ORIGINAL ARTICLE

The Effect of Cognitive Dual Tasks on Balance During Walking in Physically Fit Elderly People

Marianne B. van Iersel, MD, Heleen Ribbers, MD, Marten Munneke, PhD, George F. Borm, PhD, Marcel G. Olde Rikkert, PhD

ABSTRACT. van Iersel MB, Ribbers H, Munneke M, Borm GF, Olde Rikkert MG. The effect of cognitive dual tasks on balance during walking in physically fit elderly people. Arch Phys Med Rehabil 2007;88:187-91.

Objective: To evaluate the effect on balance of 3 different cognitive dual tasks performed while walking without and with standardization for gait velocity, and measured with both foot placements and trunk movements.

Design: Cross-sectional study.

Setting: Community.

Participants: Fifty-nine physically fit elderly people (mean age, 73.5y).

Interventions: Not applicable.

Main Outcome Measures: Stride length and time variability measured with an electronic walkway, body sway measured with an angular velocity instrument, and gait velocity.

Results: Overall, dual tasks resulted in decreased gait velocity (1.46 to 1.23m/s, $P<.001$), increased stride length (1.4% to 2.6%), and time variability (1.3% to 2.3%) ($P<.001$), and had no significant effect on body sway. After standardization for gait velocity, the dual tasks were associated with increased body sway (111% to 216% of values during walking without dual task, $P<.001$) and increased stride length and time variability (41% to 223% increase, $P<.001$).

Conclusions: In physically fit elderly people, cognitive dual tasks influence balance control during walking directly as well as indirectly through decreased gait velocity. Dual tasks increase stride variability with both mechanisms, but the increase in body sway is only visible after standardization for gait velocity. The decreased gait velocity can be a strategy with which to maintain balance during walking in more difficult circumstances.

Key Words: Equilibrium; Gait; Rehabilitation; Task performance and analysis.

FALLS ARE A COMMON PROBLEM among elderly people. Thirty percent of community-living people aged 65 and over fall at least once a year and that rate increases to 40% among people more than 80 years old. Important risk factors for falls are gait and balance impairments.[1] In daily life people often do several other things while they are standing or walking. Many falls occur during the performance of such dual tasks.[2] The explanation for this phenomenon is that performing the second task interferes with balance control, probably because of divided attention, or through structural inference in neural networks of the frontal and motor cortex.[3,4] A thorough knowledge of the effect of dual tasks on gait and balance may increase our understanding of balance control and can help identify people who are at risk of falling.[5,6]

Many studies have investigated balance with static measurements, but most falls occur during movement when the center of mass cannot be maintained within the lateral borders of the base of support. Balance during walking is controlled through both foot placements and trunk motion. However, former studies[7,8] investigated balance during walking mainly with gait variables such as gait velocity stride width, and stride variability.

Some studies[4,7,9] involving healthy elderly people found that the addition of a dual task only minimally changed these gait variables. The dual tasks in those studies probably were not sufficiently complex to interfere with balance control. Another possible explanation is that the measurement of balance with only gait variables during walking is insufficiently sensitive to change. Menz et al[10] found that adopting a slower gait speed with longer double-support phases did not stabilize the movements of head and trunk in a population of community living elderly people. Also, lowering gait velocity can be a strategy with which to maintain balance control in more difficult circumstances. Gait velocity decreases during performance of a dual task[8,11,12] and influences gait and balance variables,[13,14] but its contribution to the net effect of dual tasks on balance during walking is unknown.

Therefore we investigated the effects of 3 different cognitive dual tasks on balance control during walking in physically fit elderly people, as measured by both foot placements and trunk movements. Furthermore we investigated the effect of the dual tasks on balance control during walking after adjusting for the effect of changed gait velocity on these variables.

METHODS

Participants

We performed a cross-sectional study of physically fit elderly people who had good mobility. All were participants in the international Annual Four-Day Marches Nijmegen, in which elderly hikers walk 30 or 40km a day on 4 consecutive days. We recruited our participants with advertisements in the local and regional newspapers and the leaflet of the Four-Day Marches. Eligible participants were free of any complaints about their gait and balance, were 70 years old or older, had a normal gait pattern as observed by the researchers (MBI, HR), and could perform the Timed Up & Go (TUG) test within 10 seconds.[15] All subjects gave their written informed consent to participate. Exclusion criteria were cognitive impairments

From the Departments of Geriatrics (van Iersel, Ribbers, Olde Rikkert), Neurology and Physiotherapy (Munneke), and Epidemiology and Biostatistics (Borm), Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author(s) or upon any organization with which the author(s) is/are associated.

Correspondence to Marianne B. van Iersel, MD, Radboud University Nijmegen Medical Centre, Dept of Geriatrics, internal code 925, PO Box 9101, 6500 HB Nijmegen, The Netherlands, e-mail: *m.vaniersel@ger.umcn.nl*. Reprints are not available from the author.

0003-9993/07/8802-10908$32.00/0
doi:10.1016/j.apmr.2006.10.031

Table 1: Population Characteristics (N=59)

Characteristics	Mean ± SD
Men/women (n)	41/18
Age (y)	73.5±3.4 (70–82)
Length (m)	1.73±0.09
Weight (kg)	73.7±11.2
ISEI−92[30]	51.7±12.3 (16–87)
Voorrips sport[31]	12.6±4.2
CIRS-G[32]	2.9±2.1
No. of drugs	1.7±1.7
Subjects who fell in previous year, n (%)	14 (24)
Fear of falling (yes/no question), n (%)	9 (15)
Visual complaints (n)	3
GARS[33]	18.1±0.4
MMSE[16]*	28.6±1.4
GDS−4[17] (median)	0
UPDRS motor part[34]	0.3±0.5
TUG (s)[35]	6.2±1.0
Hand grip strength (kg)[36]	38.1±9.4

NOTE. Values are mean ± standard deviation (SD), mean ± SD (range), or as otherwise indicated.
Abbreviations: CIRS-G, Cumulative Illness Rating Scale–Geriatrics (comorbidity index) (scores ≥6 indicate frailty); GARS, Groningen Activity Restriction Scale (range, 18–76, with 18 corresponding to complete independence); ISEI–92, International Socio-Economic Index of occupational status 1992 (range, 16–87, with higher score indicating higher status); Voorrips sport, Voorrips sport participation subscale (range 0–18, with higher score meaning more participation); UPDRS motor part, Unified Parkinson's Disease Rating Scale motor part.
*Range, 0–30, with scores <25 indicating cognitive impairment.

(Mini-Mental State Examination [MMSE] score, <24/30)[16] and depressive symptoms (Geriatric Depression Scale [GDS]−4 score, ≥3/4).[17] Because of a lack of knowledge about balance during walking in the elderly per se, we chose these physically fit elderly people as a reference group for the optimal situation. To fall or not to fall is a dichotomous outcome: this very fit group had a low risk of falls and injuries mainly because they had much reserve in balance. Consequently, in most circumstances a decrease in their balance control would not have impaired their balance enough to increase their risk of falling. We expected, however, that the direction of the effects of the dual tasks on balance during walking would be the same in vigorous and more vulnerable older people. Therefore the results of this study can give a first indication of how balance during walking in more vulnerable older people may be affected by dual tasks and can provide data about the best possible performance.

The institutional review board of the Radboud University Nijmegen Medical Centre judged that the study did not need to be approved because of the very low risks and negligible burden for the participants, and because the study involved cognitively intact adults.

Table 1 lists the baseline characteristics of all participants.

Procedures

Quantitative gait analysis was performed with a 5.6×0.89-m electronic walkway (GAITRite[a]) with sensor pads (placed 12.7mm apart) connected to a computer. The electronic walkway has a good concurrent validity compared with a clinical stride analyzer (correlations of .99) and good test-retest reliability with intraclass correlation coefficients of .93 and .94 at preferred and quick gait velocity, respectively.[18] Balance was measured with 2 angular velocity transducers (Sway Star[b]) that measure mediolateral (ML) and anteroposterior (AP) angular velocities at 100Hz. The device was attached as a small box with a belt to the backs of the participants and was connected to the computer with a long wire. The software calculated 90% ranges of angular velocities and angles in ML and AP directions. Primary outcomes of our study were stride variability (stride length, stride time, stride width) and ML body sway because increased stride variability,[19] ML displacement, and angular velocity are associated with an increased risk of falling.[20]

During the measurements, the participants walked on the walkway while wearing low-heeled shoes. To measure steady state walking, the subjects started walking 2m before the walkway and then walked toward a chair positioned 2m behind the walkway. A researcher walked alongside the participants to ensure their safety. To increase the number of steps and precision, all tasks were performed twice and the results were averaged for the statistical analyses. The participants walked first at preferred, slow, quick, and very quick speeds without dual tasks on the walkway. Thereafter they walked at their preferred speed while performing 3 different oral dual tasks: subtracting 7 from 100 and 13 from 100 (attention-demanding tasks) and citing words starting with the letters "K" and "O" (verbal fluency task). Participants practiced all 3 cognitive tasks while standing so as to prevent a learning effect. During the second walk participants began with the number reached last in the subtraction task and were asked to name other words in the verbal fluency task. Tasks that interfere with attention or executive functions most likely will also interfere with balance control. Executive functions include a wide range of functions, of which verbal fluency is an example. We asked participants to indicate which of the cognitive tasks were the most difficult for them individually.

Statistical Analysis

The baseline gait characteristics of patients were summarized as mean ± standard deviation (SD). We used the coefficient of variation (CV) (SD/mean × 100%) as the measure of variability for stride time, stride length, and stride width. All body sway and stride variables were first log-transformed to remove skewness (Shapiro-Wilks tests, <.00) and heteroscedastity. We constructed a formula based on linear regression analysis (linear mixed models with the participant as the random effect and the various tasks as the fixed effect) that described how body sway and stride variables varied with gait velocity in each participant during walking without an additional task. The first step in our standardization method was the transformation of the gait and balance data to obtain a normal distribution and to decrease the influence of outliers. We then constructed a formula based on regression analysis that described how these data varied with gait velocity in each participant during walking without an additional task. We used this formula to standardize the gait and balance data for the effect of gait velocity for each participant. Thereafter body sway and stride variables stayed the same over the entire range of gait velocities: the influence of gait velocity was removed. We used these results to standardize the variables such that the means without dual task were 100, independent of gait velocity.[21] We compared the nonstandardized and standardized results for the dual tasks with the results without dual tasks. We performed an omnibus test (likelihood ratio test) that compared all tasks simultaneously and if this test was significant, the result of each dual task was compared with no task. Likelihood ratio tests were used throughout and the significance level was set at .01 (2-sided) to adjust for multiplicity.

To estimate the sample size needed for this study, we made the following assumptions based on duplo-measurements of