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Cognition and gait show a distinct pattern of association in the general population

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Abstract

Background: With brain aging, cognition and gait deteriorate in several domains. However, the interrelationship between cognitive and gait domains remains unclear. We investigated the independent associations between cognitive and gait domains in a community-dwelling population.
Methods: In the Rotterdam Study, 1232 participants underwent cognitive and gait assessment. Cognitive assessment included memory, information processing speed, fine motor speed, and executive function. Gait was summarized into seven independent domains: Rhythm, Variability, Phases, Pace, Tandem, Turning, and Base of Support. With multivariate linear regression, independent associations between cognitive and gait domains were investigated.
Results: Information processing speed associated with Rhythm, fine motor speed with Tandem, and executive function with Pace. The effect sizes corresponded to a 5- to 10-year deterioration in gait.
Conclusions: Cognition and gait show a distinct pattern of association. These data accentuate the close, but complicated, relation between cognition and gait, and they may aid in unraveling the broader spectrum of the effects of brain aging.

Keywords: Cognition; Cognitive impairment; Epidemiology; Gait; Walking

1. Introduction

Age-related pathology of the brain may cause a decline in various cognitive domains, such as memory, executive function, and information processing speed [1,2]. Cognitive decline may ultimately lead to mild cognitive impairment and dementia [1].

Gait is a complex motor function that is also heavily affected by age-related brain pathology [3,4]. Gait is a strong indicator of health, and poor gait is associated with higher mortality, morbidity, and risk of falls [5–7]. Gait can be measured in several conditions, such as normal walking, turning, and tandem walking, and gait yields many parameters. These parameters in turn constitute fewer independent gait domains, such as Rhythm, Variability, Pace, Turning, and Base of Support, which together provide a comprehensive description of gait [8–10]. A few recent studies have shown associations of certain gait domains with different brain areas; for example, step width (part of Base of Support) is associated with the pallidum whereas step length (part of Pace) is associated with the sensorimotor- and dorsolateral prefrontal cortex [3,4].

Given that cognition and gait closely reflect brain functioning, several studies have studied the link between the two [9,11–13]. These studies did so by investigating global cognition or gait velocity, but they did not study separate domains [11–13]. It is conceivable that certain cognitive domains may associate with certain gait domains, both affected by a single corresponding brain area. The one study to investigate associations among specific cognitive and gait domains found Pace to be associated with attention and executive function [9]. Additionally, they found Rhythm, Variability, and Pace to associate with cognitive decline and incident dementia [9].

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Still, given that cognition and gait are broad concepts, it remains unknown how various other cognitive and gait domains are associated. Moreover, most previous studies did not consider correlations among cognitive and gait domains, making it difficult to discern their independent effects.

In a population-based study, we investigated the independent associations between cognitive domains and gait domains. To more comprehensively assess gait, we investigated normal walking, turning, and tandem walking.

2. Methods

2.1. Setting

This study was embedded in the Rotterdam Study, a prospective population-based cohort in the Netherlands aimed to investigate causes and determinants of chronic diseases in the middle-aged and elderly [14]. The cohort was initially defined in 1990 and expanded in 2000 and 2005. In 1990 and 2000, all inhabitants aged 55 years and older of Ommoord, a suburb of Rotterdam, were invited to participate in the study. In 2005, all inhabitants aged 45 years and older were invited. A total of 14,926 persons agreed to participate (response rates of 78, 67, and 65%). At study entry and during follow-up every 3–4 years, each participant underwent a home interview and extensive physical examination at the research center. At these assessments, height and weight were measured and self-reported chronic diseases were recorded. During the interview at study entry, the attained level of education was assessed according to the standard classification of education [14]. From March 2009 onward, gait assessment has been implemented in the core protocol of all subcohorts. The current study comprises all participants that completed gait assessment until March 2011. The study has been approved by the Medical Ethics Committee of the Erasmus Medical Center. All participants gave written informed consent.

2.2. Assessment of cognitive function

Cognitive function was assessed with the following neuropsychological test battery: the Mini-Mental State Examination (MMSE) [15], the Stroop test [16], a 15-word verbal learning test (based on Rey's recall of words [17]), the Letter-Digit Substitution Task (LDST) [18], a word fluency test (animal categories) [19], and the Purdue Pegboard test [20]. To obtain more robust measures, *z* scores were first calculated for all separate tests by subtracting the individual value by the population mean and dividing by the standard deviation (SD). Then, *z* scores for different tests were combined into compound scores for memory, executive function, information processing speed, global cognition, and fine motor speed as reported previously [21]. The *z* scores for the Stroop tasks were inverted for use in these compound scores because higher scores on the Stroop task reflect worse performance whereas higher scores on all other tests reflect a better cognitive performance. The compound score for memory was calculated as the average of the *z* scores for the immediate and delayed recall of the 15-word verbal learning test. Executive function was constructed by averaging the *z* scores for the Stroop interference subtask, the Word Fluency Test (number of animals in 1 minute), and the LDST (number of correct digits in 1 minute). Information processing speed was the average of the *z* scores for the Stroop reading and Stroop color naming test and the LDST. Fine motor speed was defined by the *z* score for the Purdue Pegboard test (both hands). For global cognition, we used the average of the *z* scores of the Stroop task (average of all three subtasks), the LDST, the Word Fluency Test, the immediate and delayed recall of the 15-word verbal learning test, and the Purdue Pegboard test (both hands). For each compound score, new *z* scores were calculated.

2.3. Gait assessment

A description of the gait assessment has been published previously [10]. Gait was assessed with a 5.79-m long walkway (GAITRite Platinum; CIR systems, Sparta, NJ: 4.88-m active area; 120-Hz sampling rate) with pressure sensors. This device is considered an accurate system to determine gait parameters [22–24].

Participants performed a standardized gait protocol consisting of three different walking conditions: normal walk, turning, and tandem walk. In the normal walk, participants walked over the walkway at their own pace. This walk was performed 4 times in both directions (eight recordings). In turning, participants walked over the walkway at their own pace, turned halfway, and returned to the starting position (one recording). In the tandem walk, participants walked tandem (heel-to-toe) over a line visible on the walkway (one recording).

In recordings of the normal and tandem walks, footsteps not falling entirely on the walkway at the start and at the end were removed before the analyses. The first recording of the normal walk was treated as a practice walk and was not included in the analyses. Recordings of individual walks were removed if instructions were not followed correctly or when fewer than four footprints were available for analyses. Spatiotemporal variables were calculated by the walkway software.

Consecutively, principal components analysis on 30 gait variables was used to derive summarizing factors, as previously reported [10]. Within the principal components analysis, varimax rotation was used to ensure that the factors were totally independent from each other. Factors were selected if their eigenvalue was 1 or higher, indicating that each factor explains at least as much variance as a single variable. We appointed variables to a certain factor if their correlation with the factor was 0.5 or higher. Although a gait variable could attribute to several factors, none of the gait variables had a correlation of 0.5 or higher with more than one factor. If necessary, factors were inverted so that lower values always represent "worse" gait. This applied to all factors except for Pace. Seven factors were derived from this principal components analysis,