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Gait patterns in a community-dwelling population aged 50 years and older

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ABSTRACT

Poor gait is an important risk factor for falls and associated with higher morbidity and mortality. It is well established that older age is associated with worse gait, but it remains unclear at what age this association is first seen. Moreover, previous studies focused mainly on normal walking, but gait also encompasses turning and tandem walking. In a large study of community-dwelling middle-aged and elderly persons we investigated the association of age with gait, focusing on normal walking, turning and tandem walking. In 1500 persons aged 50 years and over, we measured gait using an electronic walkway. Participants performed normal walks, turning and a tandem walk. With principal components analysis of 30 variables we summarized gait into five known gait factors: *Rhythm*, *Variability*, *Phases*, *Pace* and *Base of Support*; and uncovered two novel gait factors: *Tandem* and *Turning*. The strongest associations with age were found for *Variability* (difference in *Z*-score −0.29 per 10 years increase (95% confidence interval: −0.34; −0.24)), *Phases* (−0.31 per 10 years (−0.36; −0.27)) and *Tandem* (−0.25 per 10 years (−0.30; −0.20)). Additionally, these factors already showed association with the youngest age groups, from 55 to 60 years of age and older. Our study shows that *Variability*, *Phases* and *Tandem* have the strongest association with age and are the earliest to demonstrate a poorer gait pattern with higher age. Future research should further investigate how these gait factors relate with gait-related diseases in their earliest stages.

1. Introduction

Proper gait is very important to function independently in a community. Not only is gait an important indicator of general health, but poor gait is also a predictor of adverse events, such as falls and mortality [1–6]. Various studies have shown that higher age is associated with worse gait [2,7–12]. With increasing life-expectancy, gait disturbances are therefore expected to become even more frequent [2].

Gait is a highly complex concept and can be studied using many different variables. These variables include simple measurements such as velocity, step length and step width, but also more complex measurements such as the variability within variables [7,8,13]. Consequently, the overlap across studies in variables used to study gait is limited. Ideally, gait is studied using as many variables as possible, but this would result in multiple testing as well as collinearity across variables.

In recent years, various studies have sought to solve this issue by principal components analysis (PCA). Using PCA on seven and eight variables, two studies summarized gait into three independent factors, referred to as *Pace*, *Rhythm* and *Variability* [3,4]. These factors were found to be associated with cognitive decline and risk of falls [3,4]. Another study expanded on this finding by including 15 additional gait variables in the PCA and uncovered two additional gait factors, which were named *Phases* and *Base of Support* [9]. Consecutively, the factors were found to be associated with age and sex [9].

The five gait factors described so far are all based on normal walking [3,4,9]. However, gait is a broader concept encompassing not only normal walking, but also turning and tandem (heel-to-toe) walking among others. Little is known about the effect of age on these aspects of gait. Furthermore, it is unknown whether these other aspects constitute additional gait factors or whether these can be captured by the previously described gait factors of normal walking.

Another consideration is that previous studies on aging and gait focused on elderly populations (60 years and over). The question

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remains whether the association between age and gait already starts at an earlier age. Investigating the earliest age-related changes in gait would provide novel insights into the normal aging progress and can serve as a basis to study pathologic gait disturbances.

The aim of our study was to investigate the association between age and gait in a population-based cohort study of middle-aged and elderly persons. We not only investigated normal walking, but also focused on turning and tandem walking. Similar to previous studies, we used PCA to summarize gait into a few independent factors.

2. Methods

2.1. Setting

The study was embedded in the Rotterdam Study, a prospective, population-based cohort study, originally started in 1990 [14]. The initial cohort was expanded in 2000 and 2005 and currently totals 14,926 persons. At study entry and during follow-up every 3–4 years, each participant undergoes a home interview and extensive physical examination at the research center. At these assessments height and weight are measured, and self-reported chronic diseases are recorded. From March 2009 onwards, gait assessment has been implemented in the core protocol. The current study comprises all participants that completed gait assessment until March 2011. All participants gave written informed consent. The study has been approved by the institutional Medical Ethics Committee.

2.2. Gait assessment

Gait was assessed with a 5.79 m long walkway (GAITRite Platinum; CIR systems, USA: 4.88 m active area; 120 Hz sampling rate) with pressure sensors, activated by the pressure of footfalls. This device is an accurate system to determine gait parameters [15–18].

Participants were asked to perform a standardized protocol consisting of three different types of walking: normal walk, turning and tandem walk. In the normal walk, participants walked over the walkway at their own pace. This walk was performed four times in both directions (eight recordings). In turning, participants walked over the walkway, 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). Examples of the three walks can be found in supplement 1.

In recordings of the normal and tandem walks, footsteps that did not fall entirely on the walkway at the start and the end were deleted. The first recording of the normal walk was treated as a practice walk and 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.

2.3. Study population

Between March 2009 and March 2011, we invited 1905 participants for gait assessment. Of these, 405 were excluded for various reasons: 196 participants were removed for technical reasons; 21 participants were excluded for use of walking aids, self-reported prosthesis or Parkinson's disease; 113 participants were excluded because of a too poor physical ability to walk; 41 participants were removed because they had fewer than 16 steps available for analyses, which lowers the validity of their gait parameters [19]; 14 participants refused to participate; nine participants refused to perform all walks; nine participants were removed because they did not follow instructions; and two participants did not perform the walks for other reasons.

After exclusion, 1500 participants were included in the analyses.

2.4. Statistical analysis

PCA with varimax rotation was performed on 30 variables to derive independent summarizing factors. A description of these 30 gait variables can be found in supplement 2. These were all variables that could be reliably measured using the GAITRite. Preliminary analysis did not suggest differences between legs; hence the mean of both legs was taken.

Factors were selected from the PCA if their eigenvalue was one or higher, signifying that each factor explains at least as much variance as a single variable. Communalities were calculated, reflecting the amount of variance in the variable explained by all factors. Variables were appointed to a certain factor if their correlation with the factor was $\geq$0.5. If necessary, factors were inverted so that lower values represent "worse" gait. The PCA yielded standardized factors (*Z*-scores) that were uncorrelated to each other.

Multiple linear regression analyses were used to determine the independent associations between demographics (age, sex, height and weight) and gait factors. Analyses involving tandem walk related variables were adjusted for the step length and step count in the tandem walk. We applied Bonferroni correction for 28 tests to correct for multiple testing. Additional adjustments were made for self-reported osteoarthritis and rheumatoid arthritis. We also calculated mean *Z*-scores of gait factors per 5-year age strata and per sex using ANOVA, adjusted for height and weight. Differences between sexes in the effects of age were tested using interaction terms (age $\times$ sex). All statistical analyses were performed using SPSS PASW version 17.0.2 for Windows.

3. Results

Characteristics of the study population are summarized in Table 1. Mean age was 68.8 years, and 817 (54.5%) were women. After summing all normal walks, an average of 41.75 (standard deviation (SD) 8.92) steps was available per participant. For turning an

Table 1
Population characteristics.

Characteristic	Total (n = 1500)	Men (n = 683)	Women (n = 817)
Age (yrs)	68.8 (10.1)	69.2 (10.3)	68.4 (9.9)
Height (cm)	168.5 (9.4)	175.7 (7.1)	162.6 (6.6)
Weight (kg)	78.0 (14.7)	85.1 (13.7)	72.1 (12.7)
Self-reported locomotor disorders			
Osteoarthritis (*n*)	343 (22.9%)	118 (17.3%)	225 (27.5%)
Rheumatoid arthritis (*n*)	46 (3.1%)	14 (2.0%)	32 (3.9%)

Values are mean (standard deviation) or numbers (%). *Abbreviations*: yrs, years; cm, centimeters; kg, kilograms; *n*, number.