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Motor Gains from Using Proprioceptive Cues in Treadmill Walking: Clinical Exercise Rehabilitation for Individuals with Parkinson's Disease

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Abstract

Treadmill walking is the conventional rehabilitation strategy used to improve gait and stability in individuals with Parkinson's disease. Current evidence suggests that coupling proprioceptive cues (such as vision and hearing) with treadmill walking can significantly improve measures of gait. Consistent with the model of the lifespan approach of motor development, these findings offer novel insight into clinical exercise rehabilitation strategies that have the potential to improve physical activity participation in individuals with Parkinson's disease. **Health & Fitness Journal of Canada 2016;9(3):54-58.**

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Introduction

Parkinson's disease (PD) is characterized by progressive degeneration of dopaminergic neurons in the basal ganglia of the brain, which reduces the production of the neurotransmitter dopamine (DA) (Borrione et al., 2014). In humans, one function of DA is to assist with the automaticity of movement patterns by transmitting electrical impulses from the basal ganglia to the cortical motor cortex, where movement (such as walking) is coordinated and maintained (Borrione et al., 2014). Since PD is most prevalent among adults over the age of 50, fall-

related injuries pose health concerns in this population; symptoms common to PD (such as muscle rigidity, bradykinesia and postural instability) can heighten the risk for fall-related injuries (Borrione et al., 2014). Thus, improving the control of gait has become the new focus in clinical exercise rehabilitation. Empirical evidence suggests that the coupling of perceptual cues (such as vision and hearing) with treadmill-walking exercises can improve gait control in individuals with PD (Frenkel-Toledo et al., 2005).

The primary purpose of this narrative review and commentary is to use the lifespan approach of motor development (a dynamic process that persists throughout an individual's lifetime) to evaluate the use of external cues in treadmill walking to improve gait rhythm and stability in individuals with PD.

Improving gait and stability enhances the experience of walking, a cost-effective physical activity that has been shown to improve the health status and quality of life in all individuals (Warburton et al., 2010). Regular physical activity is an effective primary and secondary preventative strategy against more than 25 chronic medical conditions, which are higher in prevalence in the sedentary population (Warburton et al., 2006). Because PD constrains mobility, individuals with PD are prone to sedentary behaviour and subsequent risk

for all-cause mortality. Evaluating the effectiveness of various external conditions in treadmill walking can provide novel insight into clinical exercise rehabilitation strategies that can improve the physical activity experience in individuals with PD.

Key Findings

Treadmill walking has been used as a rehabilitative strategy to improve the control of gait in patients with PD. There is evidence that the rhythmic pattern of treadmill walking provides proprioceptive cues to improve an individual's gait rhythm (Bello et al., 2010). For instance, in the work of Bello et al. (2010), patients with PD participated in three walking interventions over three consecutive days. In each intervention, patients engaged in overground walking (baseline) before participating in: 1) treadmill walking (assisted by using the hands to exert weight over the handrails), 2) simulated treadmill walking (overground walking) with assistance, and 3) simulated treadmill walking (overground walking) without assistance. The authors reported a significant increase in step length and significant reduction in cadence over the treadmill, in comparison to the overground walking intervention.

The findings by Bello et al. (2010) suggested that the gains associated with gait control may be attributed to the use of proprioceptive cues generated by the rhythmic movement of the treadmill belt. The postulation is that proprioceptive stimuli can bypass the degenerating basal ganglia and stimulate the motor cortex to maintain gait sequence, which is interrupted in individuals with PD. Hence, it was suggested that other perceptual cues, such as vision and hearing, could

also stimulate the motor cortex independent of the basal ganglia. This conclusion was consistent with findings in similar studies (Frenkel-Toledo et al., 2005; Herman et al., 2007).

To determine whether or not other sensory stimuli could function as cues to improve gait control in individuals with PD, Frazzitta and colleagues (2009) conducted a study in which visual and auditory cues were simultaneously applied in the presence or absence of treadmill training. The visual cue consisted of a target that was projected onto a screen, and participants were instructed to synchronize the footfall (left or right) on the treadmill with the appropriate target signal (left or right) displayed on the screen. The auditory cue comprised of musical beats that were synchronized with the visual cues at a fixed frequency. It was observed that in comparison to the control group, participants who used visual and auditory cues while treadmill walking experienced significant reductions in freezing of gait, as well as significant improvements in gait speed, stride cycle and distance walked. These findings provided empirical evidence that perceptual cues could be coupled with treadmill walking exercises to provide acute improvements in gait in individuals with PD (Frazzitta et al., 2009).

In contrast, Schlick et al. (2012) demonstrated that coupling perceptual (visual) cues with treadmill walking exercises could induce transferable effects of motor skill learning. In the case study conducted by Schlick et al. (2012), a patient with PD participated in six training sessions for two weeks. Changes in gait performance were assessed before, during and after the treadmill intervention. Two conditions (cued and

non-cued) were measured while the patient performed the treadmill-walking task. In the cued condition, a projector presented green and blue oval-shaped cues onto the treadmill belt in synchrony with the speed of the treadmill (Schlick et al., 2012). During the treadmill-walking task, the patient was instructed to step on the green cue with the left foot, and the blue cue with the right foot. In addition to significant improvements observed in the patient's step length, step width, gait symmetry and walking speed, the patient gained endurance in the treadmill-walking task. Remarkably, the patient (who was unable to walk with assistance prior to the intervention) regained the capacity to walk short distances with assistance. These results demonstrated the transferable benefits of coupling perceptual cues with treadmill walking to improve the control of gait in individuals with PD.

The basis of these findings can be justified by using the lifespan approach of human motor development (Gabbard, 2012). The current lifespan approach assumes that: 1) human motor development is a continuous and cumulative process that persists through older adulthood; 2) motor development is influenced by environmental stimuli, which can induce neuroplasticity; 3) motor development is subject to progression and regression; and 4) the domains of human motor development are interrelated.

Although motor skills regress progressively in individuals with PD, the human brain is capable of undergoing plasticity in the presence of environmental stimuli, such as perceptual cues (Gabbard, 2012). The lifespan approach assumes that perceptual cues (the nurture aspect) interact with the

pathophysiology of PD (the nature aspect). Hence, it can be postulated that in individuals with PD, the coupling of sensory modalities (such as vision, hearing and/or proprioception) with physical activity (treadmill walking) may promote brain plasticity. In individuals with PD, brain plasticity may be the underlying mechanism that compensates for the degradation of dopaminergic neurons in the basal ganglia. If this assumption is correct, then brain plasticity should provide individuals with PD the opportunity to re-learn an automated motor skill (such as walking) that was previously acquired during infancy and childhood years. The finding that gait improvements could persist four weeks post-treadmill training provided some evidence for brain plasticity in individuals with PD (Herman et al., 2007).

However, the presence of brain plasticity is not always indicative of improvements in motor development. Several sources of evidence provide support for this claim. For instance, Luessi et al. (2012) demonstrated that when visual cues were coupled with treadmill training at greater velocities, fewer improvements in walking performance were observed in individuals with PD. In comparison, it was demonstrated that auditory cueing interfered with treadmill walking when the velocity of the treadmill-walking task was increased (Gallo et al., 2014). In these situations, it can be seen that the same stimuli applied at different intensities may invoke different neurological effects; the increase in proprioceptive stimuli (as a result of increased velocity) hindered the gait rhythm and stability in individuals with PD. Furthermore, Nanhoe-Mahabier et al. (2012) demonstrated that when individuals with

PD were instructed to avoid obstacles during a treadmill walking task performed in the presence of auditory cues, this obstacle-avoidance task increased the rate of freezing during walking. In this example, the addition of new environmental stimuli interfered with gait control. The overall implication is that the persistence of unfavourable environmental cues may invoke brain plasticity in a manner that may promote the regression of motor development.

As outlined above, a key assumption of the lifespan approach is that the domains of human motor development are interrelated (Gabbard, 2012). The perceptual modalities used in treadmill walking exercises work in conjunction to improve gait. Evidence for the role of perceptual-motor activity is provided in studies of sensory deprivation. For instance, visual deprivation may be compensated by heightened sensitivity of the vestibular system (Tramontano et al., 2016). Based on the evidence presented, visual deprivation would be expected to further impair gait control in individuals with PD. Contrary to this hypothesis, Tramontano et al. (2016) demonstrated that blindfolded balance training in patients with PD significantly improved their control of gait in a treadmill-walking task. This finding provided insight that gait rhythm and stability may be governed by an interaction among different environmental stimuli.

Conclusion

The findings and implications provide empirical evidence that coupling perceptual cues with treadmill training can significantly improve gait rhythm and stability in patients with PD. Although the physiological mechanism behind this association is not clear, current literature

suggests that brain plasticity may be one strategy to compensate for the progressive degeneration of the basal ganglia (Gabbard, 2012; Sciada et al., 2016). This postulation is consistent with the current lifespan approach to understanding human motor development, since the interaction between environmental and biological factors is known to play a role in neuroplasticity (Gabbard, 2012). Nevertheless, further research is required in order to assess the chronic effects of perceptual-motor exercises in individuals with PD. The justification for further research stems from the high prevalence of fall-related injuries experienced by individuals with PD (Borrione et al., 2014), the health benefits of walking as a primary and secondary preventative strategy for chronic diseases (Warburton et al., 2006), and limited empirical evidence to support evidence-based practice in traditional clinical exercise rehabilitation programs (Ellis et al., 2005).

Authors' Qualifications

The authors' qualifications are as follows: Henry Lai, BSc, BKIN; Darren Warburton, MSc, PhD, HFFC-CEP.

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Proprioceptive Cues in Treadmill Walking and Parkinson's Disease

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