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ORIGINAL ARTICLE

Gait Analysis With Cognitive-Motor Dual Tasks to Distinguish Fallers From Nonfallers Among Rehabilitating Stroke Patients

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Abstract

Objectives: To evaluate fall risk in stroke patients based on single- and dual-task gait analyses, and to investigate the difference between 2 cognitive tasks in the dual-task paradigm.

Design: Prospective cohort study.

Setting: Rehabilitation hospitals.

Participants: Subacute stroke patients (N=32), able to walk without physical/manual help with or without walking aids, while performing a verbal task.

Interventions: Not applicable.

Main Outcome Measures: Functional gait measures were Functional Ambulation Categories (FAC) and use of a walking aid. Gait measures were evaluated by an electronic walkway system under single- and dual-task (DT) conditions. For the single-task, subjects were instructed to walk at their usual speed. One of the DTs was a verbal fluency dual task, whereby subjects had to walk while simultaneously enumerating as many different animals as possible. For the other DT (counting dual task), participants had to walk while performing serial subtractions. After inclusion, participants kept a 6-month falls diary.

Results: Eighteen (56.3%) of the 32 included patients fell. Ten (31.3%) were single fallers (SFs), and 8 (25%) were multiple fallers (MFs). Fallers (Fs) more frequently used a walking aid and more frequently needed an observatory person for walking safely (FAC score of 3) than nonfallers (NFs). Two gait decrement parameters in counting dual task could distinguish potential Fs from NFs: decrement in stride length percentage ($P=.043$) and nonparetic step length percentage ($P=.047$). Regarding the division in 3 groups (NFs, SFs, and MFs), only MFs had a significantly higher percentage of decrement for paretic step length ($P=.023$) than SFs.

Conclusions: Examining the decrement of spatial gait characteristics (stride length and paretic and nonparetic step length) during a DT addressing working memory can identify fall-prone subacute stroke patients.

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Falling, a common complication poststroke, can involve many consequences.[1] Several studies demonstrated that falls in stroke survivors often occur during locomotion[1-5] and gait deficits, for example, problems with obstacle-crossing or need of supervision for safety (Functional Ambulation Category [FAC][6] score of 3) are retained as an important fall-risk factor. However, different patients, all categorized with an FAC score of 3, can still differ significantly in qualitative performance or in quantitative temporal-spatial gait characteristics. These characteristics also may fluctuate based on varying circumstances, for example, walking while simultaneously performing another task. Hyndman and Ashburn[7] evaluated the ability of walking while talking, known as the "Stops walking when talking" test (SWWT) in chronic stroke patients and found it to be moderately predictive for falling. Better results were revealed for distinguishing nonrepeated from repeated fallers than nonfallers (NFs) from fallers (Fs). Andersson et al[8] confirmed the test's predictive value in subacute patients.

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Walking while talking, a plain application of a cognitive-motor dual task (DT), can create destabilizing effects because of the competing demands for attention resources needed for both tasks. If 2 simultaneously performed tasks require more than the total information processing capacity, the performance on either or both deteriorates.[9] Therefore, clinicians often emphasize the importance of not talking while walking, and therefore patients can turn all attention to maintaining balance.

Even so, these DTs are increasingly included in temporal-spatial gait analyses, and different studies have investigated gait-related cognitive-motor interference (CMI) in stroke patients.[10-15] They found different effects on gait parameters when patients walked and simultaneously performed a cognitive task, including slower gait speed,[12] reduced cadence, longer stride duration, and increased double-limb support.[11,15] In a neurologic population, DT-related gait decrements showed to be significantly correlated with the patients' functional independence (Barthel Index) score, rather than with one of the standardly used gait measures, being the ten-meter walk time.[13] These results can emphasize the benefit of gait analyses, including DT paradigms, besides clinical observations of gait when evaluating stroke patients.

In older adults, gait analysis with DTs are frequently used in fall assessment,[16,17] and some studies provided an indication that DTs may have an added value. Different outcome parameters from DT walking indicating a fall risk were the following: reduced walking speed,[18] changes in step width, step time, and step length,[17] or variability in stride time.[19]

In chronic stroke patients, Hyndman et al[15] found that Fs showed a significantly reduced stride length during DT gait analyses compared with NFs.

An important issue in studies on CMI is the nature of the secondary task, because previous research has shown that different types of secondary (cognitive) tasks have varying effects on gait parameters.[9,10,20,21] In older adults, cognitive DTs that cause more competitive interaction with executive functions are preferred to provoke DT-related gait changes.[20,21] In community-dwelling stroke patients, spontaneous speech, as addressed in the SWWT, produced more gait interference than working memory or visuospatial tasks.[10] Hyndman[15] used a silent cognitive task (remembering a shopping list), drawing on sustained and divided attention as well as short-term memory, to explore differences between Fs and NFs.

The aims of the present study were to assess differences between NFs and Fs, as well as between NFs, single fallers (SFs), and multiple fallers (MFs), based on analysis using an electronic walkway system during a solitary walk, as well as 2 DTs in the first 6 months after stroke. Based on previous studies,[17,20] 2 DTs were used, addressing mainly semantic (enumerating animals) or working memory (counting backwards by threes). Two different cognitive tasks were used to investigate the importance of type of DT in gait analysis, evaluating fall risk. A final aim was to determine which gait parameters are the most important in fall evaluation and—if the DT paradigm has an additional merit—which task should be used. More insight into the effects of specific DTs on the mobility and fall risk of subacute stroke patients may be useful in future research on gait training paradigms in order to prevent stroke patients from falling.

List of abbreviations:

CMI	**cognitive-motor interference**
DT	**dual task**
F	**faller**
FAC	**Functional Ambulation Categories**
MF	**multiple faller**
MI	**Motricity Index**
MMSE	**Mini-Mental State Examination**
NF	**nonfaller**
SF	**single faller**
ST	**single task**
SWWT	**"Stops walking when talking" test**

Methods

Participants

All participants had residual hemiparesis and were recruited within the first 6 months after a first-time stroke. They had been included in an extensive study on risk factors for falling (N=73).[5] For this gait analysis study, patients had to be able to walk without manual help, with or without walking assistive devices (FAC score ≥3) and did not have aphasia or dysarthria interfering with verbal tasks (n=38). Figure 1 illustrates the study design and dropouts. All patients had to be able to understand the meaning of the study and to follow instructions. The study protocol was approved by the central and local ethics committees, and all patients signed an informed consent of participation after explanation of the study and prior to data collection.

Data of 32 patients were included for analyses. The mean age was 64.8 years (range, 32−90) with no significant sex difference. Strokes were predominantly ischemic in origin (75%), and the mean duration since stroke onset was mean ± SD 10.6 ± 6.7 weeks.

Design

Patients underwent a baseline screening and were followed (on fall status) for 6 months. Personal and medical information was collected before assessments took place. Cognitive status was examined using the Mini-Mental State Examination (MMSE).[22] A screening gait observation was performed whereby the use of a walking aid and the level of (physical) support in order to ambulate safely (expressed as FAC[6]) was registered. The severity of hemiplegia was assessed using the Motricity Index (MI).[23]

Gait analysis

Spatial and temporal measures of gait were determined by the GaitRite system,[a] an electronic walkway connected to a personal computer with specific software. The GaitRite system has shown to be a valid and reliable method to evaluate spatial and temporal gait parameters.[24-26] Patients had to walk independently on the GaitRite walkway (with a total length of 5.79m), starting and ending both at a marked point 2m from the walkway in order to eliminate the effect of acceleration and deceleration. Patients used their customary assistive devices during all conditions. For the single task (ST), patients were instructed to walk at their normative speed. Before the verbal fluency dual task, while walking, patients received the following instructions: walk at your normative speed while simultaneously verbally enumerating as many different animals as possible, and for the counting dual task, they were told the following: walk at your normative speed while simultaneously