Walking: How the Nervous System Shapes Every Step

Executive Summary

Walking is a fundamental part of everyday life, playing an important role in mobility and independence. Although it often feels automatic, each step requires constant coordination between the nervous system, sensory systems and muscles.

Movement relies on an ongoing sensorimotor loop: the nervous system coordinates movement while receiving continuous sensory feedback from the body and environment to help guide and adapt each step. Changes in gait may result when this communication is affected by neurological injury or disease.

Objective gait measurement can describe characteristics such as walking speed, step length, timing, symmetry and variability. Considering multiple gait parameters and how they change over time can provide a more detailed picture of how a person moves.

1. Walking: A Fundamental Part of Everyday Life

Something we do every day is also one of the most complex movements our bodies perform.

Walking is an essential part of everyday life. It enables us to move around our homes and communities, participate in work and social activities, and interact with the world around us. From getting out of bed in the morning to walking to the kitchen, crossing a street or going for a walk outdoors, our ability to move from one place to another is important for our independence and daily life [1,2].

For most of us, walking feels almost automatic. We decide where we want to go, take a step and continue moving without consciously thinking about each movement. Yet beneath this apparent simplicity lies a remarkably complex process.

Every step requires the coordinated activity of the brain, spinal cord, nerves, muscles and sensory systems [2,3]. The nervous system must organize movement, activate muscles at the right time, maintain posture and balance, and respond continuously to information from the body and surrounding environment.

Therefore, walking is more than simply moving one foot in front of the other. It is the result of an ongoing dialogue between the nervous system and the body, a dialogue that continues with every step we take.

2. From Intention to Movement

How the nervous system turns the intention to walk into coordinated movement.

The nervous system is responsible for initiating walking. When we decide to move, different areas of the brain work together to plan, initiate and coordinate the movement. The brain does not control each muscle individually with every step. Instead, movement emerges from the coordinated activity of different parts of the nervous system [3,4].

The signals involved in movement travel from the brain through the spinal cord, where neural networks also contribute to coordinating rhythmic movements such as walking. From there, motor nerves carry signals to the muscles of the legs and trunk. These muscles then contract and relax in carefully coordinated patterns to generate the forces needed to support the body, move the legs forward and maintain posture while walking [4].

This coordination happens continuously. While one leg supports the body, the other moves forward in preparation for the next step. The muscles in the legs and trunk must work together with precise timing to create a smooth, coordinated walking pattern.

However, this is only one aspect of the process. The nervous system also needs to be aware of what is happening as the body moves. With every step, sensory information travels in the opposite direction, from the body and environment back towards the nervous system.

3. Movement Is a Two-Way Conversation

How sensory feedback helps the nervous system guide and adapt every step.

Movement does not stop once a signal has reached the muscles. As soon as the body starts moving, sensory information is generated and sent back to the nervous system. This continuous feedback enables the nervous system to monitor what is happening and adjust our movements as we walk [4].

Sensory receptors throughout the body provide information about the position and movement of our limbs, muscle length and tension, and pressure beneath our feet. At the same time, the vestibular system provides information about movement and orientation, and vision helps us to understand the environment ahead.

The brain and spinal cord continuously integrate this sensory information with ongoing motor activity. If the ground is uneven, if a foot lands differently to how it was expected to, or if the body begins to move off balance, sensory feedback provides information that can contribute to adjustments in posture, muscle activity and the next step [3,4].

Therefore, walking is not a one-way sequence of commands from the brain to the muscles. It is a continuous sensorimotor loop: the nervous system coordinates movement; movement generates new sensory information; and this information contributes to coordinating subsequent movements [3,4].

4. From Movement to Gait

How coordinated movement creates the repeating pattern of walking.

Walking involves a continuous sequence of coordinated movements. With every step, one leg supports the body while the other moves forward; then their roles are reversed. This repetitive pattern is known as the gait cycle [5].

A gait cycle can be broadly divided into two phases: stance and swing. During the stance phase, the foot is in contact with the ground, helping to support and propel the body forward. During the swing phase, the foot leaves the ground and the leg moves forward in preparation for the next step. For short periods while walking, both feet are in contact with the ground. This is known as double support.

The continuous coordination described in previous chapters underlies this repeating pattern. The nervous system organizes muscle activity and posture, while sensory information from the body and environment contributes to ongoing adjustments. Together, these processes enable adaptation from one step to the next [3,4] .

As walking follows a repetitive pattern, various aspects of the gait can be measured. These include walking speed, cadence, step and stride length, stance and swing time, and double support time [5]. Other characteristics, such as gait symmetry and variability, describe how similar movements are between the two sides of the body, and how consistent they are from one step to the next.

These measurements provide different ways of objectively describing how a person walks. Rather than reducing gait to a single value, considering several gait characteristics together provides a broader description of the resulting movement.

5. When the Nervous System Is Disrupted

How injury or disease can affect the communication that makes walking possible.

Walking depends on communication between many parts of the nervous system. The brain, spinal cord, peripheral nerves, sensory systems and muscles all work together to plan, coordinate and adapt movement continuously. If part of this network is injured or affected by disease, this communication can be disrupted and changes in gait may result.

The effects depend on where and how the nervous system is affected. For example, damage to the brain can interfere with the planning, initiation, or coordination of movement. Spinal cord damage can disrupt signals travelling between the brain and the body, while peripheral nerve impairment can affect motor signals to the muscles and sensory information returning to the nervous system.

Therefore, neurological conditions can affect walking in different ways. Following a stroke, for instance, damage to the areas and pathways involved in movement can result in weakness, as well as changes in coordination or symmetry [6]. In Parkinson's disease, changes in the neural circuits that control movement can result in characteristics such as reduced step length and slower walking speed [7]. Multiple sclerosis can affect the transmission of signals within the central nervous system, resulting in changes to walking ability [8]. A spinal cord injury can disrupt communication between the brain, spinal networks and the body. The effect on walking depends strongly on the location and severity of the injury [9].

These conditions do not produce a single, consistent gait pattern. The resulting changes vary depending on the condition and the individual. Depending on the underlying impairment, changes may be observed in walking speed, step length, timing, symmetry, variability, balance or foot clearance.

As gait is the observable result of many interacting neural and physical processes, changes in walking can provide information about how movement is performed. Objective gait measurement can describe these changes and document their development over time.

6. Gait as a Window into Movement

Objective gait measurement can help describe how movement is performed and how it changes over time.

Every step is the result of coordinated activity between the nervous system and the rest of the body. The brain and spinal cord control movement, motor signals activate the muscles and sensory information continuously feeds back into this process. The walking pattern we observe is the result of these interacting processes.

When this coordination is affected by neurological injury or disease, changes may become visible in the way a person walks. For example, walking may become slower, steps may become shorter or less symmetrical, or the timing and consistency of steps may change. The characteristics affected and the extent to which they are affected can vary considerably between individuals and conditions [6–9].

Objective gait measurement provides a way to describe these characteristics quantitatively. Parameters such as walking speed, step and stride length, cadence, stance and swing time, symmetry and gait variability offer different insights into how a person walks [5]. However, no single parameter provides a complete picture, so gait measurements should be considered together within a broader clinical context.

A single gait assessment provides a snapshot of walking at one point in time. Repeated measurements can objectively document changes in gait over time, for example during recovery, disease progression or rehabilitation.

Understanding gait therefore involves more than just observing whether someone can walk. Every step reflects the ongoing interaction between the nervous system, the body and the environment. By measuring different characteristics of the resulting gait, we can build a more detailed picture of how movement is performed and how it changes over time.

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