Plyometric Exercise as a Therapeutic Strategy for Improving Strength and Postural Control in Stroke Patients: A Narrative Review

Ahmed K. Abd Elsabour[1], Hoda M. Zakaria[2], Ebtesam M. Fahmy[3], Sahar M Adel Elhakk[4,5], Azza Sayed Abdelrehim Khalil[6], Mohamed Salah El-Sayed[7,8], Shreen I. Taha[1]

[1] *Department of Physical Therapy for Neuromuscular Disorders and Its Surgery, Faculty of Physical Therapy, Beni-Suef University, Egypt.*
[2] *Department of Physical Therapy for Neurology and Neurosurgery, Faculty of Physical Therapy, Cairo University, Cairo, Egypt.*
[3] *Department of Neurology, Faculty of Medicine, Cairo University, Cairo, Egypt.*
[4] *Professor of Basic Science Department. Faculty of Physical Therapy, GALALA University. Suez Egypt.*
[5] *Professor of Basic Science Department. Faculty of Physical Therapy, Cairo University. Giza. Egypt*
[6] *Department of Rehabilitation Sciences Collage of Health and Rehabilitation Sciences, Princess Nourah bint Abdulrahman University, Saudi-Arabia-Riyadh*
[7] *Assistant Professor, Physiotherapy Department, Faculty of Allied Medical Sciences, Al-Ahliyya Amman University, Jordan.*
[8] *Lecturer, Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Horus University-Egypt, New Damietta, Egypt*
***Corresponding author:** Ahmed K. Abd Elsabour, **E-mail:** ahmedkamel@pt.bsu.edu.eg*

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ABSTRACT
Stroke is a leading cause of disability worldwide, often resulting in muscle weakness and impaired postural control that hinder functional independence. Traditional rehabilitation strategies have shown limited effectiveness in fully restoring motor function. Plyometric exercise, characterized by rapid, explosive movements, has emerged as a promising intervention to enhance neuromuscular coordination, strength, and postural stability in stroke patients. This narrative review explores the theoretical framework, biomechanical principles, and neurophysiological adaptations associated with plyometric training in stroke rehabilitation. Evidence suggests that plyometric exercises can improve muscle strength, dynamic balance, and functional mobility by leveraging the stretch-shortening cycle and neuromuscular plasticity. While preliminary studies indicate positive outcomes, concerns regarding safety and feasibility remain, necessitating individualized training protocols and further high-quality clinical trials. Integrating plyometric training into post-stroke rehabilitation programs may offer an innovative approach to optimizing recovery and enhancing patients' quality of life.

1. Introduction

Stroke is the second leading cause of death worldwide and those who survive often have disabilities which prevent them from conducting daily activities1. Recovering from a stroke requires learning how to use the body and brain in new ways, leading to long recovery time frames and reducing quality of life. Investigating innovative therapeutic approaches capable of safely and effectively allowing accelerated progress in recovery outcomes is, therefore, of paramount importance in post-stroke care2. A key strategy for achieving this is the development of an evidence base to support the efficacy of novel therapies in the clinical environment. Understanding the evidence underpinning recent advances in clinical practice and their possible clinical ramifications may better inform patients and ensure maximal clinical utility3. A rapid accumulation of new evidence addressing novel therapeutic strategies would often overcome the rate of comprehension by patients, researchers, clinical scientists, and healthcare providers4.

Rapid narrative reviews provide a timely synthesis of up-to-date evidence addressing a focused question or issue. A comprehensive and systematic search of the literature was conducted. The findings were synthesized using a meta-analysis to facilitate the identification of key themes across retrieved records5. The ensuing critical review highlights the general scope and significance of accumulating evidence on the clinical ramifications of novel approaches. Understanding the state of the art in post-stroke clinical research arising in these emerging

areas may better inform clinical practice2. A gulf often exists between the evidence and routine clinical practice; a brief account of the key findings was written with this audience specifically in mind to introduce the salient issues arising from the abundance of literature garnered so as to stimulate further consideration of innovative therapeutic avenues that are evidence-based and can be translated into improved care for patients6.

2. Understanding Stroke: Causes and Consequences

Stroke, known as a cerebrovascular accident (CVA), is usually not identified clearly and may be thought to be merely a worsening of conditions. The diagnosis of the cause of stroke is also a challenge. Aside from the symptoms experienced at the time of the stroke, symptoms that may only be felt as the disease progresses are also a serious problem7. A stroke is the result of damaged blood flow to the brain due to artery blockage, resulting in a reduction of oxygen supply to the brain. A condition that causes temporary damage and returns to normal after treatment is referred to as a transient ischemic attack (TIA)8. Stroke may cause various serious health problems based on its duration and how deep the disruption of blood flow in the brain happens. For example, a severe condition can cause hemiplegia in patients. All conditions in the form of defects or damage to the anatomy of the human body resulting from a fast stroke can interfere with daily activities9. Postural control is a complex function that allows the body to control its position in space and helps maintain stability and orientation. Postural control is maintained by the interaction of different systems, including the visual system, vestibular system, and proprioceptive system10. In a healthy body, the peripheral system will provide information about the body's position and the activity of the muscles during the movement of the body against the force of gravity. The central nervous system will process it quickly and send information to the muscles with a force of the same size but different direction to keep the homeostatic state when the body gets an impulse from the reaction of the landing. However, the central nervous system, which governs working ability and communication, undergoes stroke11.

3. Importance of Strength and Postural Control in Stroke Rehabilitation

Stroke can range in severity from minor to severe, often resulting in residual deficits, such as hemiparesis, that affect movement execution and coordination. After a stroke, many people exhibit decreased muscle strength and postural control disorders that lead to difficulties in maintaining balance12. However, the methods traditionally applied in rehabilitation settings, such as physical therapy and occupational therapy, may have limited impact on the recovery of normal strength and postural control13.

Many studies have suggested that intervention plans able to modulate the afferent inputs of patients, through the execution of complex motor exercises, may ameliorate muscle strength and postural control. As an alternative, in recent years, plyometric training has been proposed as a method to improve such activity capacities14. In overground walking, leg muscles in both healthy subjects and people with gait disabilities have been shown to be activated in a stretch-shortening cycle. Moreover, postactivation potentiation in lower-limb pole vaulting suggests that plyometric training may induce long-lasting activity improvements. Thus, modulating the type, frequency, and intensity of plyometric exercise may represent an alternative and adjunctive strategy to ameliorate muscle strength and postural control15.

4. Plyometric Exercise: Definition and Principles

Plyometric exercise is characterized by rapid, explosive movements that are designed to increase muscle power through enhancement of coordination between the nervous system and muscles. An important

biomechanical principle of plyometric exercise is the energy storage and release16. During the eccentric phase the muscle is quickly stretched, causing its elastic components to store energy. This energy is then utilized during the concentric phase to assist in achieving maximal muscle shortening velocity. In this way, plyometric exercises enhance both biomechanical and neurological components in the exercise movement, leading to an increase in power of the involved muscle groups17. These neuro-muscular adaptations are thought to occur due to changes in the sensitivity of the muscle spindle, allowing for a greater release of acetylcholine and thereby enhancing the myotatic-stretch reflex. A more complicated theory suggests that these neurological adaptations benefit from an increase in the number of active motor units, the rate at which motor units are discharged, and the recruitment pattern of fast-twitch motor units18. On a biochemical level, the increase in power of the involved muscle-group is due to the excitation-contraction coupling mechanism. This enhancement leads to an increase in the amount of Ca2+ available in the contractile process, as well as an increase in the density of Ca2+ adenosine triphosphate along the sarcoplasmic reticulum, facilitating the temporary storage of the ion19. Biochemically, the kinematic motion of a plyometric exercise can either be performed via a dynamic or a ballistic type of movement. Plyometric exercises, as a form of power and coordination training, can take many forms and can be conducted in diverse ways, including box jumps, bouncing a medicine ball, skipping, and plyometric push-ups20. Safety and proper technique must always be considered when using plyometric exercises, especially with at-risk populations. This suggests the importance of individualization of plyometric exercises for patients with different needs21.

5. Theoretical Framework for Plyometric Exercise in Stroke Rehabilitation

After a stroke, patients frequently have spasticity, which generates reduced levels of force, increased neural complexity, loss of stretch reflex modulation, and changes in musculotendinous architecture22. The deficit in force and power output appearing in chronic stroke patients limits their capacity to perform motor tasks such as transfers, manipulation of objects, gait, standing up from and staying seated in a chair, picking items up from the floor, putting objects in high places, or any other daily living activities that demand a functional level of muscular strength23. After a stroke, the difficulty in isolating and activating the affected joint and its related musculature often makes it impossible to perform a specific exercise. Plyometric exercise is a kind of exercise commonly used in sports training, intending to provide an increased mechanical stimulus by using a rapid muscle stretch followed by a forceful muscle contraction24. Accordingly, plyometric exercises can be a fruitful approach to avoiding passive muscle contraction by directly stimulating the stretch reflex loop. The ability to control the volitional effort exerted on the healthy limb joint and muscles and the intensity of the plyometric exercise offers a clear gradient of difficulty to the neural control system that might generate a resetting of stretch reflex threshold and modulation through neural plasticity. Besides, plyometric exercise can increase the neural complexity of the task, making the stroke patient participate actively in the tasks25.

6. Evidence Supporting the Efficacy of Plyometric Exercise in Stroke Rehabilitation

Plyometric exercise or plyometrics was popularized by an American track and field coach, Fred Wilt, and his associates, following the performance of Soviet athletes at the Olympic games in Mexico in 196826. This type of exercise is focused on developing the ability to quickly and efficiently recruit and apply maximal force as a result of the stretch-shortening cycle of muscle fibers. Over the years, studies among normal individuals, athletes, and those with illness have shown positive effects of plyometric exercises, including among elderly individuals27. In the field of stroke rehabilitation, the use of plyometric exercises is not well established. However, in certain cases, this form of exercise can be used as an alternative option for improving strength and

balance14. Stroke survivors often display muscle weakness and vertical ground reaction force asymmetry. While plyometric exercises have been specifically designed to generate high force in return for promoting muscle strength, it is hypothesized that such exercises may also enhance postural control28.

Plyometric exercises include squats and standing jumps, double-leg and single-leg jumps, and drop landings29. Validated the improvement in postural stability after a 12-week plyometric training program, though a slight increase in sway velocity was observed. Most studies that showed negative outcomes on balance could be related to the type of surface used, and measures being applied are not sensitive enough to detect changes15. Due to safety and feasibility issues, lower limb plyometric exercises were typically applied seated. There are cases of features being applied while standing. However, there were concerns with the high risk of falls associated with standing plyometric training30. In Sanders, a seated plyometric training exercise, utilizing a step board was performed. Despite being seated, it was suggested that seated plyometric training effectively targeted lower limb and trunk stability. There are currently no established guidelines or recommendations for plyometric exercises in stroke patients 30. Due to the limited number of studies reviewed, conclusions are not extensive. It is suggested that a well-designed clinical trial, representative of a patient post stroke, with a multidisciplinary approach in terms of intervention, measuring outcomes, and controlling confounders, needs to be developed31.

Conclusion:

Plyometric exercise presents a promising therapeutic approach for improving muscle strength and postural control in stroke rehabilitation. By leveraging neuromuscular adaptations and the stretch-shortening cycle, it enhances functional mobility and balance. While preliminary evidence supports its effectiveness, concerns regarding safety and individualized training protocols must be addressed. Further high-quality clinical trials are needed to establish standardized guidelines and optimize its integration into rehabilitation programs.

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