

Refractive Errors and Human Gait: Visual Contributions to Locomotion and Postural Stability

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Abstract

Human locomotion is a complex process that requires the integration of multiple sensory and motor systems, including the musculoskeletal, vestibular, proprioceptive, and visual systems. Among these, vision plays a critical role in maintaining balance, spatial orientation, and safe navigation through the environment. Gait, defined as the coordinated pattern of walking, relies heavily on visual information to guide foot placement, detect obstacles, and maintain postural stability. Refractive errors—such as myopia, hyperopia, astigmatism, and anisometropia—are among the most common causes of visual impairment worldwide and can significantly alter visual perception when left uncorrected.

The chapter highlights the current evidence on the relationship between refractive errors and gait performance. The review highlights how visual blur, reduced visual acuity, impaired contrast sensitivity, altered depth perception, and binocular imbalance may influence locomotor behavior and gait parameters. Evidence from experimental, observational, and interventional studies indicates that uncorrected refractive errors can lead to measurable changes in gait, including reduced walking speed, increased toe clearance, altered step length, and greater gait variability. Individuals often adopt compensatory strategies to maintain stability and reduce fall risk, particularly in environments requiring precise visuomotor coordination.

The chapter also discusses the mechanisms linking visual dysfunction to gait alterations, including impaired spatial judgment, reduced motion perception, and deficits in binocular vision. Age-related differences in gait adaptation are highlighted, with children, adults, and older individuals showing varying responses to visual blur and refractive correction. Additionally, the potential influence of optical correction methods such as spectacles and contact lenses on gait stability is explored.

Understanding the interaction between visual function and locomotion is essential for improving mobility, reducing fall risk, and enhancing quality of

life. The findings emphasize the importance of timely detection and correction of refractive errors and highlight the need for further interdisciplinary research integrating optometry, neuroscience, and biomechanics to better understand vision-related gait adaptations.

Keywords: Refractive error, gait, locomotion, visual function, myopia, hyperopia, astigmatism, anisometropia, postural stability, visual blur, depth perception, falls risk.

1. Introduction

Human locomotion is a highly coordinated motor activity that depends on the interaction of multiple physiological systems, including the musculoskeletal, vestibular, proprioceptive, and visual systems. Among these components, the visual system plays a particularly crucial role in guiding movement, maintaining balance, and enabling individuals to navigate safely through their environment. Walking, or gait, represents the most fundamental form of locomotion and involves rhythmic and repetitive limb movements that allow forward progression while maintaining postural stability.¹

Visual information provides essential cues regarding environmental layout, obstacle location, and body orientation relative to surrounding objects. These cues allow individuals to plan movements, adjust foot placement, and maintain equilibrium while walking. When visual input is compromised, locomotor behavior often changes as individuals adopt compensatory strategies to maintain safety and stability. Research has consistently demonstrated that individuals with reduced vision tend to walk more slowly and exhibit altered gait parameters compared with individuals with normal visual function.^{2,3,4}

Refractive errors represent one of the most common causes of visual impairment worldwide. Although refractive errors can typically be corrected using spectacles, contact lenses, or refractive surgery, uncorrected refractive errors may result in blurred vision, reduced contrast sensitivity, impaired depth perception, and binocular imbalance. These visual disturbances may influence gait patterns, postural control, and locomotor stability.

Understanding how refractive errors influence locomotion is important not only for vision science but also for fields such as rehabilitation, gerontology, and fall prevention. Visual impairment has been strongly associated with gait dysfunction and increased risk of falls, particularly among older adults. Consequently, investigating the relationship between visual function and locomotion may provide insights into strategies for improving mobility and reducing fall-related injuries.

This chapter synthesizes current knowledge regarding the relationship between refractive errors and gait performance. It explores the mechanisms through

which visual blur and altered visual function affect locomotor behavior and highlights the implications for mobility and postural stability across different age groups.

2. Classification of Refractive Errors

Refractive errors occur when the optical system of the eye fails to focus incoming light precisely on the retina. As a result, the retinal image becomes blurred, leading to reduced visual clarity. The primary forms of refractive error include myopia, hypermetropia, astigmatism, and anisometropia.

2.1 Myopia

Myopia, commonly referred to as near-sightedness, occurs when parallel rays of light entering the eye are focused in front of the retina while accommodation is relaxed. This condition results in clear near vision but blurred distance vision. Myopia typically arises due to axial elongation of the eyeball, increased corneal curvature, variations in refractive index, or positional changes of the crystalline lens.

The increasing global prevalence of myopia has made it a major public health concern. In addition to affecting visual clarity, myopia-related blur may influence visuomotor coordination during locomotion.

2.2 Hypermetropia (Hyperopia)

Hypermetropia occurs when parallel rays of light are focused behind the retina in the relaxed state of accommodation. Individuals with hyperopia often experience difficulty with near tasks because accommodation must compensate to achieve clear retinal focus. In higher degrees of hyperopia, distance vision may also become blurred.

Sustained accommodative effort in hyperopic individuals may lead to visual fatigue, headaches, and reduced visual comfort, potentially affecting mobility and locomotor stability.

2.3 Astigmatism

Astigmatism arises from unequal refractive power in different meridians of the eye, typically due to irregular curvature of the cornea or lens. As a result, light rays fail to converge at a single retinal point and instead form two focal lines, leading to orientation-dependent optical blur.

Astigmatism may be categorized as regular or irregular and often occurs in combination with myopia or hypermetropia.

2.4 Anisometropia

Anisometropia refers to a difference in refractive power between the two eyes. Significant interocular differences can produce unequal retinal image sizes (aniseikonia), binocular imbalance, and impaired stereopsis. These visual disturbances may disrupt binocular coordination and affect spatial perception during locomotion.

3. Gait and Locomotion

Locomotion refers to the ability of an individual to move from one location to another through activities such as walking, running, crawling, or climbing. Among these forms, walking is the most common and energy-efficient mode of human locomotion.¹

Gait specifically refers to the coordinated pattern of limb movements during walking that produces forward progression while maintaining balance. A normal gait cycle includes alternating phases of stance and swing for each limb. Efficient gait requires the integration of several physiological systems, including:

- Musculoskeletal function for force generation and joint movement
- Neural control for coordination and timing of muscle activation
- Sensory feedback from visual, vestibular, and proprioceptive systems

Any disruption in these systems may lead to gait abnormalities or increased risk of falls.

4. Rationale for Investigating Refractive Errors and Gait

Visual impairment has been strongly associated with gait dysfunction and increased fall risk. Individuals with reduced visual function frequently adopt cautious walking patterns characterized by slower speed and altered step parameters.⁵

Several studies have reported that individuals with visual impairment walk more slowly than age-matched individuals with normal vision.^{2,3,4} Reduced gait speed is considered a protective adaptation intended to increase stability and provide additional time for environmental assessment.

Peripheral visual fields are particularly important for detecting obstacles and monitoring terrain during locomotion. Loss of peripheral vision reduces environmental awareness and may impair real-time adjustments in foot placement.^{6,7}

Experimental studies further demonstrate the importance of visual input for gait stability. Walking with eyes closed significantly increases variability in step length, step width, and stability parameters in both young and older adults.⁸

In older adults with glaucoma, progressive visual field loss has been associated with decline in gait parameters such as stride velocity and cadence over time⁵. Similarly, children and adolescents with visual impairment demonstrate poorer balance performance and altered locomotor skills compared with sighted peers.⁹ Importantly, visual functions such as contrast sensitivity, depth perception, and visual field integrity have been shown to be stronger predictors of falls than visual acuity alone.¹⁰

Despite growing evidence linking visual impairment to gait dysfunction, considerable variability exists in how visual and gait parameters are measured across studies, highlighting the need for further research to clarify these relationships.¹¹

5. Visual Contribution to Gait and Postural Control

5.1 Role of Vision in Locomotion

Vision plays a central role in planning and controlling locomotor movements. Visual information allows individuals to estimate distances, identify obstacles, and determine appropriate foot placement during walking. During obstacle negotiation, individuals rely on visual cues regarding obstacle location and limb position to guide accurate stepping movements.¹²

Locomotor control involves two complementary mechanisms:

Feedforward control, which involves anticipatory motor commands generated based on predicted movement requirements, and Feedback control, which relies on sensory inputs—including visual, vestibular, and proprioceptive signals—to correct ongoing movements and maintain stability.¹³

5.2 Integration of Visual, Vestibular, and Proprioceptive Inputs

Postural stability depends on the integration of visual, vestibular, and somatosensory information. Each system contributes unique information about body orientation and motion.

Visual and somatosensory cues significantly enhance balance performance, and the availability of multiple sensory inputs provides greater stability than reliance on a single modality.¹⁴

Experimental studies have demonstrated that humans can adapt their gait when visual feedback is altered. For example, when visual feedback of lower limb movement is artificially scaled during treadmill walking, individuals gradually adjust their gait to reduce tracking errors and restore symmetry.¹⁵

5.3 Functional Impact of Refractive Errors on Gait

5.3.1 Myopia

Myopic individuals exhibit differences in blur sensitivity compared with emmetropic individuals. Studies indicate that myopes demonstrate poorer monocular blur discrimination across the visual field, although binocular viewing may reduce this difference.¹⁶

Blur induced by myopia can influence locomotor stability. A kinematic study reported that simulated myopic blur increased variability in vertical center-of-gravity movement and altered joint angle patterns at the hip and knee during walking.¹⁷ These changes suggest that myopic blur may disrupt precise visuomotor coordination during gait.

5.3.2 Hyperopia

In hypermetropia, the visual system must exert additional accommodative effort to achieve clear vision. Sustained accommodation can lead to visual fatigue and discomfort.¹⁸

Although fewer studies have examined hyperopia in relation to gait, emerging research suggests that simulated hyperopic blur can alter gait kinematics and reduce walking stability.¹⁹

5.3.3 Astigmatism

Astigmatism produces orientation-dependent optical blur because light rays focus at two different focal lines instead of a single point. This can lead to perceptual distortions in which edges or lines appear smeared along the blurred meridian.²⁰

Experimental studies using astigmatic lenses have shown that older adults exhibit larger subjective visual vertical errors compared with younger adults, particularly when lenses are oriented obliquely.²¹ Such distortions may affect spatial orientation and postural control during walking.

5.3.4 Anisometropia

Anisometropia can produce unequal retinal image sizes between the eyes and disrupt binocular fusion.²² Research has shown that individuals with anisomyopia may demonstrate significant binocular imbalance at higher spatial frequencies, indicating asymmetrical visual processing due to interocular refractive differences.²³ This imbalance may impair depth perception and visuomotor coordination during locomotion.

6. Mechanisms Linking Refractive Error to Gait Alterations

6.1 Visual Blur and Reduced Visual Acuity

Visual blur reduces spatial resolution and limits the ability to accurately judge distances. Individuals experiencing visual blur often adopt cautious gait strategies, such as increasing toe clearance and reducing walking speed. Studies show that even small levels of monocular blur (0.50 D) can cause elderly individuals negotiating raised surfaces to increase toe clearance as a safety measure.

6.2 Depth Perception and Spatial Judgment

Depth perception plays a crucial role in locomotor planning. Metrics such as the Romberg Quotient (RQ) highlight the importance of visual input for maintaining postural stability.²⁴ Loss of stereopsis may significantly impair locomotor coordination. Individuals with reduced stereoscopic vision often adjust their gaze toward closer footholds when navigating complex terrain.²⁵ Minimum Toe Clearance (MTC), defined as the smallest distance between the swinging foot and the ground during mid-swing, is an important determinant of tripping risk. Increased variability in MTC has been observed in individuals with visual impairment.²⁶

6.3 Contrast Sensitivity and Motion Perception

Contrast sensitivity enables detection of objects and environmental boundaries under varying lighting conditions. Motion perception allows individuals to detect dynamic hazards. Reduced motion sensitivity has been associated with slower hazard detection in driving environments.²⁷ Similarly, reduced peripheral contrast sensitivity due to uncorrected refractive error may impair hazard detection during walking.

6.4 Binocular Dysfunction

Binocular vision anomalies such as suppression, fixation disparity, and reduced fusional reserves can disrupt visuomotor coordination. These conditions may impair depth perception and lead to increased variability in foot placement during walking.²⁸

6.5 Evidence from Experimental and Clinical Studies

6.5.1 Simulated Refractive Error Studies

Experimental studies using induced refractive errors provide controlled insight into the effects of visual blur on gait. Choi et al. (2020) induced refractive errors of ± 1 –3 diopters in healthy adults and observed reductions in step length

and increases in cadence, particularly in hyperopic conditions due to accommodative strain.²⁹

Similarly, simulation studies in older adults demonstrate that visual blur and cataract simulation increase body sway and reduce postural stability.³⁰

6.5.2 Observational Studies

Observational studies indicate that uncorrected refractive error can significantly influence gait behavior. Chapman et al. (2011) demonstrated that uncorrected refractive error altered obstacle-crossing gait patterns in older adults, resulting in shorter step lengths and increased toe clearance.³¹

Population studies have reported that the prevalence of uncorrected refractive error among elderly individuals ranges from 30% to 50%, and these individuals often exhibit slower gait speed and higher fall risk.³²

6.5.3 Interventional Studies

Optical correction may influence gait and balance. Spectacle lenses can introduce peripheral distortions and restrict the visual field, whereas contact lenses provide a wider field of vision and more natural optical correction.³³Comparative studies suggest that contact lens wearers may exhibit better medio-lateral stability during walking than spectacle wearers.³⁴However, multifocal spectacles may introduce visual distortions during stair negotiation, potentially increasing the risk of tripping among inexperienced users.³⁵

7. Age-Related Considerations

7.1 Children

Visual input is essential for the development of motor coordination during childhood. Uncorrected refractive errors may impair depth perception and spatial orientation, leading to cautious gait patterns characterized by shorter step lengths and increased stride variability.³⁶

7.2 Adults

Young adults typically demonstrate greater adaptability to visual perturbations. However, induced refractive errors as small as ± 1 diopter can still influence gait parameters by slowing walking speed and increasing safety margins during obstacle negotiation³⁷.

8. Conclusion

Vision plays a fundamental role in locomotor control by providing information about spatial orientation, environmental hazards, and body position. Refractive

errors—particularly when uncorrected—can degrade visual input through blur, reduced contrast sensitivity, impaired depth perception, and binocular imbalance.

These visual deficits may lead to measurable changes in gait patterns, including slower walking speed, increased toe clearance, altered step length, and greater variability in gait parameters.

Although individuals often develop compensatory strategies to maintain stability, persistent visual impairment may increase fall risk and mobility limitations, particularly among older adults. Therefore, accurate detection and correction of refractive errors are essential not only for visual performance but also for maintaining safe and efficient locomotion.

Future research should focus on developing standardized methods for assessing visual function and gait parameters, as well as conducting longitudinal studies to determine how refractive error correction influences locomotor behavior across different age groups.

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