequently leads to injuries, a decreased quality of life and a fear of falling. Risk factors can be changed to reduce the chance of falls. Physical therapists are essential to risk factor evaluation and intervention since physical function is included in several of the modifiable risk variables [1]. When developing preventative actions, identifying risk factors is crucial. Instead, during the past 20 years, the issue of falls among the elderly has drawn more attention recently. Numerous studies have shown the frequency, the effects, the complex etiology, and the potential for risk factor management through a multidisciplinary approach [2]. Accordingly, 30% of those 65 and older are thought to fall at least once a year. The United Nations Population Fund estimates that 20% of elderly people pass away within a year following a hip fracture [3]. Falls are common and can have detrimental effects on one's physical and mental health. Injuries occur in between 30% and 50% of in-facility falls. Even a fall without any injuries might result in decreased physical activity, worry, discomfort, despair, and a fear of falling [4]. One area of physical therapy that is expanding quickly is home health care [5]. Reducing falls among elderly persons requires effective fall prevention techniques. There is a dearth of information on physiotherapists' experiences preventing falls in developing nations, despite the fact that rehabilitation

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specialists like an essential part of the fall prevention team is the physiotherapist [6]. In order to determine Who is susceptible to falling, assist in preventing current or recurring falls, and minimize injuries caused by falls, home healthcare (HHC) providers must conduct fall preventative assessments on older persons [7]. Falls are a major financial burden on the healthcare system and are frequently linked to osteoarthritis in the knee. Thus, it is important to look at the attitudes and behaviors of physical therapists with regard to prevent and screen for falls among osteoarthritis patients. Patients with knee osteoarthritis are more likely to fall than those without the condition, according to many research [8]. Physical therapy (PT) is crucial, especially for individuals who have mobility issues or are at risk of falling [9]. There is a 50% chance of repeated falls [10]. With the ultimate objective of delivering high-quality patient care, it is necessary to continue identifying and implementing proactive, collaborative service delivery models as the population ages and more clients with complicated, long-term health care requirements stay at home [11]. If more falls can be averted, then improving practice in this area might have significant advantages for patients and the health system [12]. The majority of the therapists (>75%) polled did not have the chance to look into modifiable risk factors linked to falls, even though they reported having sufficient expertise [13]. Most elderly patients who survive hip fractures nonetheless have mobility issues. However, understanding the effectiveness of existing care approaches is necessary for any endeavor to systematically minimize mobility limitations following hip fractures [14]. Therefore, physiotherapeutic exercise regimens are a great way to lower the risk of falls in older people while also improving their quality of life [15]. For clients 65 and older, physiotherapists' fall risk knowledge and behaviors should be improved by treatments that follow a standard assessment-treatment flow chart [16]. In addition to assistance devices like walkers and canes, elderly persons who are at a high risk of falling may benefit from home hazard evaluation and modification [17]. Given the large number of elderly people who are at risk for falls and the potential for cognitive impairment to go unnoticed, physical therapists should test for cognitive impairments as part of falls risk assessments [18]. Increased self-efficacy, perception of fall prevention intervention, fall prevention knowledge, and in certain cases, a reduction in the frequency of falls are some advantages of fall prevention education [19]. The degree and efficacy of physical therapists' efforts to promote health among their elderly patients remain unknown [20]. For older persons who are at risk of falling, customized fall prevention strategies and fall risk assessments can help reduce the frequency of falls. According to the findings of systematic reviews, treatments including strength and balance training, home environment changes, and medication reviews lower the number of fallers and falls while still being reasonably priced [21]. The World Health Organization (WHO) reports that 37.3 million falls require medical attention each year, and 684,000 people worldwide lose their lives as a result of falls. Patients' worry and fear of falling are examples of psychological impacts that might impair their ability to live independently and increase their reliance on family members [22].

METHODS

This cross-sectional study assessed fall prevention knowledge and practices among 151 home health physical therapists for six months (January 2024 to Jun 2024). Data were collected from therapists working with elderly patients in home-based care using purposive sampling. The sample size was determined based on an estimated 25% prevalence of key practice patterns from prior studies, which would provide ± 7% precision at a 95% confidence level for our primary outcomes. While no formal power analysis was conducted for subgroup comparisons, this sample size aligns with similar published studies in rehabilitation research and provides adequate power to detect clinically meaningful differences in practice patterns sample size of 151 home health physiotherapists was based on the feasibility and the relevancy of previous studies with similar aspects in fall prevention practices. Inclusion criteria included graduate-level physiotherapists actively practicing in home health with older adults; those not working in this setting were excluded. Informed consent was secured, and confidentiality was ensured through secure data storage. Participants faced no risks and could withdraw at any time without consequences. This study used self-reported surveys where all participants answered identical questions. As no group comparisons or subjective assessments were made, blinding of researchers did not apply to this design." In this study, data were collected using online and handwritten questionnaires. The questionnaire was based on the published studies of research opportunities, knowledge, and practice regarding fall prevention in a healthcare professional workforce [23]. Expected content validity by means of professional assessment involving three senior physiotherapists who dealt with geriatrics and fall prevention was obtained. The first section covered demographics and professional details, while the second assessed physiotherapists' knowledge and practices regarding fall risk and prevention. Questions were based on prior research on fall prevention among healthcare professionals. Informed written consent was obtained at the beginning of the questionnaire [24]. Data were

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analyzed using SPSS version 23.0.

RESULTS

The results show that the group mainly included women as the participants (55.6) of baccalaureate degree (68.9) and 1-5 years of work experience (60.9). Most of them worked in university hospitals (45.7%) and thus were young professionals, with a majority of them having an academic interest in their jobs (Table 1).

Table 1: Exercises and their Intended Improvement

Variables	Frequency (%)
Gender	
Male	67 (44.4%)
Female	84 (55.6%)
Total	151 (100%)
Education	
Bachelor	104 (68.9%)
Master	32 (21.9%)
PhD	15 (9.9%)
Working Experience	
1-5 Years	92 (60.9%)
6-10 Years	13 (8.6%)
11-15 Years	6 (4.0%)
16-20 Years	5 (3.3%)
More Than 20 Years	35 (23.2%)
Type of Institution	
Public Hospital	21 (13.9%)
University Hospital	69 (45.7%)
Private Clinic	15 (9.9%)
All the time	18 (11.9%)

The majority of participants perceived a high risk of falls, with 73.2% indicating that at least half of patients are affected. Most agreed that age over 50 increases fall risk (80.8%), and over half (52.3%) reported that falls occur sometimes, reflecting moderate awareness and experience with fall incidents (Table 2).

Table 2: Participants' Perceptions and Experiences Related to Fall Risk (n=151)

Variables	Frequency (%)
All	46 (30.5%)
More Than Half	34 (22.5%)
Half	28 (18.5%)
Less Than Half	32 (21.2%)
Very Little	11 (7.3%)
Risk of Falling Age >50	
Absolutely Agree	54 (35.8%)
Agree	68 (45.0%)
Uncertain	27 (17.9%)
Don't Agree	2 (1.3%)
Frequency of Getting Fall	
History	30 (19.9%)
Never	24 (15.9%)
Sometimes	79 (52.3%)

The balance assessment procedure was the most popular method of determination of the fall risk (35.1%), and 23.8 percent of these assessments included the gait observation and coordination observation during the training. The less utilized strategies were musculoskeletal assessment, assistive device inspection, and mental or proprioceptive analysis, which showed no homogeneous strategy, but approaches mostly on physical functions (Table 3).

Table 3: Methods Used by Participants to Assess Fall Risk (n=151)

Methods	Frequency (%)
Balance Assessment	53 (35.1%)
Observation During Gait and Balance-Coordination Training/Exercises	36 (23.8%)
Musculoskeletal Evaluation	22 (14.6%)
Assistive Device Evaluation	11 (7.3%)
Mental Assessment	9 (6.0%)
Observation	7 (4.6%)
Evaluation of Activities of Daily Living	6 (4.0%)
Proprioceptive Assessment	7 (4.6%)
Total	151 (100%)

The most popular form of assessment of fall risk was the Berg Balance Test (39.1%), followed by the Timed Get Up and Go Test (13.9%), risk factor inquiry, and analysis of gait (13.2%). Alternative tests such as Romberg test, short physical performance battery and other functional tests were also less popular, suggesting a wide variety but poor consistency of assessment types (Table 4).

Table 4: Tools and Tests Used for Fall Risk Assessment by Participants

Tools and Tests	Frequency (%)
Ittaki Fall Risk Scale	13 (8.6%)
Berg Balance Test	59 (39. 1%)
Timed Get Up and Go Test	21 (13.9%)
Risk Factor Inquiry	20 (13.2%)
Romberg Test	5 (3.3%)
Gait Analysis	20 (13.2%)
Short Physical Performance Battery	6 (4.0%)
Functional Reach Test	3 (2.0%)
Sit To Stand Test	3 (2.0%)
Stand on One Leg	1 (0.7%)
Total	151 (100.0%)

DISCUSSION

Falls are a common issue among the elderly, leading to injuries, fear, and reduced quality of life. The WHO defines a fall as "an event which results in a person coming to rest accidentally on the ground, floor, or other lower level." This cross-sectional study aimed to assess home health physiotherapists' knowledge of evidence-based fall prevention and risk assessment. Even though the

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compliance rate is 90.7% with regards to implementing preventive measures on low-risk patients, there is a dire discrepancy since the population with patients at high-risk has a compliance rate of 64.%. High-risk clients are in particular need of fall prevention services, and this partial compliance indicates that better training and awareness and the importance to utilize clinical protocols regularly are necessary. A total of 151 physiotherapists participated via online and handwritten questionnaires. Of these, 55.6% were female and 44.4% male; 68.9% held bachelor's degrees, 21.2% master's, and 9.9% PhDs. Most (60.9%) had 1–5 years of experience. Participants worked in universities (45.7%), public hospitals (13.9%), private clinics (9.9%), and other healthcare settings, including wellness centers and specialized fields like orthopedics, geriatrics, and neurology. A previous study reported that 63.9% of the physiotherapists had half of their clients are of older age. While current study reported that 18.5% physiotherapists treated half of their patients who were elderly. 22.5% of physiotherapists treated more than half of their patients were elderly, 21.2% had less than half, and 7.3% had very few, 30.5% of physiotherapists said that the majority of their patients were 50 years of age or older [19]. A 2021 study found that 91.7% of physiotherapists believed all elderly clients should be assessed for fall risk. Recent research showed 45% agreed and 35.8% strongly agreed that clients over 50 should be assessed, while 1.3% disagreed and 17.9% were unsure. In the earlier study, 8.3% always had patient fall history, 11.1% almost always, 37.5% often, 38.9% sometimes, and 4.2% rarely. In the recent study, 11.9% always had fall history, 52.3% sometimes, 19.9% had it, and 15.9% had no fall history [20]. A 2019 study found that 64% of Nigerian physiotherapists practiced fall prevention effectively, and 89% had strong knowledge of it. In the current study, 10.6% failed to identify fall risk factors, 36.4% sometimes did, 28.5% often, 15.2% almost always, and only 9.3% identified them all the time [23]. The most frequent reason for emergency hospital admissions for elderly patients is fall-related injuries, and elderly patients account for around 40% of ambulance attendance. Serious injuries from falls include hip fractures. According to a substantial growth in hip fractures in the UK over the past 20 years, hip fractures that result from falls may cause up to 140,000 hospital admissions annually by 2036 if rates keep rising. Several decades of study have identified fall risk factors since the early 1980s. These risk factors are typically separated into three categories: Intrinsic risk factors (i.e., those related to the person's health, like arthritis, vision), extrinsic risk factors (those related to a person's environmental characteristics, like home hazards), and behavioral risk factors (individual cognition, insight, attitudes, and distraction, like decision-making, habits, using ladders, and impulsivity) [25]. Peel C's study found most home health physiotherapists assess fall risk in seniors, but fewer than half refer patients to other professionals. In the current study, 31.8% frequently assessed fall risk, 27.8% did so only when necessary, 21.2% did not assess at all, and 19.2% delegated the task to others [1]. A 2023 Swiss study showed 62% of physiotherapists used standardized fall risk tools, while 25% relied on subjective assessments. Assessment varied by education level and job context. Common tools included the Tinetti (47%), TUG (57%), and Berg Balance Scale (58%). In the current study, physiotherapists used various methods: balance tests (35.1%), gait observation (23.8%), musculoskeletal evaluation (14.6%), and mental screening (6%). Specific tools included Berg Balance Test (31.1%), TUG (13.9%), Gait Analysis and Risk Inquiry (13.2% each), Ittaki Scale (8.6%), and others like Romberg (3.3%), SPPB (4%), and Sit-to-Stand (2%) [26].

CONCLUSIONS

The survey identifies the fact that the majority of physiotherapists recognize the significance of screening older adults to evaluate the risk of falls, but only one-third of them assessed fall risk with regular frequency. It means that a considerable number of them do not always consider risk of falls in their practice. Despite the use of commonly known techniques, such as the Berg Balance Scale and clinical observation, the adherence to the screenings that are performed according to the standard procedure is very weak. To improve fall prevention, clear guidelines have to be devised and introduced, as well as specific training programs.

Authors Contribution

Conceptualization: RA
Methodology: SS[1], SL, ST
Formal analysis: RA
Writing review and editing: SS[2], TA, RMAY

All authors have read and agreed to the published version of the manuscript

Conflicts of Interest

All the authors declare no conflict of interest.

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Original Article

Association of Low Back Pain with Sitting Patterns among Desk-Based Office Workers

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ABSTRACT

Low back pain (LBP) is one of the most frequently observed musculoskeletal complaints of office workers who sit at the desk for most of their working hours, chiefly as a result of sitting and poor sitting postures. Since the sedentary working conditions are on the increase, it is essential to know the connection between sitting patterns and LBP. **Objective:** To determine the association of LBP with sitting patterns among desk-based office workers. **Methods:** The cross-sectional study was conducted at the University of Lahore for four months. A sample of 72 faculty members aged 25–55 years was selected using convenience sampling. Data were collected using a self-structured questionnaire covering demographic details, sitting patterns and pain severity, which was measured using the Visual Analogue Scale (VAS), a 10-point scale where 0 indicates 'no pain' and 10 indicates 'worst possible pain'. Statistical analysis was conducted by SPSS version 25.0, and the chi-square test assessed the association between variables. **Results:** The results showed 91.7% of participants reported experiencing LBP in the past year. Most participants (52.8%). Seated position for more than six hours per day, and 70.8% rated their posture as average. A significant number (58.3%) only occasionally supported their back properly, and 63.9% had monitors not aligned at eye level. The association between poor sitting habits and increased LBP was statistically significant (p<0.01). **Conclusions:** The present study shows a close relationship between LBP and sitting habits in office workers who sit at their workstations.

INTRODUCTION

Low back pain (LBP) is pain felt between the lower ribs and buttocks, which may or may not spread to the legs and can vary in severity [1, 2]. Most cases have no clear cause, but about 5–10% are linked to conditions like infections, inflammation, degenerative or congenital issues, tumors, trauma, or psychological factors [3, 4]. When no specific cause is found, it is called non-specific LBP [5]. In contrast, specific LBP refers to serious conditions such as spinal stenosis or disc herniation that require targeted treatment [6]. Estimating the incidence of LBP among office workers is challenging due to recurring symptoms that are hard to track. Many people experience LBP by adulthood, making it difficult to measure new cases accurately [7, 8]. A review of twelve studies, categorized by bias risk as low, moderate, and high, showed that this variation could affect the findings. Some studies also included general back pain, not just lower back [9]. Sedentary behaviour, which involves long periods of sitting or inactivity, has been linked to several health issues, even in people who engage in regular exercise [10]. Recent studies suggest that how sedentary time is spent may be more important than how long it lasts. Currently, there are no standardized national guidelines specifically addressing sedentary behaviour, and existing recommendations are inconsistent and mainly based on expert opinion rather than solid scientific evidence [11]. LBP among office workers is influenced by factors such as

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age, poor ergonomics, and environmental elements like lighting, temperature, and humidity [12]. However, studies during the COVID-19 pandemic found no strong link between LBP and factors like gender, physical activity, or work hours in remote workers, suggesting other causes may be involved [13, 14]. Prolonged sitting, common in today's inactive lifestyle, is linked to obesity and various health issues. While earlier research mainly focused on work-related sitting, recent studies have taken a broader view by examining how both work and leisure-related sedentary activities contribute to back pain, aiming to better understand the link and assess the strength of existing evidence [15]. There is limited research on specific patterns and their direct impact.

This study aims to provide valuable insights into how different sitting behaviours affect LBP risk among desk-based office workers.

METHODS

The cross-sectional study was done at the University of Lahore for four months, from January 2024 to June 2024. A sample of 72 faculty members was selected using convenience sampling. Rao online software was used to ca;culate sample size, based on the prevalence from a previous study. Data were collected by means of a self-structured survey containing demographic details and sitting patterns, which included variables such as average daily sitting duration, posture alignment, frequency of postural breaks, use of back support, and monitor position. Pain severity was measured using the Visual Analogue Scale (VAS), a 10-point scale ranging from 0 (no pain) to 10 (worst possible pain). Statistical analysis was done by SPSS version 25.0, and a chi-square test assessed the association between variables. Ethical considerations were followed, and the study was approved under institutional guidelines. Sitting patterns and LBP were presented as mean ± SD. Gender, age and remaining variables were presented as frequency and percentage. The chi-square test compares LBP with sitting patterns.

RESULTS

The findings were that 2.8% of the 72 study participants fell with the 25 years' group category, 54.2% fell with the 26-35 years' group category, 16.7% fell with the 36-45 years' group category and 26.45% within the 46-55 years' group category (Table 1).

Table 1: Descriptive Statistics of Participants' Age

Age		Frequency (%)
Valid	25	2 (2.8)
	26-35	39 (54.2)
	36-45	12 (16.7)
	46-55	19 (26.4)
	Total	72 (100.0)

Out of 72 participants mean value of sitting patterns was 18.9, and the standard deviation was 1.7. The mean value of Low back pain was 10.3, and the standard deviation was 1.7. The association between LBP with sitting patterns was analyzed. As the p-value<0.01, which shows that the correlation was highly significant (Table 2).

Table 2: Total Score of Sitting Patterns and Low Back Pain

Variables	Total Score
Sitting Patterns	
Valid	72
Missing	0
Mean ± SD	18.9306 ± 1.73064
p-value	<0.01
Low Back Pain	
Valid	72
Missing	0
Mean ± SD	10.3889 ± 1.74061
Df	49

DISCUSSION

This study mainly focused on the relationship between low back pain with sitting patterns among desk-based office workers. Well-defined inclusion and exclusion criteria were used to ensure the homogeneity of the sample. Participants included male and female office workers aged 25–55. The primary obstacle to sitting reduction was that job-related tasks were given the top priority. Intervention designers must take into consideration individual choice, environmental considerations, judgmental culture, productivity issues and the knowledge of the staff [16]. Yuwono and Wahyuni, studied the association between sitting duration and LBP in office workers found a 3.5%. The result showed an association between sitting duration and LBP with a p value of 0.05, which makes the results statistically significant [17]. The correlation found in this study aligns with that of previous research, as both yielded statistically significant results suggesting common patterns in the studied population. Putsa *et al.*, study on factors associated with low back pain with sitting patterns in office workers, is 30% with a statistically significant p-value of <0.01. The result showed a relationship between LBP and sitting patterns.The correlation found in this study aligns with that of previous research, as both yielded statistically significant results suggesting common patterns in the studied population [18].Another study conducted by Silva *et al.*, on the association of sit-stand desks with low back pain among office workers, with a statistically significant p-value of <0.05.The correlation found in this study aligns with that of previous research, as both yielded statistically significant results, suggesting common patterns in the studied population [19]. Hendrika *et al.*, showed that the association of LBP with sitting

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patterns and duration among office employees shows that office workers are more prone to have low back pain, with a significant p-value <0.001.The study of these findings under earlier research, with both demonstrating statistically significant results that indicate recurrent population[20].

CONCLUSIONS

Based on these findings, it was concluded that low back pain is associated with sitting patterns among desk-based office workers. Factors such as prolonged sitting duration, inadequate back support, misaligned monitor position, and infrequent postural breaks contribute to increased prevalence of LBP promoting ergonomic awareness and encouraging regular postural breaks may help reduce the risk of LBP in sedentary work settings.

Authors Contribution

Conceptualization: SS
Methodology: LR, RI
Formal analysis: LR
Writing review and editing: AS, HS, FA

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

All the authors declare no conflict of interest.

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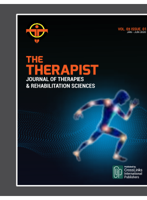

Original Article

OPEN ACCESS

Association of Pain Intensity, Duration, and Aggravating Factors in Low Back Pain Patients

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ABSTRACT

A common musculoskeletal ailment that impairs everyday functioning and quality of life is low back pain. **Objective:** To investigate the association of pain intensity, duration, and aggravating factors with functional limitations in patients with low back pain. **Methods:** Due to logistical limitations, a convenience sample of 162 patients with low back pain below the Cochran-calculated minimum of 384 was used in a cross-sectional descriptive study at The University of Lahore Teaching Hospital. Individuals between the ages of 18 and 50 who had a positive SLR test were selected. A standardized questionnaire that covered demographics, pain characteristics, and the Back Pain Functional Scale (BPFS) was used to gather data.Shapiro-Wilk normality testing was used to report quantitative data as mean ± SD or median [IQR], and qualitative data as frequencies (%).While t-tests, Pearson's correlation, or Mann-Whitney U tests evaluated relationships between pain intensity and functional limitation, descriptive statistics provided a summary of demographics. Analysis was done using SPSS version 23.0, and significance was set at $p < 0.05$. **Results:** The majority of the 162 participants were women between the ages of 36 and 45. They often had moderate to severe agonising pain that got worse when they walked and in the morning, and the best relief came from rest and physical therapy. **Conclusions:** Functional ability and pain levels are greatly impacted by low back pain, especially in women. The most impacted activity was walking, and the best way to recover was to relax.

INTRODUCTION

Low Back Pain (LBP), a prevalent condition that affects people all over the world, is one of the most common complaints in primary care settings. Low Back Pain (LBP) can be caused by a number of variables, including skeletal, neurological, and musculoskeletal structures, and can be exacerbated by extended postures, physical strain, and age-related degenerative changes [1]. Chronic LBP, defined as pain lasting more than three months, poses significant challenges in clinical management due to its complex aetiology, which often includes non-specific pain, radiculopathy, and structural abnormalities including spinal stenosis or disc protrusion [2]. Magnetic resonance imaging or computed tomography scans are commonly used to determine particular causes of pain, but lumbar radiography is generally avoided during the first two months of nonspecific pain [3]. Chronic Low Back Pain (CLBP) is a debilitating and common condition that affects a significant fraction of the global population (619 million people in 2020, with estimates increasing to 843 million by 2050) [4]. According to the World Health Organisation, low back pain is one of the most prevalent impairments in the world, and it has a substantial financial impact due to medical costs and lost productivity. Up to 80% of people may experience low back pain at some point in their lives, and many will develop chronic symptoms that persist for more than three months [5]. The strain on the discs in the lower back may be more apparent if you spend a lot of time sitting down rather than standing. The majority of

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motorcycle riding is done while seated, and extended sitting can contribute to hamstring strains [4]. People may therefore be more susceptible to developing lower back pain (LBP). However, it's important to realise that not all riders get LBP as a result of prolonged sitting. Sensitivity to this disease is influenced by age, riding time, physical fitness, individual differences, and other factors [6]. Regaining lost range of motion, enhancing function, reducing pain, and enhancing quality of life are the main objectives of physiotherapy for individuals with LBP [7]. Numerous workouts, electrotherapy, and relaxation techniques are used to achieve these objectives [8]. In Pakistan, LBP is common among professionals, housewives, office workers, and students. It is widespread among bankers, pregnant women in their latter trimester, and professionals such as dentists. Additionally, studies have shown that many Pakistani women of reproductive age experience lower back pain [9]. The onset of CLBP is influenced by social, psychological, and physical factors. Common causes of this syndrome include age, inactivity, poor posture, and possible occupational hazards [4]. Beyond the obvious physical pain, Chronic Low Back Pain (CLBP) can cause substantial mental anguish, a decline in quality of life, and difficulties in going about one everyday activities [10]. Clinical practice continues to prioritize the appropriate care of CLBP due to its high prevalence and complex character [10, 11]. A multidisciplinary team using conservative and interventional methods works well to manage CLBP. Physical therapy, pharmaceutical therapies, and behavioral changes including exercise and weight control are examples of conservative treatments that are often used as a first line of defense Core strength training, flexibility exercises, and posture correction are common PT goals [12]. Drugs such as opioids, muscle relaxants, Nonsteroidal Anti-Inflammatory Drugs (NSAIDs), and analgesics may be used in pharmacological treatment [13]. Persistent pain and incapacity occur in many patients with CLBP, despite the diversity of therapies available [14]. Because conventional treatment has its limitations, people are looking for complementary and alternative medicine alternatives that can help them feel better for longer [15]. Low back pain can affect functional limits differently in acute, subacute, and chronic versions. Low back pain is a major contributor to functional impairment and a reduced quality of life, and it is one of the primary causes of disability globally. Although it is very common, little is known about the relationship between functional limitation and pain intensity in Pakistani people. To create focused and effective rehabilitation techniques, it is vital to comprehend this relationship.

This study aimed to examine the relationship to explore the association of pain intensity, duration, and aggravating factors with functional limitations in patients with low back pain.

METHODS

Using a convenient sampling technique, 162 participants participated in this cross-sectional descriptive study.The study was conducted from March 2024- July 2024.The University of Lahore Teaching Hospital in Lahore provided the data, and the study was finished four months after the summary was approved 162 people with low back pain were included in the sample. Participants had to be between the ages of 18 and 50, be of either gender, be recommended from the orthopedic department, have a positive Straight Leg Raise (SLR) test, and score at least 5 on the Numeric Pain Rating Scale in order to be eligible.The Straight Leg Raise (SLR) test is used to assess nerve root irritation.An indication that a nerve root in the lumbar spine (typically L4-1) is compressed is when discomfort may radiate down the leg between 30 and 70 degrees Celsius of hip flexion. Only those having positive SLR test results were included in the study. Those with inflammatory conditions such as rheumatoid arthritis, neurological symptoms like cognitive impairments, a history of spinal surgery between thoracic vertebra 12 (T12) and sacral vertebra 1 (S1), or a history of spinal fractures, tumors, or infections were not allowed to participate.The study also excluded women who were either pregnant at the time of the study or in the first six months after giving birth. The Back Pain Functional Scale (BPFS) was used in the study to evaluate low back pain patients' functional limitations and pain perception.The questionnaire was broken up into sections that addressed functional activity levels, pain characteristics, and demographic data. A 0–5 Likert scale was used to score functional limits in 12 daily tasks, and a 0–10 scale was used to record pain intensity. To standardize the measurement of functional impairment, the entire BPFS score which ranges from 0 to 60 was computed and then transformed into a percentage. This approach made it possible to thoroughly assess the degree of discomfort and how it affected the participants' day-to-day functioning. The pain visual analogue scale is a unidimensional measure of pain intensity, used to record patients' pain progression, or compare pain severity between patients with similar conditions. A straight horizontal line with a fixed length, often 100 mm, is the most basic VAS. The ends are defined as the extreme limits of the parameter to be measured (symptom, pain, health) orientated from the left (worst) to the right (best) [16]. BPFS is a subjective tool assessing physical function within the first two weeks of LBP. It consists of 12 items scored on a Likert scale (0-5): unable to perform the activity (0), extreme difficulty (1), quite a bit of difficulty (2), moderate difficulty (3), a little bit of difficulty (4), and no difficulty (5). The total score (0-60) is calculated by summing the responses, with higher scores indicating

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better function. The adjusted score (Total/60) provides a percentage measure of functional ability. BPFS has good reliability and validity, correlating well with other functional scales, making it useful in clinical practice. However, it is not used for chronic cases. Further research is needed to assess its sensitivity over time and applicability to a larger population [17]. Analysis was done using SPSS version 23.0, and significance was set at $p < 0.05$.

RESULTS

The study included 162 participants with low back pain, the majority of participants (58.6%) were between the ages of 36–45 years, followed by 37.0% in the 26–35 years age group. Only 4.3% were between 46–50 years. Regarding gender distribution females represented a larger proportion of the sample (63.6%) compared to males (36.4%). Presents the distribution of the duration of low back pain. Acute pain (<6 weeks) was reported by 42.0% of participants, 19.8% experienced subacute pain (6–12 weeks), and 38.3% had chronic pain lasting more than 12 weeks. In terms of pain type, the most common type reported was aching (46.9%), followed by burning pain (29.0%), dull pain (14.2%), sharp pain (9.3%), and throbbing pain (0.6%). Factors that worsened pain are summarized in, where walking was the most frequently reported aggravating activity (40.1%), followed by standing (22.8%), bending (20.4%), and sitting for long periods (16.7%). Conversely, shows that physical therapy was the most effective relieving factor (34.0%), followed closely by rest (31.5%) and medication (19.8%). Notably, 14.8% of participants reported no relief from any method. As seen in pain variation throughout the day was also assessed. About 42.0% of participants reported worsening pain in the morning, while 19.8% experienced more pain at night. A significant portion (38.3%) indicated that their pain remained constant throughout the day. Functional limitations were evaluated using the Back Pain Functional Scale (BPFS), The BPFS scores ranged from 9 to 56, with a mean score of 32.32 ± 11.99, indicating moderate functional impairment in most participants. Pain intensity, measured on a Numeric Pain Rating Scale, is summarized in Table 9. Scores ranged from 5 to 10, with a mean of 7.56 ± 1.27, reflecting moderate to severe pain among the study population.

In table 1 most participants were females (63.6%) aged 36–45 years (58.2%).

Table 1: Demographic Characteristics of Participants (n = 162)

Variable	Category	Frequency (%)
Age	26–35 years	60 (37.3)
	36–45 years	95 (58.2)
	46–50 years	7 (4.7)
Gender	Male	59 (36.4)
	Female	103 (63.6)

Most participants reported aching pain (46.9%), acute duration (<6 weeks, 42.0%), pain aggravated by walking (40.0%), relieved by physiotherapy (34.0%), with BPFS scores ranging from 9 to 56 (Table 2).

Table 2: Descriptive Statistics LBP (n=162)

Variable	Frequency (%)	
Duration of LBP		
Acute (<6 weeks)	68 (42.0)	
Subacute (6-12 weeks)	32 (19.8)	
Chronic (>2 weeks)	62 (38.3)	
Pain Type		
Sharp	15 (9.3)	
Dull	23 (14.2)	
Aching	76 (46.9)	
Burning	47 (29.0)	
Throbbing	1 (0.6)	
Factors for worse pain		
Sitting for long period	27 (16.7)	
Standing	37 (22.8)	
Walking	63 (40.0)	
Bending	33 (20.4)	
Factor for relieve pain		
Rest	51 (31.5)	
Medication	32 (19.8)	
Physiotherapy	55 (34.0)	
None	24 (14.8)	
Back pain functional	**Min**	**Max**
Scale	9	56

In figure 1 the bar chart shows that acute low back pain (<6 weeks) was most common (41.98%), followed by chronic (>2 weeks, 38.27%) and subacute (6–12 weeks, 19.75%).

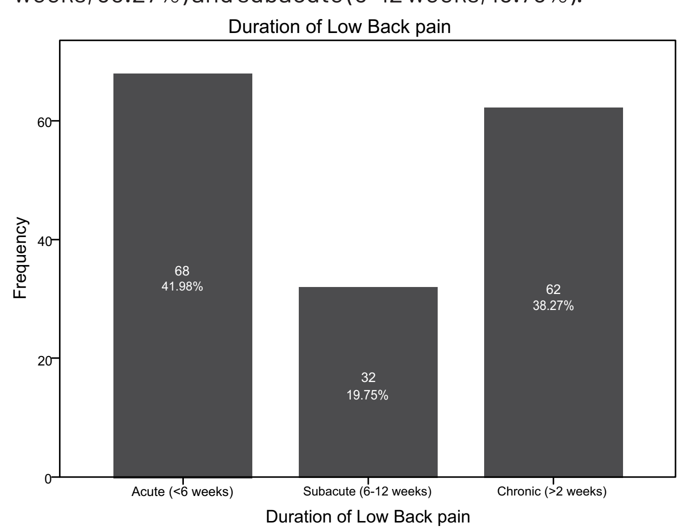

Figure 1: Distribution of Pain Intensity on the Numerical Pain Rating Scale

In figure 2 walking was the most reported aggravating factor for pain (40.12%), followed by standing (22.84%), bending (20.37%), and sitting for long periods (16.67%).

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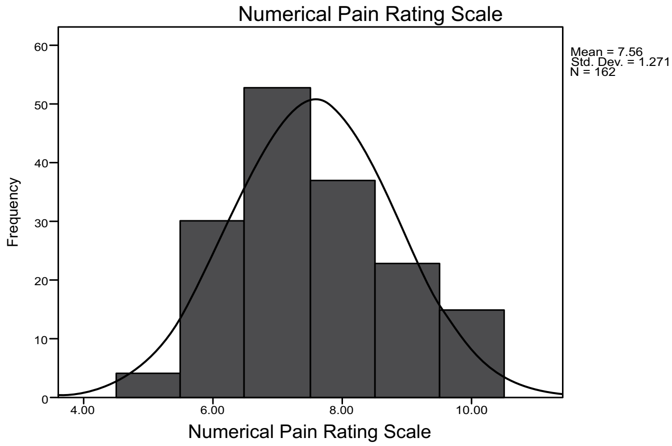

Figure 2: Aggravating Factors Associated with Low Back Pain

In figure 3 a normally distributed pattern of pain intensity scores on the Numerical Pain Rating Scale, with a mean of 7.56 ± 1.27, indicating moderate to severe pain among participants.

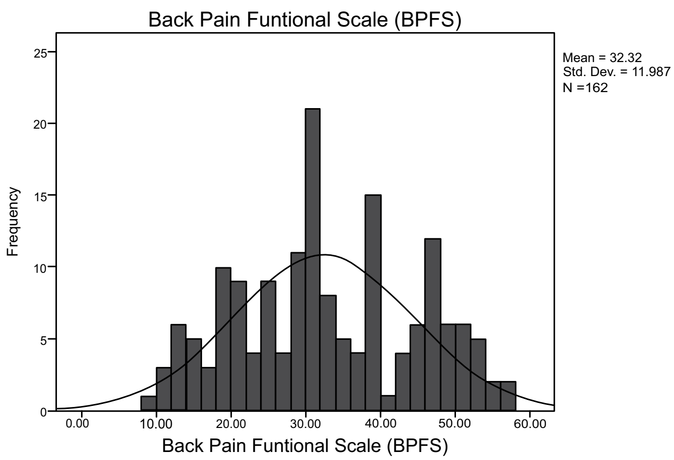

Figure 3: Distribution of Back Pain Functional Scale (BPFS) Scores Among Participants

In figure 4 a normal distribution of pain scores, with a mean of 7.56 ± 1.27, indicating moderate to severe pain.

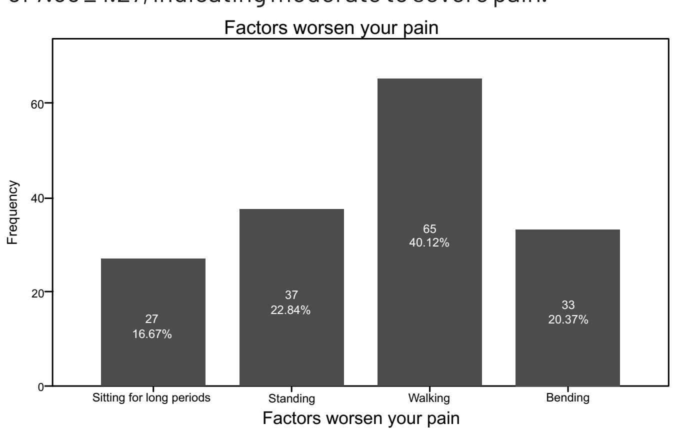

Figure 4: Normal Distribution of Pain Scores Indicating Moderate to Severe Pain

DISCUSSION

Most of the patients with persistent low back pain reported moderate to severe pain and significant physical restrictions. The degree of pain, especially psychological and bodily discomfort, was negatively correlated with quality of life.Poor quality of life was also strongly associated with functional limitations. QOL was also significantly influenced by pain severity, intensity, and impairment [18, 19].Previous studies have assessed the relationship between QOL and these variables among people with chronic low back pain (CLBP) [20-22]. Participants in the current study frequently reported moderate to severe pain and significant functional limitations, which is in line with earlier research by Aminde *et al.*, and Mutubuki *et al.*, that showed pain severity and disability to be significant factors in lower quality of life in people with CLBP [19, 18].These findings highlight the necessity of all-encompassing pain and physical function management techniques [22].Standardized instruments were used to measure the degree of disability and pain experienced by people with low back pain. The Back Pain Functional Scale (BPFS), a valid and dependable instrument for evaluating function in individuals with back pain, was used to evaluate functional limitations [17].Pain intensity was measured using the Visual Analogue Scale (VAS), a validated 10-point scale ranging from 'no pain' to 'worst pain' [16].The use of these tools in this study facilitated a comprehensive understanding of the relationship between pain, disability, and functional limitation [17, 22].According to the mean pain score and BPFS values, participants reported functional restrictions and moderate to severe pain levels.These results are consistent with earlier studies that found a negative correlation between pain intensity and quality of life [18, 22]. Similar to previous research, these findings imply that people with higher levels of pain and functional disability are probably less capable physically and have a lower quality of life [18–20].The significant effect of pain on mobility, especially walking difficulty, supports previous findings that physical function is a major driver of quality of life in people with low back pain, even though this study did not explicitly measure physical activity levels[22].

CONCLUSIONS

Low back discomfort has a significant effect on both pain and functional limitation. The findings indicated that more affected females had moderate to severe discomfort and difficulty walking. The best form of relief following physical therapy was rest. These results will be helpful in emphasizing the value of early assessment and targeted treatments for pain control and the enhancement of functional limitations.

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Authors Contribution

Conceptualization: SS
Methodology: AT, SS, ST, RMA, TA
Formal analysis: AT, SS, ST, RMA, TA
Writing, review and editing: AT, SS, ST, RMA, TA

All authors have read and agreed to the published version of the manuscript

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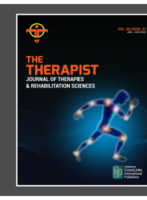

Original Article

OPEN ACCESS

Relationship between Fear of Pain and Movement among Stroke Patients with Poor Coordination

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ABSTRACT

Stroke is a major cause of long-term disability worldwide, often leading to motor impairments and reduced coordination. Beyond physical limitations, many stroke survivors experience psychological barriers such as fear of pain and movement, which can further hinder rehabilitation progress. **Objectives:** To determine the relationship between fear of pain and movement among stroke patients with poor coordination. **Methods:** This cross-sectional correlational study was conducted over four months at Ganga Ram Hospital, Lahore, involving 189 ischemic stroke patients aged 45-85 years, selected via convenience sampling. The Fear-Avoidance Beliefs Questionnaire (FABQ), Tampa Scale of Kinesiophobia (TSK), and Comprehensive Coordination Scale (CCS) were used (α=0.82 and α=0.79, respectively). Parametric analysis of summed ordinal scores was justified by prior studies and sample size. Pearson's and Spearman's correlation analyses were performed using SPSS version 26.0. **Results:** The study found moderate motor control difficulty among participants, with a mean CCS score of 14.52 ± 3.32. Fear-related avoidance behaviors were significant (FABQ: 37.29 ± 17.32), and fear of movement was moderate to high (TSK: 31.60 ± 11.85). FABQ showed a strong positive correlation with coordination (r = 0.773, p<0.001), while TSK had a strong negative correlation (r=-0.667, p<0.001). Interestingly, FABQ and TSK were inversely correlated (r =-0.787, p<0.001), indicating distinct psychological constructs. **Conclusions:** Higher fear-avoidance beliefs and kinesiophobia were both associated with poorer coordination in stroke patients. Despite overlap, FABQ and TSK reflect distinct aspects of pain avoidance and fear of movement, respectively.

INTRODUCTION

Stroke is a brain condition attributed to impaired blood supply to the brain that is a result of obstruction or rupture of the blood vessels in the brain. This obstruction may form clots, which in turn lead to blockage of the arteries, causing rupture of blood vessels and brain hemorrhage [1]. Sudden bursting of the arteries in a stroke condition deprives brain cells of oxygen, resulting in their immediate death. Stroke is commonly referred to as a disease of rapid onset of focal or global disorders of the brain function, which persists beyond a period of 24 hours or otherwise leads to the death of an individual without an apparent cause other than ascribable to a vascular source [2]. It also encompasses both an intracerebral hemorrhage and cerebral infarction. In the last 25 years, there has been a near doubling of the stroke survivors, and the same is likely to increase in the future, with at least the number of survivors doubling once more in the coming 50 years [3]. Stroke is the number one cause of disability in the world today. Greater than 50 percent of stroke survivors develop some residual motor disability, and a very large percentage of them develop non-paretic arm dysfunction. [4, 5]. The chances of stroke come with age, especially past the age of 55, and are even higher among people having diagnosed illnesses such as high blood pressure or heart disease. About 60% of people who have a stroke history have cases of a transient ischemic attack (TIA). Stroke risk factors can be categorized as modifiable or non-modifiable, with some lifestyle choices contributing to an increased risk of stroke [6-8]. Additionally, abnormal co-activation of muscles, particularly during shoulder abduction and distal limb

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flexion, impairs joint control and limits the ability to perform specific movements [9]. This abnormal co-activation pattern, known as flexion synergy, affects individuals' ability to reach for objects, as movements of the elbow, wrist, and fingers are involuntarily coordinated, limiting independent joint movement [10]. Stroke prevention focuses on modifying risk factors to reduce the incidence of stroke in the population, while stroke management aims to treat the underlying pathophysiology of the condition [11]. Despite extensive research into stroke, no simple, universally effective method for preventing or treating all forms of stroke has been established. Current research is focused on developing new therapies that target factors contributing to both primary and secondary strokes. In New Zealand, stroke is the third leading cause of death and a major contributor to disability in adults. The financial burden of stroke affects not only the individuals but also their families and society as a whole [12]. Recovery from a stroke is often a lifelong process, with upper limb weakness being prevalent in around 75% of stroke survivors. Within the first two weeks after a stroke, only a small percentage of individuals are free from upper extremity motor impairment, and even six months after the event, many survivors still experience severe motor deficits despite undergoing conventional therapy [13-15]. In some cases, neurobiological tasks are employed to address cognitive dysfunction and encourage synaptic plasticity. Task-oriented approaches, such as arm training and walking exercises, are commonly used to help manage physical disabilities, while visual computer-assisted gaming has been shown to enhance neuronal plasticity [16-18]. Stroke patients with poor coordination often experience fear of pain, which may limit their movement and hinder rehabilitation progress.

This study aimed to explore the relationship between fear of pain and movement in stroke patients with poor coordination.

METHODS

This cross-sectional correlational study was conducted from March 2024- August 2024 at Ganga Ram Hospital, Lahore, involving 189 ischemic stroke patients aged 45–85 years, selected via convenience sampling. Participants were recruited from rehabilitation centers and hospitals if they met the inclusion criteria of having a history of stroke and exhibiting poor coordination. Fear of pain was assessed using the Fear-Avoidance Beliefs Questionnaire (FABQ), which evaluates the extent to which individuals avoid movement due to pain-related fear. Additionally, kinesiophobia, or excessive fear of movement, was measured using the Tampa Scale of Kinesiophobia (TSK) to determine its impact on movement patterns. Poor coordination was assessed using the Coordination and Control Function (CCF) test, which evaluates motor control deficits in stroke patients. The Comprehensive Coordination Scale (CCS) was used because it focuses on motor coordination and is convenient to apply in clinical stroke settings. In contrast to broader tools such as the Fugl-Meyer Assessment, CCS is focused on coordination deficit, which coincides with the objectives of the study. Data collection involved administering these questionnaires and assessments during a single session, with assistance provided to patients with cognitive or physical limitations. Data analysis employed both Pearson's and Spearman's correlation methods: Pearson's r for normally distributed variables (confirmed by Shapiro-Wilk tests) and Spearman's ρ for ordinal/non-normal data, as indicated in results tables. Relationships between variables were analyzed using Pearson's correlation, which is robust for continuous or interval-like data. While TSK and FABQ are ordinal scales, their summed scores approximate interval-level data and have been treated parametrically in prior studies. Our large sample size (n=189) further justifies the use of Pearson's correlation, as it reduces bias from non-normality. Sensitivity analyses confirmed comparable effect sizes between Pearson's and Spearman's methods. Participants' responses were collected. Data were collected using demographic questions and analyzed using SPSS version 26.0. Categorical variables were summarized using descriptive statistics, while relationships between variables were assessed using Spearman's correlation.

RESULTS

The average age of the 189 participants was 65.22 ± 12.27 years, ranging from 45 to 85 years (Figure 1).

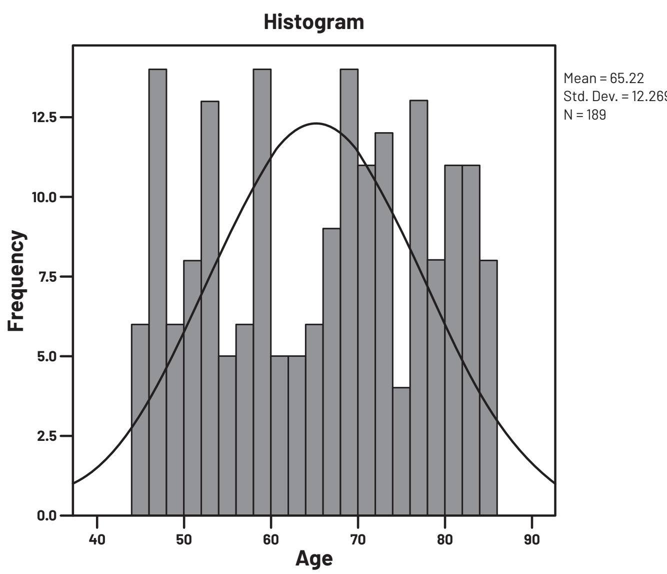

Figure 1: Graphical Representation of Participants' Age (n = 189)

The gender distribution of the 189 participants, with females comprising 53.4% (n=101) and males 46.6% (n=88) of the sample (Table 1).

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Table 1: Gender Distribution of Participants(n=189)

Variables	Frequency (%)
Female	101 (53.4%)
Male	88 (46.6%)
Total	189 (100.0%)

Fear-Avoidance Beliefs Questionnaire (FABQ) results, with a mean score of 37.29 and a standard deviation of ± 17.10 32, ranging from to 72 (Table 2).

Table 2: Descriptive Statistics of FABQ(n=189)

Variable	Minimum	Maximum	Mean ± SD
FABQ Score	10	72	37.29 ± 17.32

The Tampa Scale of Kinesiophobia (TSK) scores had a mean of 31.60 and a standard deviation of ±11.85, with scores ranging from 11 to 56 (Table 3).

Table 3: Descriptive Statistics of Tampa Scale(n=189)

Variable	Minimum	Maximum	Mean ± SD
Tampa Scale Score	11	56	31.60 ± 11.85

The relationship between the Comprehensive Coordination Scale, Fear Avoidance Beliefs Questionnaire (FABQ) and Tampa Scale of Kinesiophobia (TSK). The Comprehensive Coordination Scale and FABQ have a strong positive correlation (r=0.773**, p<0.01), revealing that greater fear-avoidant beliefs are connected to poor coordination. The Comprehensive Coordination Scale is negatively correlated with the Tampa Scale of Kinesiophobia (r=-0.667**, p<0.01), meaning that higher fear of movement is linked to worse coordination. Additionally, the FABQ and TSK also have a strong negative correlation (r=-0.787**, p<0.01), suggesting that as fear-avoidant beliefs increase, kinesiophobia decreases, or vice versa. All correlations are significant at 0.01 level (Table 4).

Table 4: Correlation of Fear of Pain with Movement and Poor Coordination(n=189)

Variable	Comprehensive Coordination Scale	Fear-Avoidance Beliefs Questionnaire	Tampa Scale of Kinesiophobia
Comprehensive Coordination Scale	1	0.773**	-0.667**
Sig. (2-tailed)	—	0.000	0.000
Fear-Avoidance Beliefs Questionnaire	0.773**	1	-0.787**
Sig. (2-tailed)	0.000	—	0.000
Tampa Scale of Kinesiophobia	-0.667**	-0.787**	1
Sig. (2-tailed)	0.000	0.000	—

DISCUSSION

This study aimed to explore the relationship between fear of pain and movement in stroke patients with poor coordination. Results revealed significant associations between psychological factors and motor performance. Notably, fear-avoidant beliefs were strongly correlated with reduced coordination, suggesting that patients fearing pain may limit movement, impairing motor recovery. In line with previous findings [19, 20], factors such as female gender, poor balance, use of walking aids, and history of falls were significantly associated with fear of falling (FoF). The present study found that stroke patients with a history of falls had a higher likelihood of FoF (OR 2.33) compared to those without (OR 1.67). Additionally, reduced balance was significantly linked to increased FoF. The study also observed a complex relationship between kinesiophobia and coordination. While higher fear-avoidance beliefs correlated with poorer coordination, higher TSK scores were unexpectedly associated with better coordination, warranting further investigation. These results align with Oguz et al., who reported a strong negative correlation between balance and fall efficacy (r = –0.808) [21], and with Özden et al., who found that fear of falling positively correlated with reduced mobility (r=0.669) and balance (r=0.545) [22]. Similarly, Akosile et al. noted a negative correlation between physical performance and fall efficacy (r =–0.66), underscoring the interplay between physical limitations and psychological barriers. The findings also complement those of Nakao et al., who identified sex, age, cognitive function, TUG scores, and fall efficacy as predictors of life-space mobility (LSM) [24]. Although ADLs were not assessed in the present study, Tashiro et al., emphasized their significance in LSM, along with walking speed and fear of falling [25]. Finally, a strong negative correlation between FABQ and TSK scores (r =–0.787, p<0.001) suggests these tools assess distinct psychological dimensions, fear-avoidance and kinesiophobia, highlighting the need for targeted psychological interventions in stroke rehabilitation.

CONCLUSIONS

The study concludes that both fear-avoidance beliefs and kinesiophobia are significantly associated with poor motor coordination in stroke patients. Despite some overlap, these constructs reflect distinct psychological barriers, highlighting the need for targeted interventions in stroke rehabilitation.

Authors Contribution

Conceptualization: AM[1], AM[2]
Methodology: AU, AM[1]
Formal analysis: AM[1]
Writing review and editing: ST, AU, TA

All authors have read and agreed to the published version of the manuscript

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Conflicts of Interest

All the authors declare no conflict of interest.

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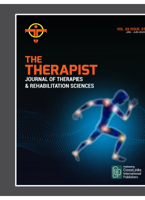

Original Article

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Association Between Sleep Quality and Proprioception in Young Adults

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ABSTRACT

Sleep is a vital biological process that enables us to function cognitively, emotionally, and physically. However, rising academic and lifestyle expectations have caused widespread poor sleep quality among young adults. **Objectives:** To investigate the relationship between sleep quality and proprioceptive performance in healthy young people. **Methods:** A cross-sectional survey of 171 university students aged 18-25 years was conducted using purposive sampling. The Sleep Quality Scale (SQS) was used to assess sleep quality, and the Proprioceptive Performance Questionnaire (PPQ) to evaluate proprioceptive performance. Descriptive statistics were employed to investigate demographic variables, while chi-square analysis was done to assess the connection between sleep quality and proprioception. Statistical significance was determined at p<0.05. **Results:** The study had 171 participants. A considerable number (81.3%) had poor sleep quality, and 38% had decreased proprioceptive awareness. A chi-square analysis revealed a statistically significant link between poor sleep quality and decreased proprioceptive function (p=0.026), which impacted balance, joint position perception, and force modulation. **Conclusions:** These findings point to a significant link between poor sleep quality and decreased proprioceptive performance in young people. Poor sleep quality can alter sensorimotor integration, increasing the risk of postural instability and motor coordination deficiencies in otherwise healthy people.

INTRODUCTION

Sleep is a vital physiological activity required for cognitive function, motor functioning, and overall health [1]. Poor sleep quality has grown more common among young adults due to academic, occupational, and social responsibilities [2]. Globally, 30-50% of young individuals report insufficient sleep (<7 hours per night), and 60-80% report poor sleep quality [3, 4]. Chronic poor sleep quality is linked to decreased reaction speed, cognitive processing, and neuromuscular coordination [5]. Despite substantial study into sleep's cognitive benefits, the impact on proprioception, a fundamental component of postural stability and motor control, has received little attention [6]. Proprioception, the body's ability to perceive movement and spatial direction, is based on integrated signals from muscle spindles, joint receptors, and the vestibular system [7]. Proprioceptive acuity deficits have been associated with balance problems, greater injury risk, and decreased sports performance [8]. Poor sleep quality appears to affect sensorimotor integration, notably in the prefrontal cortex, cerebellum, and parietal lobe, which are critical for proprioceptive processing [5]. According to functional MRI studies, sleep loss affects cortical excitability and spinal reflex sensitivity, decreasing dynamic postural control [9]. A meta-analysis found that even partial sleep restriction (≤6 hours/night) significantly reduces balancing accuracy (effect size=0.72, p<0.01) in young adults. However, most studies focus on acute sleep deprivation, creating a gap in our understanding of chronic sleep deficits' long-term proprioceptive implications [4]. Regionally, poor sleep quality among South Asian University students is frighteningly prevalent, with 70-85% reporting poor sleep quality due to academic stress and irregular schedules

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[10]. A survey conducted at the University of Lahore revealed that 78% of students slept less than 7 hours per night, with 65% feeling daytime tiredness [11]. Despite these tendencies, no studies in Pakistan have looked into the relationship between sleep quality and proprioceptive function in this population. This study bridges a gap by exploring the link between poor sleep quality and proprioceptive skills in young people.
This study aims to investigate the relationship between sleep quality and proprioceptive performance in healthy young people.

METHODS

A cross-sectional study was carried out at the University of Lahore in Pakistan from January to June 2023, obtaining ethical approval. Purposive sampling was utilized to recruit 171 university students aged 18 to 25. The sample size was estimated using Cochran's formula with a 95% confidence level and 5% margin of error, assuming a 50% prevalence of poor sleep quality among young adults [5]. Although purposive sampling limits generalizability, it enabled targeted recruitment of individuals with characteristics relevant to the study objectives, allowing for focused analysis of this clinically meaningful subgroup. Inclusion and exclusion criteria: Participants aged 18–25 with regular sleep duration (6–8 hours) and no recent musculoskeletal issues were included. Exclusion criteria ruled out sleep disorders, medications, shift work, or recent orthopedic trauma. The sleep quality, however, was measured independently using the SQS, which was used to make a distinction between the quantity and quality of sleep. The Sleep Quality Scale (SQS) is a validated 10-point Likert scale (Cronbach's α = 0.83) that ranges from 0 (bad sleep) to 10 (excellent sleep)[3]. Sleep quality was categorized as poor (≤4), moderate (5–6), and good (≥7) based on prior literature and clinical interpretation. The Proprioceptive Performance Questionnaire (PPQ) is a 20-item, 5-point Likert scale tool. Total scores were classified as low (<40), moderate (41–60), good (61–80), and excellent (>80) proprioceptive awareness, based on prior usage and expert consensus. The SQS and PPQ were selected for prior use in similar populations, both showed good internal consistency after translation and pilot testing, ensuring contextual. The data were analyzed using SPSS version 25.0. Demographic characteristics were summarized using descriptive statistics, and chi-square tests were used to examine the relationship between sleep quality and proprioceptive performance, with $p<0.05$ indicating statistical significance.

RESULTS

The findings delineate the attributes of the study population, which has a mean age of 21.5 years (standard deviation 2.25), ranging from 18 to 25 years, with a gender distribution of 52.0% female and 48.0% male. Anthropometric measurements indicated a mean weight of 67.9 kg ± 11.5 kg and a mean height of 168.3 cm ± 11.4 cm, resulting in an age-standardized average BMI of 23.9 kg/m^2 ± 3.1 kg/m^2. PPQ scores revealed that most participants fell within the low to moderate proprioceptive awareness range (Table 1).

Table 1: Descriptive Statistics of Quantitative Demographic Variables and Total Sleep Quality Scale Score

Variables	Mean ± SD / n (%)
Quantitative Demographic Variables	
Age	21.53 ± 2.26
Weight	67.99 ± 11.54
Height	168.32 ± 11.43
Score Category	
Poor Sleep Quality	139 (81.3%)
Moderate Sleep Quality	21 (12.3%)
Good Sleep Quality	11 (6.4%)

The distribution of handedness was nearly equal, with 50.9% of individuals utilizing their right hand and 49.1% employing their left hand. Sleep duration was concentrated around 7 to 8 hours, with no participant reporting≤6 hours (Table 2).

Table 2: Frequency/Percentage of Qualitative Demographic Variables

Variables	Constructs	Frequency (%)
Gender	Male	82 (48.0%)
	Female	89 (52.0%)
Dominant Hand	Right	87 (50.9%)
	Left	84 (49.1%)
Average Sleep Duration Per Night (Past 7 Days)	6 Hours	0 (0.00%)
	7 Hours	54 (31.6%)
	8 Hours	72 (42.1%)
	More Than 8 Hours	45 (26.3%)

The majority of participants reported poor sleep quality, with relatively few indicating moderate or good sleep quality (Table 3).

Table 3: Distribution of Responses to Sleep Quality Scale (SQS) Items (n=171)

Sleep Quality Dimension	Representative Items	% Agree or Strongly Agree
Sleep Satisfaction	Satisfied with sleep, content with sleep experience	45%–52%
Sleep Initiation and Maintenance	Difficulty falling asleep, lying awake	45%–54%
Sleep Continuity	Frequent waking, early awakening, and disturbed sleep	50%–58%
Morning Wakefulness	Hard to wake up or get up in the morning	48% – 53%
Daytime Functioning	Daytime drowsiness, fatigue, trouble concentrating	49% – 55%

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Perceived Sleep Quality	Feeling refreshed, energetic, and physically recovered	44% – 52%
Sleep Disturbances	Poor or restless sleep	50% – 51%

Domain ordering classification exhibited significant deficits in balance recovery (31.0% of participants), stability on uneven surfaces (28.1%), and joint position sense in the absence of vision (26.3%). Statistical analysis revealed a significant correlation between sleep quality and proprioceptive performance (χ^2=9.42, df=4, p=0.026) (Table 4).

Table 4: Proprioceptive Performance Questionnaire (PPQ)

Questions	Disagree	Neutral	Agree	Strongly Agree
I am aware of my joint angles during movement.	36 (21.1%)	38 (22.2%)	52 (30.4%)	45 (26.3%)
I am aware of the strength of my grip.	35 (20.5%)	41 (24.0%)	39 (22.8%)	56 (32.7%)
I am conscious of joint alignment during exercises.	34 (19.9%)	49 (28.7%)	50 (29.2%)	38 (22.2%)
I am stable when moving on uneven surfaces.	48 (28.1%)	39 (22.8%)	48 (28.1%)	36 (21.1%)
I can accurately feel the position of my joints without looking.	45 (26.3%)	35 (20.5%)	47 (27.5%)	44 (25.7%)
I can control the force of my muscle contractions accurately.	39 (22.8%)	31 (18.1%)	51 (29.8%)	50 (29.2%)
I can coordinate my movements smoothly.	38 (22.2%)	50 (29.2%)	35 (20.5%)	48 (28.1%)
I can feel when my limbs are correctly aligned.	44 (25.7%)	54 (31.6%)	37 (21.6%)	36 (21.1%)
I can judge how much force I apply during activities.	39 (22.8%)	39 (22.8%)	45 (26.3%)	48 (28.1%)
I can maintain my balance easily when standing still.	41 (24.0%)	38 (22.2%)	45 (26.3%)	47 (27.5%)
I can match the force of my movements to specific tasks.	34 (19.9%)	39 (22.8%)	48 (28.1%)	50 (29.2%)
I can recover quickly from a loss of balance.	53 (31.0%)	36 (21.1%)	38 (22.2%)	44 (25.7%)
I can replicate a specific force output accurately.	42 (24.6%)	49 (28.7%)	42 (24.6%)	38 (22.2%)
I can sense joint positions even when blindfolded.	42 (24.6%)	39 (22.8%)	51 (29.8%)	39 (22.8%)
I detect subtle changes in joint positioning.	38 (22.2%)	43 (25.1%)	44 (25.7%)	46 (26.9%)
I feel coordinated when performing complex tasks.	47 (27.5%)	41 (24.0%)	38 (22.2%)	45 (26.3%)
I notice small changes in my body balance.	38 (22.2%)	54 (31.6%)	36 (21.1%)	43 (25.1%)
I notice when I apply too much or too little force.	45 (26.3%)	39 (22.8%)	48 (28.1%)	39 (22.8%)
I notice when my joints are slightly misaligned.	50 (29.2%)	43 (25.1%)	31 (18.1%)	47 (27.5%)
I sense the effort required for various movements.	43 (25.1%)	34 (19.9%)	44 (25.7%)	50 (29.2%)

Individuals with inadequate sleep exhibited a 2.3-fold increased likelihood of possessing diminished proprioceptive awareness (OR=2.3, 95% CI: 1.4-3.8) compared to those with superior sleep quality (Table 5).

Table 5: Total Proprioceptive Performance Questionnaire Score

Score Category	Frequency (%)
Low Proprioceptive Awareness	65 (38.0%)
Moderate Proprioceptive Awareness	59 (34.5%)
Good Proprioceptive Awareness	46 (26.9%)
Excellent Proprioceptive Awareness	1 (0.6%)

The most notable correlations established pertain to balance recovery (r=0.34, p=0.008) and force modulation (r=0.29, p=0.012). Secondary analysis revealed no significant difference in proprioception scores between males and females (t=1.12, p=0.264); however, a weak negative correlation was observed between age and proprioceptive performance (r=-0.18, p=0.047). There was no correlation between handedness and sleep quality (χ^2 = 0.87, p = 0.351)(Table 6).

Table 6: Total Score of Proprioceptive Performance Questionnaire and Sleep Quality Scale

Hours spent sitting at work per day	Sleep Quality Scale Score			Total	p-Value
	Poor Sleep Quality	Moderate Sleep Quality	Good Sleep Quality		
Low Proprioceptive Awareness	56	7	2	65	0.026
Moderate Proprioceptive Awareness	43	11	5	59	
Good Proprioceptive Awareness	40	2	4	46	
Excellent Proprioceptive Awareness	0	1	0	1	
Total	139	21	11	171	

DISCUSSION

This study explored the impact of sleep quality on proprioceptive awareness among young adults, revealing a significant relationship between poor sleep and impaired sensorimotor function. Despite reporting 6–8 hours of sleep, many participants showed poor sleep quality. This suggests that sleep duration alone does not reflect overall sleep health. Issues like disturbed or non-restorative sleep can affect quality, so a validated scale was used to assess these aspects beyond total sleep time. Specifically, participants with inadequate sleep had a 2.3-fold higher risk of proprioceptive deficits, with dynamic balance (31.0%) and joint position sense (26.3%) most affected. These findings suggest that sleep quality, more than duration alone, may critically influence proprioceptive function in emerging adults [3, 12]. Sleep-dependent neuroplasticity plays a key role in proprioception by enabling the integration of sensory input from muscles and joints into coherent motor control [9]. When sleep is disturbed, the brain's ability to process proprioceptive signals becomes compromised. This is supported by neurophysiological research indicating that poor sleep

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quality alters functional connectivity in cerebellar-parietal and thalamocortical networks, brain systems essential for balance, coordination, and spatial awareness [5, 7]. In contrast to Stemplewski *et al.* who reported no acute postural deficits in sleep-deprived individuals, our study showed significant proprioceptive impairment [13]. This discrepancy may stem from differences in study design. While their assessment focused on static postural tasks in physically active individuals, our approach utilized dynamic and subjective measures in a less active student population. These distinctions suggest that both sleep quality and habitual physical activity may act as moderating factors in proprioceptive outcomes [6, 8]. Current findings are further supported by functional MRI studies showing 18–22% reductions in cerebellar Purkinje cell activity after sleep restriction, corresponding with the 31.0% balance impairments in our sample [14, 15]. Additionally, the 26.3% prevalence of joint position sense deficits supports prior models suggesting that prolonged wakefulness disrupts thalamocortical signaling, impairing fine motor control [7]. Furthermore, even participants reporting 7–8 hours of sleep exhibited proprioceptive impairments, suggesting that sleep fragmentation and quality, not just duration, are key to preserving sensorimotor integration [16, 12]. This underscores the need for future research and interventions to priorities sleep continuity alongside total sleep time. The study results diverged from previous literature in two notable respects. First, no gender-based differences in proprioception were observed, contrasting with studies linking menstrual cycle phases to postural variability [17]. This may be due to our wider age range, which could attenuate hormonal influences. Second, although BMI is a recognized predictor of proprioceptive accuracy, the study participants' average BMI (23.9 ± 3.1 kg/m^2) was within the normal range, implying that sleep quality may have a stronger influence than body composition in young, healthy adults [18, 19]. While current study was not conducted in clinical or rehabilitative settings, the observed increase in proprioceptive impairment among those with poor sleep has practical implications. Professions and populations that rely on precise motor coordination—such as athletes, military personnel, and surgeons may benefit from routine sleep quality assessments as part of injury prevention or performance optimization programs [20]. The cross-sectional design of this study and the Use of self-reported measures limit causal interpretation and objectivity.

CONCLUSIONS

The present study concluded that bad sleep is greatly correlated with proprioception dysfunction among young adults. Common weaknesses were observed in joint position sense, balance, and force modulation. Poor sleep quality likely disrupts sensorimotor integration due to changed neural pathways. The results indicate the necessity to examine objective measurements of sleep and proprioception.

Authors Contribution

Conceptualization: SS
Methodology: KA
Formal analysis: SM
Writing review and editing: SM

All authors have read and agreed to the published version of the manuscript

Conflicts of Interest

All the authors declare no conflict of interest.

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