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Special issue:
Effects of aging on locomotor patterns

Editorial: Effects of aging on locomotor patterns

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ABBREVIATIONS

AD Alzheimer's disease
PD Parkinson's disease
CoM Center of mass

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ABSTRACT
Aging and age-associated neurological diseases, such as Alzheimer's disease (AD) and Parkinson's disease (PD), may impair walking performance. Changes in walking performance are related to an increase in fall risk, institutionalization, hospitalization, survival rate, and mortality. Due to the increase in the segment of the old population and, consequently, in the number of individuals with age-related diseases, the amount of research aiming at understanding the mechanisms underlying walking changes, examining tools to measure walking, and developing interventions to improve walking performance in older individuals and in age-related diseases has increased substantially. In this special issue, we target to compile information and strengthen the discussion about whether and how aging and neurological diseases, specifically AD and PD, affect walking, and on potential interventions to improve walking in these populations. A total of five studies compose this special issue, including four original papers and one review.

KEYWORDS: Gait | Walking | Parkinson's disease | Older people | Alzheimer's disease

1. INTRODUCTION

Older population is growing drastically. World Health Organization projections indicate that individuals aged over 65 years old will almost triple from 524 million in 2010 to 1.5 billion by 2050 [1]. As the segment of the old population increases, incidences of age-associated neurological diseases rise nearly parallel, being Alzheimer's disease (AD) and Parkinson's disease (PD) the most prevalent ones (4% and 1.1%, respectively) [2,3]. With the increase in the number of older individuals and people with AD and PD, the consequent age-, AD-, and PD-related declines in motor and cognitive functions are serious and growing concerns for public health, and health and life sciences[1,4].

As a consequence of those age-, AD- and PD-related declines in functions, the capacity to maintain bipedal locomotion (i.e., ability to move from one place to another), control postural stability, and adapt walking to different conditions (e.g., concomitant tasks, or dealing with obstacles while perambulating) is affected in those populations. In this special issue, we target to compile information and strengthen the discussion about whether and how aging and AD, and PD affect walking (the most common way of human locomotion), and potential interventions to improve walking in these populations. A total of five studies compose this special issue, including four original papers and one review. The main findings of these studies are briefly introduced in topics organized in ideas on how aging, AD, and

PD affect locomotion, the role of walking task conditions (i.e., obstacle crossing and dual-task), the mechanisms involved in gait stability and potentials interventions for walking for older individuals and people with PD and AD.

2. AGING, AD, AND PD EFFECTS ON LOCOMOTION

Aging typically involves remarkable changes in walking, including spatial-temporal (shorter and wider steps/strides, and slower walking speed) and neuromuscular control (higher knee agonist-antagonist coactivation and lower synergistic ankle muscle coherence) [5–8]. Slowing speed is the most recognizable age-related change in walking (decreasing by 16% per decade from 60 years old). In AD and PD, those age-typical declines in walking performance are even more evident (e.g., accentuated reductions in stride length and gait speed, and increased gait variability in PD and AD compared to healthy older individuals) [9,10]. A decrease in walking performance overall, and walking speed in particular, is a hallmark of health, as it predicts mobility independence, cognitive function, institutionalization, hospitalization, survival rate, and mortality [11]. It is not a surprise that there is a substantial growing of studies targeting understanding the underlying neural and associative mechanisms of age-, AD- and PD-related decrease in walking performance, stability, and, mainly, walking speed.

Regarding potential associative aspects related to poor walking performance, Barbieri and colleagues [12] examined whether body composition of the lower limbs would be associated with spatial-temporal walking parameters in people with PD. The rationale was based on the idea that exacerbated sarcopenia (muscle loss) and osteopenia (bone mass loss) in people with PD would somehow be linked to poorer walking performance. In fact, the reduced lean and bone mass were related to slower gait speed in PD. This observation points out that the potential cause of slow walking and stability may be multifactorial, but certainly, the preservation of locomotion is related to the maintenance of body composition. Another potential interpretation is that maintaining body composition would reflect musculoskeletal plasticity, ensuring the neuromuscular control of walking and leading to preserving walking speed and stability.

Following the hypothesis that aging would impair the capacity to modulate the neuromuscular control to different walking speeds, Santos et al. [8] (intermuscular coherence) tested the effects of aging and walking speed on intermuscular beta coherence. They expected that age and walking speed would interact (e.g., older vs. younger individuals would have lower coherence without modulating it with walking speed). Curiously, the authors observed that aging but not walking speed affected intermuscular beta coherence (also only between synergistic ankle but not thigh muscles). The authors also did not find associations between speed-induced changes in spatial-temporal gait outcomes with changes in beta coherence. Therefore, it is likely that other neuromuscular features (e.g., antagonistic coactivation [13]) instead of intermuscular beta coherence explain the age differences in the neural control of walking speed.

3. OBSTACLE AVOIDANCE AND DUAL-TASK WALKING CONDITION IN AGING AND DISEASE

Due to the age-, PD- and AD-typical declines in cognitive functions, the capacity to allocate cognitive resources to walk performing a concomitant secondary task (dual-task) is affected [14–16]. This is supported by empirical data showing decreased walking performance during dual-task walking [14–16]. Reasonably, the decline in either walking and/or cognitive task may support the idea that cognitive function and walking are intrinsically linked [17,18]. Partially supporting this idea, Costa et al. [19] compared longitudinally (32 months apart) the effect of AD, mild cognitive impairment (MCI) on functional mobility (Timed Up and Go - TUG) isolated and combined with a secondary test (dialing on the phone) with cognitively preserved individuals. They found time-induced differences in time and cadence for both TUG conditions and in the number of steps in dual-task TUG in AD vs. cognitively preserved, AD vs. MCI, but not in MCI vs. AD. The results suggest that the progression of AD over time affects, even more, the performance of walking, while in MCI, after three years, the performance of mobility was virtually similar to the baseline. It partially reiterates the need to maintain preserved cognition that certainly reflects "better" locomotion in older individuals.

Additionally, aging, AD, and PD affect the capacity to modulate walking to different conditions of walking. A clear example is based on cumulative evidence showing that when those populations need to negotiate with an obstacle, the risk of falls due to trips increases substantially [20]. Trips during steps over obstacles are an eminent problem in healthy aging and diseases since trips are one of the main reasons for falls [21]. The cause of the higher number of trips in old age is still not fully elucidated, and studies are exploring potential factors that increase the risk of trips and falls.

In this special issue, Becker and Rietdyk [22] quantified inadvertent trips and differentiated factors present in those older individuals who tripped from those who did not. They observed that 15 out of 41 older adults tripped while crossing obstacles at least once. Those 15 individuals walked with slower walking speed, shorter stride length, higher variability in the gait cycle time, indicated higher fatigue ratings, and took more medications than those who did not have any trips. Therefore, walking performance during obstacle avoidance can be a marker of the risk of falls. Even more, the presence of fatigue, as well as the number of medications, may somehow be associated with trips and falls. Particularly relevant, the present study supports the understanding of the circumstances related to trips and the development of effective interventions to prevent trip-related falls in older individuals [22]. The authors also argued that whether the trip occurs with the leading or trailing limb may be harder to control the center of mass (CoM) and restore stability during walking, which is particularly challenging, as pointed out by van Leeuwen et al. [23] and discussed as follow.

4. MECHANISM TO CONTROL STABILITY DURING WALKING

Although trips and slips lead to a major number of falls in older individuals, the occurrence of falls is somehow linked to the inability or difficulty to maintain (re)actively dynamic stability. Walking stability requires a complex interaction of several mechanisms [23] that involves a net of functions affected by aging, and even more in AD and PD. Investigating those mechanisms, van Leeuwen et al. [23] proposed an overview of potential mechanisms of gait stability control during unperturbed and perturbed walking. The focus of the review was on detailing three mechanisms of walking stability: (1) foot stability, (2) stance leg control, and (3) angular momentum changes. Briefly discussing each mechanism, firstly, to stabilize walking in the mediolateral direction, the foot placement should be lateral to the extrapolated CoM position, while for anteroposterior, the foot placement seems to be dependent on the anteroposterior pelvis velocity with mediolateral pelvis position and velocity. Secondly, by ankle movements (inversion/eversion and plantar/dorsiflexion), stance leg control can modulate the center of pressure shift in both mediolateral and anteroposterior directions. Thirdly, the angular momentum can be used to stabilize walking to a certain extent, suggesting a relatively minor role in controlling the CoM.

In aging and age-related diseases, errors in foot placement, changes in pelvis velocity and movement, limited active control of ankle movements, or even the typical changes in steps metrics (width, length) may reflect in the reduced stabilization of walking. For instance, by increasing step width, typically observed in older and PD individuals, the strength of the coupling of the mediolateral CoM state and foot placement may decrease [24]. Additionally, as also mentioned by van Leeuwen et al. [23], sensing and actuation of those mechanisms are strictly relevant to actively controlling stability during gait. As both sensing and actuation are diminished in aging and diseases, these factors combined may partially explain the reduced control of gait stability in those populations. Thus, understanding how walking is stabilized, combined with the information of the studies composing this special issue, can support optimizing training targeting aging and age-related disease populations.

5. POTENTIAL INTERVENTIONS AND FUTURE DIRECTION

One of the main clinical relevance of understanding the mechanisms and factors linked with whether and how age- and age-related diseases affect walking is centered on developing or optimizing intervention strategies (e.g., prevention and rehabilitation). Not differently, papers composing this special issue suggested [12,22], or even directly indicated [23], training strategies for general or specific aspects related to improving walking. Barbieri and colleagues [12] suggested that exercise programs focusing on maintaining body composition (especially with a mechanical load) would reflect in the maintenance of walking speed and stability. Becker and Rietdyk [22] also briefly mentioned, because of the link between fatigue increasing the risk of trips, the relevance of intervention programs in improving endurance capacity. Those suggestions confirm the cumulative and systematic evidence on exercise effectiveness on walking ability, improving performance, and reducing falls in older and PD individuals [25,26]. Specifically considering intervention focusing on the mechanisms of gait stability, van Leeuwen et al. [23] discussed detailed strategies to improve foot placement and stance leg control. The authors suggested that mechanically perturbed gait stability, specifically perturbed or augmented use of stabilizing mechanisms, may be potential training approaches for improving gait stability.

Even when not directly suggested, we still can use the information from the studies published in the special issue to raise potential strategies of intervention in old and AD populations based on the studies of Santos et al. [8] and Costa et al. [19] Considering that aging seems to affect the strength of synaptic inputs (inferred by intermuscular beta-coherence) to ankle, but not thigh, muscles during walking [8], intervention mainly focusing on the ankle muscle seems to be more relevant for older individuals. Indeed, improving ankle functions may be relevant, considering that this can also be beneficial for foot placement (a mechanism of gait stability [23]) and because of the typical distal-to-proximal redistribution of joint work during walking in older adults [27]. Also, since exercise-induced neuroplasticity is associated with improvements in motor function [28], enhancing physical activity level may reflect in the strength of synaptic inputs optimizing the motor control, reducing the negative effects on intermuscular beta coherence. Exercise as an intervention is also important to reduce the progression of the disease and improve cognitive-motor function in AD [29]. Thus, extending for discussing around the results of Costa and colleagues[19], we can interpret that exercise would avoid or minimize the interference of the cognitive decline of AD, reflecting in lesser decline in mobility (alone or in dual-task conditions).

In light of all findings, this special issue proposes an overlook on whether and how aging, AD, and PD affect gait, targeting to contribute to strengthening the discussion on the age-, PD- and AD-related factors and mechanisms that can interfere with walking, and on potential intervention strategies that can improve walking in those populations.

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