Gait & Posture 59 (2018) 242–247

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Age-associated changes in obstacle negotiation strategies: Does size and timing matter?

I. Maidan[a,*], S. Eyal[a,b], I. Kurz[a,c], N. Geffen[a], E. Gazit[a], L. Ravid[a], N. Giladi[a,d,e,f], A. Mirelman[a,d,f,g], J.M. Hausdorff[a,b,d,h]

[a] Center for the Study of Movement, Cognition, and Mobility, Neurological Institute, Tel Aviv Medical Center, Israel
[b] Department of Physical Therapy, Sackler Faculty of Medicine, Tel Aviv University, Israel
[c] Department of Physical Therapy, Faculty of Health Sciences, Ben-Gurion University of the Negev, Beer-Sheva, Israel
[d] Sagol School of Neuroscience, Tel Aviv University, Israel
[e] Sieratzki Chair in Neurology Tel Aviv University, Israel
[f] Department of Neurology and Neurosurgery, Sackler School of Medicine, Tel Aviv University, Israel
[g] Laboratory of Early Markers of Neurodegeneration; Neurological Institute, Tel Aviv Medical Center, Tel Aviv, Israel
[h] Rush Alzheimer's Disease Center and Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, IL, United States

ARTICLE INFO

Keywords:
Obstacle negotiation
Trailing foot
Leading foot
Aging
Strategies

ABSTRACT

Introduction: Tripping over an obstacle is one of the most common causes of falls among older adults. However, the effects of aging, obstacle height and anticipation time on negotiation strategies have not been systematically evaluated.
Methods: Twenty older adults (ages: 77.7 ± 3.4 years; 50% women) and twenty young adults (age: 29.3 ± 3.8 years; 50% women) walked through an obstacle course while negotiating anticipated and unanticipated obstacles at heights of 25 mm and 75 mm. Kinect cameras captured the: (1) distance of the subject's trailing foot before the obstacles, (2) distance of the leading foot after the obstacles, (3) clearance of the leading foot above the obstacles, and (4) clearance of the trailing foot above the obstacles. Linear-mix models assessed changes between groups and conditions.
Results: Older adults placed their leading foot closer to the obstacle after landing, compared to young adults ($p < 0.001$). This pattern was enhanced in high obstacles (group*height interaction, $p = 0.033$). Older adults had lower clearance over the obstacles, compared to young adults ($p = 0.007$). This was more pronounced during unanticipated obstacles (group*ART interaction, $p = 0.003$). The distance of the leading foot and clearance of the trailing foot after the obstacles were correlated with motor, cognitive, and functional abilities.
Conclusions: These findings suggest that there are age-related changes in obstacle crossing strategies that are dependent on the specific characteristics of the obstacle. The results have important implications for clinical practice, suggesting that functional exercise should include obstacle negotiation training with variable practice of height and available response times. Further studies are needed to better understand the effects of motor and cognitive abilities.

1. Introduction

Falls are the most frequent cause of injuries in older adults, accounting for 90% of hip [1,2] and wrist fractures [3], and 60% of head injuries [4]. The incidence of falls in the elderly population is high. Approximately 30% of community-dwelling adults over the age of 65 years experience one or more falls each year [5,6]. Thus, falls and their consequences are one of the largest risks to the health and independence of older adults. The increased risk of falling with aging is multifactorial in nature and can be divided into intrinsic factors associated with the individual, and extrinsic factors related to the environment [7,8]. Intrinsic risk factors include (1) motor aspects such as musculoskeletal deterioration, reduced reaction time, and changes in balance and gait, and (2) cognitive aspects such as executive function, attention, and visual special abilities [7,9,10]. Extrinsic factors include environmental properties, for example, anticipated and unanticipated obstacles [7]. The interaction between these intrinsic and extrinsic factors likely makes tripping while negotiating obstacles one of the most common causes of falls in older adults [6–8].

Previous work has shown that older adults adopt a more

* Corresponding author at: Center for the Study of Movement, Cognition and Mobility, Neurological Institute, Tel Aviv Medical Center, 6 Weizmann Street, Tel Aviv 64239, Israel.
E-mail address: inbalm@tlvmc.gov.il (I. Maidan).

http://dx.doi.org/10.1016/j.gaitpost.2017.10.023
Received 18 July 2017; Received in revised form 24 September 2017; Accepted 21 October 2017
0966-6362/

conservative strategy when negotiating obstacles, compared to young adults, to compensate for the motor and cognitive decline associated with aging [7]. These strategies include slower and shorter steps and higher foot clearance while crossing over the obstacles, all parameters that are further reduced when motor and cognitive abilities decline [7,10]. These compensatory strategies allow for additional time to adjust steps in order to reduce the risk of tripping [8]. Spatiotemporal measurements such as foot clearance and the distance of the foot before and after an obstacle are associated with increased risk of tripping over an obstacle [7]. Nonetheless, conflicting age-related findings regarding these measurements have been reported.

Some studies report no effect of age on foot distance above obstacle [7,11], another showed larger distance of foot above obstacle in older adults [12], and another reported smaller distance of foot above obstacle, compared to young adults [13]. Conflicting results were also observed in the distance of the trailing foot before the obstacle and distance of the leading foot after the obstacle. Several studies reported that older adults land with the leading foot closer to an obstacle [13,14] while others showed they land further from the obstacle [12], as compared to young adults. These discrepancies between studies may be attributed to differences in methodologies such as different size of obstacles and timing in the gait cycle.

Two obstacle parameters that presumably have a direct impact on successful obstacle avoidance are the height of the obstacle and the available response time (ART) to obstacle appearance (anticipated vs. unanticipated obstacles). With aging, reaction time increases, making this a crucial component in the ability to negotiate unanticipated changes [10]. Previous studies reported that as obstacle height increases, older adults modify their strategy to decrease crossing speed and increase clearance of both leading and trailing limbs [9,13]. In addition, several studies demonstrated that older adults contact the obstacle more frequently than young adults under time-constrained conditions [9,15]. Older adults adopt a short step strategy to avoid obstacles when time to response to obstacle appearance is limited and obstacles are unanticipated [16].

These adopted strategies have clinical implications as they can influence performance in everyday life and may be associated with falls. Due to technology constraints in presenting unanticipated obstacles while walking, previous work generally employed protocols using virtual obstacles and/or walking on treadmill [15–18]. The dimension of the obstacles was usually fixed and the depth was limited [19]. The lack of consensus regarding the effects of different obstacles height and ARTs on obstacle negotiation strategies with aging warrants further investigation. To better understand the effects of aging on obstacle crossing, we used a computer controlled obstacle course that allows for over-ground walking while negotiating obstacles of different heights that appear with different ARTs. We hypothesized that older adults will utilize a more conservative obstacle negotiation strategy, compared to young adults, as obstacle height increases and ART decreases. In addition, we hypothesized that these changes in obstacle negotiation would be correlated with age-associated changes in motor and cognitive abilities.

2. Methods

2.1. Participants

Twenty healthy young adults and twenty healthy older adults were included in this study. Participants were included if they were able to walk for 30 min unassisted with or without breaks, had no underlying orthopedic or neurological disorders, and were cognitively intact based on the Mini Mental State Examination (MMSE > 24) [20]. All participants provided informed written consent prior to participating in the protocol. The study was approved by the local human studies committee of the Tel Aviv Medical Center.

2.2. Protocol

The assessment included three parts: (1) gait and obstacle negotiation, (2) evaluation of cognitive function, and (3) balance and mobility tests. Assessment of gait and obstacle negotiation performance was examined while participants walked with a safety harness along an elliptical path of 50 m (see Fig. 1B). The ascending part of the elliptic path consisted of two obstacles. One obstacle was "anticipated"; it appeared on the walking path before the person started walking, allowing for a long preparation time. The second one "was unanticipated" obstacle; it appeared just as the subject approached the obstacle, presenting a shorter preparation time (see Fig. 1C). The descending part of the ellipse included usual walking that in part was performed on a 10 m sensorized carpet "Zeno Walkway" (ProtoKinetics, Havertown, PA). Gait spatio-temporal measurements obtained included gait speed and stride length [21].

2.3. The computerized obstacle course

The unique computerized obstacle course in the ascending part of the elliptic path (see Fig. 1) consists of two modules that are controlled by a computer and are imbedded under the floor over a 30 m corridor, allowing for complete integration of the obstacles in the floor. The first module included one obstacle of 60 cm width and 20 cm depth that was

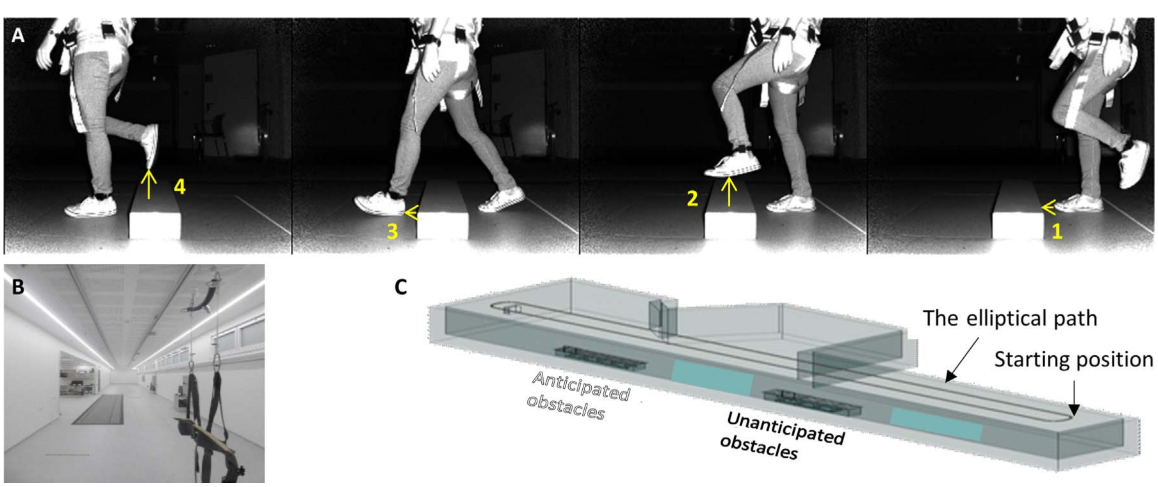

Fig. 1. Portion of our unique obstacle course. (A) A trace of a person walking as captured by the Kinect camera: (1) distance of trailing foot before the obstacle, (2) clearance of leading foot, (3) distance of leading foot after the obstacle, and (4) clearance of trailing foot. (B) The obstacle course. (C) Scheme of the elliptical path.