

REVIEW ARTICLE

Evidence Synthesis of Gait Impairments in Stroke Patients and Various Mechanisms Controlling Gait: Narrative Review

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ABSTRACT

Most strokes cause severe gait impairments due to disruptions in the various mechanisms controlling gait. This narrative review describes the classification and contribution of these mechanisms in stroke patients, synthesizing recent evidence published from 2014 through 2024. Central control mechanisms reviewed will include the roles of the motor cortex, corticospinal tract, basal ganglia, and cerebellum, focusing on how damage to these areas affects gait. It also covers peripheral mechanisms, including muscle weakness, joint contractures, spasticity, and sensory nerve damage, and their influence on gait performance. Sensory feedback systems are also discussed, such as proprioceptive, visual, and vestibular inputs, in relation to their influence on gait stability and adaptation. This review collates findings from recent research with a view to providing an overview of how such disruptions in these mechanisms contribute to gait abnormalities in stroke patients, with an emphasis on targeted rehabilitation strategies which could hope to address such issues.

KEYWORDS

• Gait • Stroke • Gait control • Hemiplegia.

INTRODUCTION

Stroke is one of the top causes of disability worldwide. The effect of stroke may include severe disturbances in gait¹. Gait control is a very complex process involving interaction among central neural pathways, peripheral

muscular and joint mechanisms, and sensory feedback systems. Disruptions in stroke patients across these mechanisms yield a gamut of gait abnormalities that could severely affect mobility and quality of life. The following review categorizes and discusses the role of different gait control mechanisms in

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patients with stroke, based on evidence from recent articles².

CENTRAL CONTROL MECHANISM

Central control mechanisms include those neural processes in the brain and spinal cord that coordinate and regulate gait. The central mechanisms can be further subdivided: into motor cortex and corticospinal tract involvement, and functions of the basal ganglia and cerebellum.

1. Motor Cortex and Corticospinal Tract

The motor cortex is important in the voluntary control of gait, more so the primary motor cortex¹. The loss of M1 function due to stroke reduces the transmission of motor command and subsequently affects coordination. The reduced activation of the motor cortex during walking has also been reported by a number of recent studies in stroke patients. For instance, Alakkam *et al.* (2020) demonstrated that decreased M1 activation in patients with stroke has associated gait impairments and functional limitations¹. In this line, Yang *et al.* (2023) have shown that damage to the corticospinal tract-the bundle of axons carrying motor commands from the cortex to the spinal cord-is associated with reduced gait speed and coordination².

2. Basal Ganglia and Cerebellum

The basal ganglia and cerebellum play decisive roles in motor planning, coordination, and balance. Impairment in these regions usually results in serious gait disturbances. Lesions of the basal ganglia, commonly from stroke conditions, result in bradykinesia and unsteadiness in gait³. According to Smith *et al.* (2021), it has been noted that asymmetrical gait patterns and lower gait velocity in individuals have been associated with basal ganglia dysfunction. Cerebellar involvement in stroke may also involve the motor's assistance with coordination and balance³. Lee *et al.* (2019) have reported that cerebellar lesions result in increasing gait variability and problems with balance and, therefore, underlined the contribution of the cerebellum to stable and coordinated gait⁴.

3. Spinal Cord Mechanisms

Central pattern generators (CPGs) residing in the spinal cord generate rhythmic patterns associated with gait. Stroke can disorganize

the CPGs as they release an irregular gait pattern. In the paper, as identified, Wang *et al.* (2022), it was realized that stroke patients displayed a type of the irregular CPG pattern with a combing impairment in their gait and locomotion. This is destructive because the stroke patients cannot achieve free and regular gait, leading to the inability to be a proper walker, which in turn limits general mobility⁵.

PERIPHERAL MECHANISMS

Peripheral mechanisms are those that involve muscles, joints, and sensory nerves in the performance of gait. The following are the usual abnormalities found in stroke patients:

1. Muscle Weakness and Imbalance

Hemiparesis, defined as muscle weakness as a result of stroke, has a huge impact on the symmetry and efficiency of gait. Shimada H *et al.* (2010) reported a customarily reduced gait speed due to muscle weakness on the affected side of the body, which leads to considerable energetic cost. In addition, muscle imbalances with decreased muscle strength on one side of the body further contribute to gait deviations. Saunders DH *et al.* (2020) demonstrated how muscle imbalances of stroke patients are associated with abnormal gait patterns and are linked to an elevated incidence of falls⁶.

2. Joint contractures and spasticity

Such gait impairment could be due to spasticity caused by increased muscle tone and/or joint contractures. In fact, Chen *et al.* (2022) identified a strong relationship between spasticity in post-stroke individuals and poor gait measures, such as stride length and speed^{7,8}. At the same time, they saw a limited gait range and functional mobility reported by Nguyen *et al.* (2020) due to joint contractures, shedding light on the impact of such peripheral impairments on gait^{8,9}.

3. Sensory Nerve Damage

Sensory nerve damage, especially that which impairs proprioceptive and tactile feedback, is disruptive to gait control. Impaired proprioception in providing information related to limb position and movement is very common in stroke patients. Liu *et al.* (2024) reported that proprioceptive deficits contributed to gait instability and difficulty in adjusting gait¹⁰. Similarly, Harris *et al.*

(2017) reported decreased tactile feedback was related to increased gait variability and falls in stroke patients¹¹.

SENSORY FEEDBACK SYSTEMS

Sensory feedback systems make an essential contribution to the alteration and regulation of gait. These systems enable the delivery of information about the position and movement of the body. The three subsystems composing sensory feedback systems include the following: proprioceptive, visual, and vestibular feedback.^{11,12}

1. Proprioception

Indeed, proprioceptive feedback is not only essential but also crucial for the stability of gait and adjustments of movement according to limb position. Thus, in the work of Park *et al.* (2022), proprioceptive training improved gait performance in stroke patients through enhanced sensory input and motor control. This means that proprioceptive feedback is crucial in gait rehabilitation.¹²

2. Visual System

The visual system provides the spatial information that is necessary for the maintenance of human balance and gait coordination. In the case of most stroke patients, there is an onset of visual impairments resulting from strokes which may cause problems with gait stability. Sun *et al.* (2024) showed that visual deficits were associated with increased gait variability and fall risk, emphasizing thereby the role of visual feedback in gait control.¹³

3. Vestibular System

Stroke could further lead to gait instability by increasing the vulnerability of vestibular systems responsible for balance and spatial orientation. In this regard, vestibular dysfunction has been linked to patients with stroke presenting impaired gait and balance control in a study conducted by Meng L *et al.* (2023). It would, therefore, imply that the vestibular deficits must be addressed if any rehabilitation for gait stability improvement is to be achieved.¹⁴

CONCLUSION

Gait in stroke patients is modulated by the complex interaction of central neural

mechanisms, peripheral muscular and joint functions, and sensory feedback systems. In the light of the central control mechanisms, functions of motor cortex and corticospinal tract, basal ganglia, cerebellum, and spinal CPGs are critically involved in gait regulation. Muscle weakness, joint contractures, spasticity, and peripheral sensory nerve damages are other peripheral factors that further influence the gait performance. Such sensory feedback systems are critical in providing proprioceptive, visual, and vestibular information towards the generation of gait adjustments in order to maintain stability. Knowledge about the working of this and similar mechanisms, including interaction between them, is important while developing specific rehabilitation strategies for improvement in walking and mobility in stroke patients.

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