

Coordination of Gait

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Bipedal human walking has an element of inherent unsteadiness and requires a substantial amount of coordination and balance. Our neurological system has a complex but generally effective system for maintaining the dynamic equilibrium needed for smooth walking, and for the even more difficult gait activities such as running and dancing. However, problems in several anatomical regions can hamper this delicate mechanism, resulting in less economical -and sometimes even pathological - gait asymmetries.

The instability found in normal human walking results primarily from biomechanical disadvantages. These include a heavily weighted upper body and a small base of support. Perhaps most important, however, is the relatively long time we spend in single-support. For about 80 percent of the gait cycle, we have all of our weight balanced over one leg. A series of carefully coordinated muscle contractions is required to overcome this inherent unsteadiness by controlling the trunk and upper body.¹ In other words, we incorporate compensatory muscle forces and joint torques onto the normal gait pattern to minimize the destabilizing forces that occur at certain points in the gait cycle. These coordinated contractions help us maintain balance during complex movements. Unfortunately, this critical balance can be interfered with in several anatomical regions.

Dynamic Equilibrium

Efficient human gait is heavily dependent on "dynamic equilibrium." This describes the balance that is required during the movements and instabilities that occur with bipedal locomotion. As we move about from one location to another, maintaining dynamic equilibrium during walking ensures a steady and safe progression. Two neurological control strategies are used to achieve this state in human walking: proactive balance and reactive balance.²

Proactive balance control arises primarily from the trunk and hip muscles. These muscles contract in a sequence that activates postural adjustments to compensate for the destabilizing forces associated with walking movements. Reactive balance control, on the other hand, is a strategy to recover from external disturbances that are encountered. This has been found to occur primarily in the more distal muscles of the lower extremities.³ These two systems normally work together to counteract the various forces that are placed on our bodies during walking. Problems arise when either the proximal or the distal balance control systems do not function smoothly.

Lower Extremity Control

The distal balance control of the lower extremity must react rapidly to changes in terrain and ground reaction forces. The mechanoreceptors in the feet and legs provide the information necessary for smooth and balanced coordination of the muscles in the lower legs. From heel strike, through foot flat, to toe off, this region adapts to regain balance from moment to moment.

Problems that will interfere with this coordinated response to gait often arise in the complex biomechanics of the foot and ankle. With many small joints, lots of connective and articular tissues,

and both intrinsic and extrinsic muscles, the feet are well supplied with proprioceptive nerve endings. Mechanoreceptors in the joints and the muscle spindles of the foot muscles are responsible for the positive support reflexes and a variety of automatic reflexive reactions.⁴ These include the flexor/extensor reflex, which converts the lower limb into a firm yet compliant pillar. Weightbearing compresses the joints and muscles, evoking reflexive activity in the extensors and inhibition of the flexor muscles.⁵ When there is excessive pronation, these reflexive responses are sluggish, and the reactive control of gait is poor.

Hip and Trunk Control

The proactive balance strategy for coordination of gait is found primarily in the trunk and hip extensor muscles, the erector spinae, hamstrings, and *gluteus maximus*, which start to become active before heel strike and stay active during the first half or "stance" phase of locomotion.⁶ These proximal and trunk muscles must work together to maintain upper body steadiness and trunk rotation. Recent studies have found that both aging⁷ and low back pain⁸ will interfere with normal functioning of this system. In fact, both chronic and acute low back pain result in significantly altered muscle responses during gait.⁹

At the same time that gravity and ground reaction forces are affecting the legs and feet, the muscles of the trunk and even the shoulder must begin responding. With each step, the scapula reacts to opposite-leg-loading by tipping anteriorly in the sagittal plane, rotating upward in the frontal plane, and gliding around the rib cage in the transverse plane (protraction). This reaction at the shoulder produces the appearance of a hunched and forward-rounded shoulder, and has been described as "shoulder pronation."¹⁰ Appreciating the biomechanical and neurological processes that link shoulder pronation to lower extremity pronation on the opposite side helps us understand the complexity of gait coordination.

The Importance of Posture

As the leg is loaded in gait, trunk side-bending occurs to the loading leg. The lumbar spine rotates away from the loaded leg, and a balancing rotation occurs in the thoracic spine to the same side as the loading leg. The entire relationship of the shoulder, rib cage, and thoracic spine is driven by the "cross-crawl" neurological reaction to gait. And even the upper cervical region plays an important role in maintaining and correcting postural alignment, and in determining whole-body balance. The deep neck muscles have been found to have many more proprioceptive nerve endings than other skeletal muscles.¹¹ The mechanoreceptors in the upper cervical joints are very sensitive to changes in postural alignment, and are a critical component (along with the vestibular system) in equilibrium and balance.¹² DeJong, et al., were able to cause major changes in gait simply by anesthetizing the muscle and joint receptors in the neck.¹³

Conclusion

Coordination of gait is dependent on proper function in the lower extremity and multiple factors in the proximal muscles and trunk. The inherent instability of human walking requires a complex interaction to provide both proactive and reactive balance control. Whenever the foot/ankle complex is not functioning correctly during the stance phase of gait, this stress is transmitted to the pelvis and spine with each step. We can improve gait coordination and help to ensure balanced function throughout the entire musculoskeletal system with custom orthotic support for each phase of the gait cycle. Such orthotics should be carefully designed to support the foot through all three

parts of the stance phase - from heel strike, through foot flat, to toe off.

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JANUARY 2002