Effect of Music-Based Multitask Training on Gait, Balance, and Fall Risk in Elderly People

A Randomized Controlled Trial

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Background: Falls occur mainly while walking or performing concurrent tasks. We determined whether a music-based multitask exercise program improves gait and balance and reduces fall risk in elderly individuals.

Methods: We conducted a 12-month randomized controlled trial involving 134 community-dwelling individuals older than 65 years, who are at increased risk of falling. They were randomly assigned to an intervention group (n=66) or a delayed intervention control group scheduled to start the program 6 months later (n=68). The intervention was a 6-month multitask exercise program performed to the rhythm of piano music. Change in gait variability under dual-task condition from baseline to 6 months was the primary end point. Secondary outcomes included changes in balance, functional performances, and fall risk.

Results: At 6 months, there was a reduction in stride length variability (adjusted mean difference, −1.4%; P<.002) under dual-task condition in the intervention group, compared with the delayed intervention control group. Balance and functional tests improved compared with the control group. There were fewer falls in the intervention group (incidence rate ratio, 0.46; 95% confidence interval, 0.27-0.79) and a lower risk of falling (relative risk, 0.61; 95% confidence interval, 0.39-0.96). Similar changes occurred in the delayed intervention control group during the second 6-month period with intervention. The benefit of the intervention on gait variability persisted 6 months later.

Conclusion: In community-dwelling older people at increased risk of falling, a 6-month music-based multitask exercise program improved gait under dual-task condition, improved balance, and reduced both the rate of falls and the risk of falling.

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FALLS ARE COMMON AND DEVastating among elderly people.[1-4] Each year, one-third of the population 65 years and older experiences at least 1 fall, and half of those fall repeatedly.[1,3-5] This problem will continue to grow as the number of older adults increases over the coming decades.[6] Thus, preventing falls in elderly individuals is a major concern. Measures to reduce falls are often of limited benefit.[7] Exercise can counteract key risk factors for falls, such as poor balance, and consequently reduce risk of falling in elderly community-dwelling individuals.[7,8]

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A large proportion of falls in elderly people occurs during walking.[9,10] Moreover, older adults are more likely to fall when performing concurrent tasks, such as walking while performing other motor or cognitive tasks.[11,12] Gait variability (ie, stride-to-stride fluctuations in walking), particularly during dual-task walking conditions, can objectively characterize gait impairment, with greater variability reflecting a more unstable gait pattern, that in turn leads to an increased risk of falling.[1,13-17] There is little information regarding effective measures to improve or even reverse age-related gait impairment under dual-task conditions in elderly people.

Jaques-Dalcroze eurhythmics is a music education through movement method developed by the composer Emile Jaques-Dalcroze (1865-1960) in Geneva, Switzerland, in the early 20th century. It is now practiced worldwide in the field of music, as well as dance, theater, and therapy. Practitioners are introduced to music's basic elements with special emphasis on musical rhythm and body movements through vari-

ous multitask exercises performed to the rhythm of improvised piano music.[18] Recently, specific classes for older adults have been developed. The integrated motor and cognitive components are key features of this program, which involves a greater interest for dual- or multiple-task practice than other multicomponent attention-demanding exercise forms (eg, Tai Chi). In a cross-sectional study of older, long-term practitioners of Jaques-Dalcroze eurhythmics, age-related increase in stride-to-stride variability in a dual-task context appeared to be attenuated.[19]

We conducted a randomized controlled trial to determine whether a 6-month music-based multitask exercise program (ie, Jaques-Dalcroze eurhythmics) would improve gait and balance and reduce fall risk in community-dwelling older adults at high risk of falling. Change in gait variability under dual-task condition from baseline to 6 months was the primary end point. Secondary end points were to assess changes in other quantitative gait and balance measures, functional test performances, and falls and to determine through a 6-month postintervention follow-up whether the benefit due to the intervention could be maintained over time.

METHODS

STUDY DESIGN

In this 12-month monocenter, randomized controlled trial, subjects were randomly assigned to either a music-based multitask exercise program or a delayed intervention control group for 6 months (or 25 weeks). The primary end point was assessed at 6 months. During the second 6-month period, the delayed intervention control group participated in the intervention program, while the early intervention group returned to their usual habits (ie, no more intervention). Both groups were assessed at baseline and months 6 and 12. Enrollment began in February 2008, and the follow-up period ended in December 2009. The study was approved by Geneva University Hospitals ethics committee. All study participants provided written informed consent.

STUDY PARTICIPANTS

Participants were recruited in the local community through multiple strategies, including advertisements in local newspapers. The inclusion criteria were (1) adults 65 years or older, (2) living in the community, (3) without previous experience of Jaques-Dalcroze eurhythmics, except during childhood, and (4) at increased risk of falling. Participants were considered at risk of falls if they met at least 1 of the following criteria: (1) 1 or more self-reported falls after the age of 65 years, (2) balance impairment as assessed by a simplified Tinetti test with a score higher than 2 of 7,[3,20] and (3) 1 or 2 criteria of physical frailty.[21] Subjects were excluded if their medical history or physical examination revealed (1) a neurological disease associated with motor deficit or an orthopedic disease with a significant impact on gait and/or balance that would compromise outcomes assessment (2) or any other medical conditions that would limit participation (eg, terminal illness). Participants fully dependent on an assistive device were excluded.

RANDOMIZATION

Eligible subjects were randomized to either the intervention or the delayed intervention control group in a 1:1 ratio according to a computer-generated list prepared by an independent statistician, without stratification, using a permuted block randomization design. Allocation assignment was concealed from the enrolling assessors.

INTERVENTION

The intervention was a structured 1-hour weekly class exercise program led by an experienced instructor. It featured various multitask exercises, sometimes involving the handling of objects (eg, percussion instruments or balls), which became gradually more difficult over time.[22] Basic exercises consisted of walking in time to the music and responding to changes in the music's rhythmic patterns. Exercises involved a wide range of movements and challenged the balance control system mainly by requiring multidirectional weight shifting, walk-and-turn sequences, and exaggerated upper body movements when walking and standing.

Subjects in the delayed intervention control group were instructed to maintain their usual physical and social activities, as was the early intervention group after the program ended, ie, during the second 6-month period. Both groups were asked to avoid any new additional exercise programs during the course of the study. No instructions were provided to perform any specific exercise outside class time. Adherence to the Jaques-Dalcroze eurhythmics program was verified by weekly attendance records.
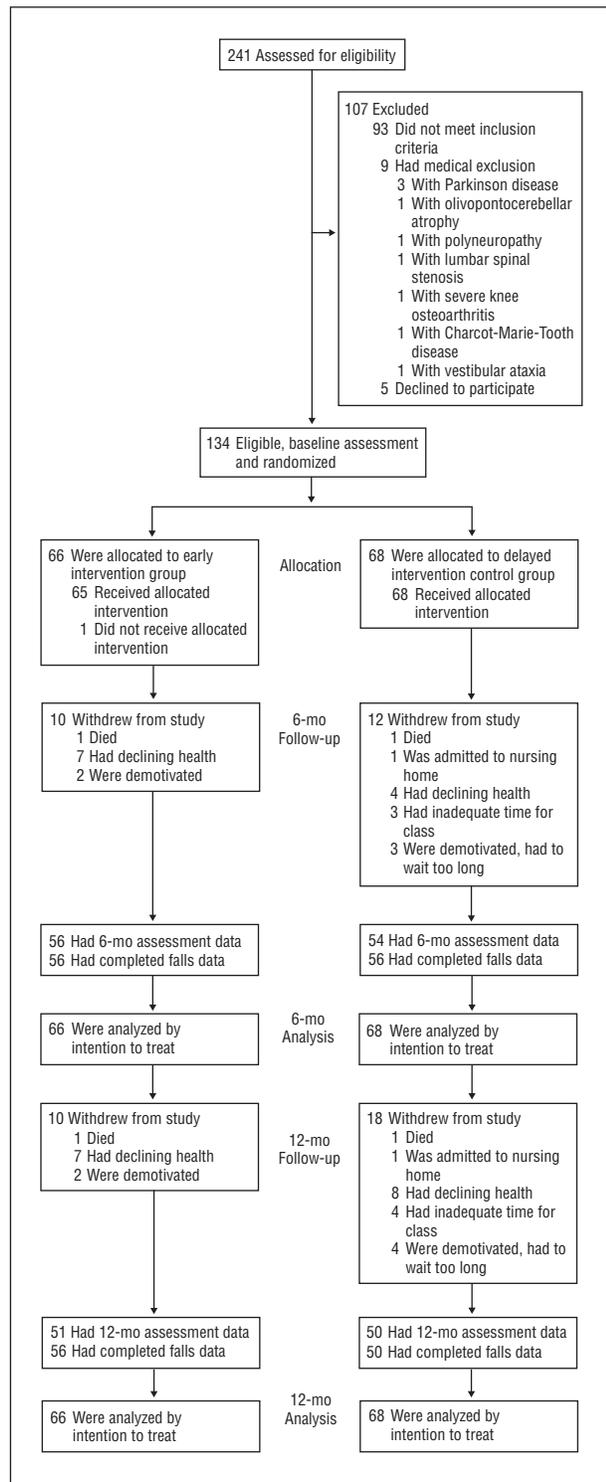
FOLLOW-UP VISITS

Participants were assessed by a trained multidisciplinary team blind to the participants' group allocations and to information from previous evaluations. Functional tests and instrumental gait and balance analysis were conducted using a standardized protocol, as detailed in the following subsection. Interviews collected sociodemographic characteristics, fall history, nutritional status,[23] physical activity level,[24] and neuropsychological status.[25-29] All participants also underwent a complete physical examination.

ASSESSMENT OF GAIT, BALANCE, AND FUNCTIONAL PERFORMANCE

Gait and balance were assessed using an electronic pressure sensitive walkway (GAITRite; CIR Systems Inc, Havertown, Pennsylvania) and angular velocity transducers (SwayStar; Balance International Innovations GmbH, Iseltwald, Switzerland), respectively. Gait parameters were collected according to the spatiotemporal gait analysis guidelines.[30] The subjects were asked to walk at their self-selected usual, slow, and fast speed as a single task. Then, they were asked to walk at a self-selected speed and to simultaneously count aloud backward by 1 starting from 50, as a dual task, without specific instruction to prioritize either task. Coefficient of variation (CV) was used as a measure of variability for stride time and stride length parameters (CV = [standard deviation/mean] × 100). The relative and absolute test-retest reliability of gait outcome measures was examined in a random sample of 30 study participants. Under the dual-task condition, intraclass correlation coefficients (2,1) for gait variability measures were all above 0.68. The standard error of measurement values were 1.59% and 0.99% for CV of stride time and stride length, respectively.

The SwayStar system consists of 2 angular velocity transducers worn on the lower trunk.[31] Each participant was tested for a 2-legged stance task for 20 seconds and a 1-legged stance task for 10 seconds with eyes open and for 1 dynamic task (ie, getting up from a chair, sitting down, standing up again, and remaining standing).[32] Four outcome variables were calculated for each task, in addition to task duration, ie, 90% range of both trunk angular displacement and angular velocity, in me-

Flowchart (Figure 1):

241 Assessed for eligibility

107 Excluded
  93 Did not meet inclusion criteria
  9 Had medical exclusion
    3 With Parkinson disease
    1 With olivopontocerebellar atrophy
    1 With polyneuropathy
    1 With lumbar spinal stenosis
    1 With severe knee osteoarthritis
    1 With Charcot-Marie-Tooth disease
    1 With vestibular ataxia
  5 Declined to participate

134 Eligible, baseline assessment and randomized

Allocation

66 Were allocated to early intervention group
  65 Received allocated intervention
  1 Did not receive allocated intervention

68 Were allocated to delayed intervention control group
  68 Received allocated intervention

6-mo Follow-up

10 Withdrew from study
  1 Died
  7 Had declining health
  2 Were demotivated

12 Withdrew from study
  1 Died
  1 Was admitted to nursing home
  4 Had declining health
  3 Had inadequate time for class
  3 Were demotivated, had to wait too long

56 Had 6-mo assessment data
56 Had completed falls data

54 Had 6-mo assessment data
56 Had completed falls data

6-mo Analysis

66 Were analyzed by intention to treat

68 Were analyzed by intention to treat

12-mo Follow-up

10 Withdrew from study
  1 Died
  7 Had declining health
  2 Were demotivated

18 Withdrew from study
  1 Died
  1 Was admitted to nursing home
  8 Had declining health
  4 Had inadequate time for class
  4 Were demotivated, had to wait too long

51 Had 12-mo assessment data
56 Had completed falls data

50 Had 12-mo assessment data
50 Had completed falls data

12-mo Analysis

66 Were analyzed by intention to treat

68 Were analyzed by intention to treat

Figure 1. Flowchart for enrollment, randomization, and follow-up of study participants.

diolateral and anteroposterior directions.[33] For functional tests, each participant underwent Timed Up & Go[34,35] and simplified Tinetti tests.[3,20,36]

ASSESSMENT OF FALLS

Falls were defined as "unintentionally coming to rest on ground, floor, or other lower level."[37] Falls were prospectively monitored

SAMPLE SIZE CALCULATION

The sample size was determined using data from a previous study.[19] Ninety-six participants (ie, 48 in each group) were needed for a statistical power of 90% to detect a difference between groups at a 2-sided significance level of 5% on the primary outcome gait variability in dual-task condition, assuming that gait variability in this population was 4%. This allowed us to detect a difference of 1% in gait variability between the intervention and the control groups at completion of the first 6-month intervention. With 10% mortality and 20% dropout rates, a sample size of 130 participants was targeted.

STATISTICAL ANALYSIS

All analyses were based on intention-to-treat, with the last value carried forward for missing values. The χ^2 test, t test, or Wilcoxon rank sum test were used, as appropriate, to compare baseline characteristics. Changes from baseline to 6 months were summarized as means and standard deviations. Estimates of between-group mean differences, adjusted for baseline values, were computed, together with 95% confidence intervals (CIs). Analyses of covariance were performed to examine differences in changes across groups, with baseline value as covariate. Because gait velocity may represent a potential confounder when evaluating gait variability,[38] additional analyses with adjustments for changes in gait velocity were performed for all variability measures. Data were also analyzed at a normalized velocity of 100 cm/s (ie, within the individual range of velocities and close to the mean usual gait velocity) using an interpolation procedure, pooling the 3 walking conditions under a single task (ie, self-selected slow, usual, and fast speeds), as described elsewhere.[39,40] Six- to 12-month changes were summarized as means and standard deviations. Crossover analyses were performed using a specific Stata procedure (command pkcross) that enables analysis of crossover experiments and provides significance values for sequence, period, intervention, and carryover effects. The data were reanalyzed (1) without adjustment for baseline covariates, (2) using per-protocol analysis of study completers without imputation, and (3) using linear mixed-effects regression models (with Stata "xtmixed" command) to predict the primary end point, with visit, intervention, and visit by intervention interaction as exploratory variables.

For fall outcomes, log-binomial regression models were used to calculate relative risks comparing both the number of subjects with 1 or more falls and subjects with multiple falls (≥ 2 falls during the study period) in both groups. The incidence rate ratio for the number of falls was analyzed using a negative binomial regression model. In addition, survival analyses were conducted: hazard ratios were estimated from a Cox proportional hazards model for the first fall, and its extension, the Andersen-Gill model,[41] for all falls. In these models, subjects who did not achieve expected follow-up were censored at the time of last follow-up.

All statistical significance tests were 2-sided, and $P < .05$ was considered statistically significant. Analyses were performed using Stata software version 11.0 (StataCorp, College Station, Texas).

RESULTS

As shown in the flowchart (**Figure 1**), 241 individuals were screened and 134 (56%) enrolled. Of these, 22 (16%) and 28 (21%) dropped out of the study at 6 and 12 months,

respectively. There was no difference between groups in the number of participants with incomplete follow-up. Mean attendance rate at the exercise program was 78% and did not vary by group. The attendance rate of the participants completing the intervention was 83%, 77% of whom attended at least 20 classes (ie, 80% of the classes). The main reasons for not attending classes included health problems, family constraints, or difficulties related to travel. No major adverse events occurred during the study, and there were no adverse effects, such as falls, cardiovascular events, or any injury during or following the exercise classes.

The mean (SD) age of the participants was 75.5 (6.9) years, and 96% were women (**Table 1**). Baseline characteristics were identical in both groups, except for height ($P=.04$), with no differences in study outcomes (**Table 2** and **Table 3**). Participants in both groups displayed similar baseline fall history profiles in the year before the study. Completers and dropouts did not differ significantly on baseline characteristics.

Under the single-task condition, intervention group subjects increased their usual gait velocity (adjusted mean difference [AMD], 4.7 cm/s; 95% CI, 0.5 to 8.8; $P=.03$), and their stride length (AMD, 3 cm; 95% CI, 0.5 to 5.6; $P=.02$) compared with the delayed intervention control group (Table 2). In the intervention group, the stride time variability improved (AMD, –0.4%; 95% CI, –0.7 to –0.1; $P=.01$). When normalized for a gait velocity of 100 cm/s (see the "Methods" section), the change in gait variability was no longer significant. Under the dual-task condition, intervention group subjects increased their stride length (AMD, 3.1 cm; 95% CI, 0.1 to 6.1; $P=.04$) and decreased their stride length variability (AMD, –1.4%; 95% CI, –2.3 to –0.6; $P<.002$) (**Figure 2**) compared with controls. Adjustments for gait velocity changes did not influence gait variability modifications. Other statistical approaches (ie, without adjustment, per-protocol analysis as well as mixed-effects regression model) provided similar results in both magnitude and direction for the primary end point.

By comparison with the delayed intervention controls, the intervention group improved stance time for the 1-legged stance task (AMD, 0.9 s; 95% CI, 0.3 to 1.6; $P=.006$) (Table 3) and decreased mediolateral angular velocity (AMD, –4.6 degrees/s; 95% CI, –8.6 to –0.6; $P=.02$). In the Tinetti and Timed Up & Go tests, the intervention group did better than the controls (Table 3).

Compared with the control group, the intervention group experienced fewer falls during the first 6-month period: the unadjusted incidence rate ratio for falls was 0.46 (95% CI, 0.27 to 0.79; $P=.005$) and remained similar when adjusted for age, falls history over the previous 12 months, Tinetti test performance, and the number of frailty criteria (according to Fried et al[21]) met (**Table 4**). The number of subjects with 1 or more falls was also statistically different between both groups (relative risk, 0.61; 95% CI, 0.39 to 0.96; $P=.03$) with a number needed to treat of 5 (95% CI, 2.1 to 34.4). The relative risk for multiple falls was 0.19 (95% CI, 0.06 to 0.63; $P=.007$). Using a Cox proportional hazards model, we found that the unadjusted hazard ratio for the time to first fall was 0.53 (95% CI, 0.30 to 0.94; $P=.03$) in the intervention group compared with

Table 1. Baseline Characteristics of Participants

Characteristic	Early Intervention (n=66)	Delayed Intervention (n=68)
Age, mean (SD), y	75 (8)	76 (6)
Sex, No. (%)		
Male	2 (3)	3 (4)
Female	64 (97)	65 (96)
Marital status, No. (%)		
Married	16 (24)	21 (31)
Other	50 (76)	47 (69)
Home help services, No. (%)	21 (32)	19 (28)
Educational level, No. (%)		
Primary school	7 (11)	13 (19)
Middle school	45 (68)	45 (66)
High school	14 (21)	10 (15)
Height, mean (SD), cm	161 (6)	158 (7)[a]
Body weight, mean (SD), kg	67 (11)	67 (11)
BMI, mean (SD)	26 (4)	27 (4)
History of falls, No. (%)	60 (91)	58 (85)
Fall(s) in the past 12 mo, No. (%)	37 (56)	37 (54)
Frailty components, No. (%)[b]		
Unintentional weight loss	10 (15)	5 (7)
Exhaustion	20 (30)	15 (22)
Low physical activity level	0	1 (1)
Slow walking speed	10 (15)	9 (13)
Grip strength	27 (41)	33 (49)
Physical activity level, mean (SD), kcal/wk	2336 (1036)	2714 (1370)
SF-12, mean (SD), score		
Physical health component	44 (9)	47 (8)
Mental health component	45 (12)	47 (9)
MNA short-form, mean (SD), score	12 (2)	13 (1)
≤11, No. (%)	14 (21)	7 (10)
HADS anxiety subscale, mean (SD), score	7 (4)	7 (3)
≥8, No. (%)	25 (38)	32 (47)
HADS depression subscale, mean (SD), score	4 (3)	4 (3)
≥8, No. (%)	11 (17)	5 (7)
MMSE, mean (SD), score	26 (3)	26 (3)
<24, No. (%)	14 (21)	11 (16)
Clock-drawing test, mean (SD), score	9 (0)	9 (2)
<8, No. (%)	9 (14)	12 (18)
FAB, mean (SD), score	16 (2)	15 (2)
<16, No. (%)	27 (41)	28 (41)
Self-rated health status, mean (SD)[c]	3 (1)	3 (1)
Total No. of medications, mean (SD)	4 (2)	3 (2)
Current use of psychotropic medication, No. (%)	18 (27)	13 (19)
Medical condition, No. (%)		
Trouble with vision	14 (21)	10 (15)
Dizziness or balance disorder	8 (12)	8 (12)
Arthritis of the lower limb	7 (11)	12 (18)
Central nervous system disorder	6 (9)	4 (6)
Peripheral nervous system disorder	7 (11)	5 (7)
Rhythm disorder	5 (8)	1 (1)
Prosthesis (lower limb)	7 (11)	8 (12)
Tendon rupture (lower limb)	1 (2)	1 (1)
Osteoporosis	23 (35)	28 (41)
Charlson comorbidity index, mean (SD), score[d]	1 (1)	1 (1)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); FAB, Frontal Assessment Battery; HADS, Hospital Anxiety and Depression Scale; MMSE, Mini-Mental State Examination; MNA, Mini-Nutritional Assessment; SF-12, 12-item Short-Form Health Survey.
[a] Significant difference between groups ($P<.05$).
[b] According to Fried et al.[21]
[c] Five-point Likert scale from 1 (excellent) to 5 (bad).
[d] According to Charlson et al.[42]

Table 2. Change in Gait Outcome Measures by Groups

| | Mean (SD) | | | | Adjusted Between-Group Mean Difference (95% CI) | P Value[c] | Mean (SD) | | Effect,[d] P Value | | | |
| | Baseline | | Changes at 6 mo[a] | | | | Changes at 12 mo[b] | | | | | |
Outcomes	Early Intervention (n=66)	Delayed Intervention (n=68)	Early Intervention (n=66)	Delayed Intervention (n=68)			Early Intervention (n=66)	Delayed Intervention (n=68)	Sequence	Inter-vention	Carry-over	Period
Single-Task Condition												
Gait speed												
Gait velocity, cm/s	104.2 (19.0)	102.4 (18.8)	5.5 (12.8)	1.2 (12.7)	4.7 (0.5 to 8.8)	.03	−2.5 (10.9)	2.1 (12.7)	. . .	. . .	. . .	. . .
Stride length, cm	115.6 (15.4)	113.6 (16.0)	3.0 (8.0)	0.2 (7.0)	3.0 (0.5 to 5.6)	.02	−1.6 (7.0)	1.3 (7.2)	. . .	<.05	. . .	. . .
Cadence, steps/min	108.1 (10.6)	108.2 (9.5)	2.9 (7.3)	1.3 (7.9)	1.7 (−0.8 to 4.1)	.18	−1.1 (6.8)	0.9 (6.9)	. . .	. . .	. . .	. . .
Dynamic balance												
Double support phase, %	23.8 (3.4)	23.8 (3.5)	−0.7 (2.2)	−0.2 (2.5)	−0.5 (−1.3 to 0.2)	.18	−0.9 (2.3)	−0.8 (2.6)	. . .	. . .	. . .	. . .
Support base, cm	8.4 (3.1)	8.3 (3.2)	−0.4 (3.9)	0.3 (1.6)	−0.7 (−1.7 to 0.3)	.14	0.4 (3.8)	0.0 (1.5)	. . .	. . .	. . .	. . .
Gait variability												
Stride time variability, %CV	2.3 (1.0)	2.6 (1.1)	−0.2 (1.1)	0.0 (1.1)	−0.4 (−0.7 to −0.1)	.01	0.4 (1.3)	0.0 (1.4)	. . .	. . .	. . .	. . .
Stride length variability, %CV	2.9 (1.1)	2.8 (1.0)	−0.3 (1.2)	0.2 (1.7)	−0.4 (−0.9 to 0.0)	.07	0.4 (1.2)	−0.1 (1.7)	. . .	< .05	. . .	. . .
Dual-Task Condition[e]												
Gait speed												
Gait velocity, cm/s	83.8 (23.0)	84.7 (23.0)	7.1 (17.2)	3.6 (14.3)	3.3 (−1.6 to 8.1)	.19	−2.7 (11.8)	3.0 (16.2)	. . .	. . .	. . .	. . .
Stride length, cm	109.2 (17.1)	107.7 (17.6)	4.2 (10.5)	1.3 (7.4)	3.1 (0.1 to 6.1)	.04	−1.7 (7.3)	1.6 (8.0)	. . .	. . .	. . .	. . .
Cadence, steps/min	91.5 (16.3)	93.9 (16.5)	4.5 (13.4)	3.0 (11.7)	0.3 (−3.1 to 3.8)	.84	−1.6 (9.3)	2.0 (11.9)	. . .	. . .	. . .	. . .
Dynamic balance												
Double support phase, %	25.9 (7.2)	25.3 (4.5)	−1.5 (6.2)	−0.5 (4.3)	−0.9 (−2.4 to 0.6)	.25	−1.1 (3.1)	−1.2 (3.7)	. . .	. . .	. . .	. . .
Support base, cm	8.8 (3.9)	8.6 (3.4)	−0.1 (2.3)	0.1 (1.8)	−0.1 (−0.8 to 0.5)	.68	0.0 (2.4)	0.0 (1.8)	. . .	. . .	. . .	. . .
Gait variability												
Stride time variability, %CV	5.3 (6.3)	5.1 (6.0)	−1.8 (6.1)	−0.3 (6.6)	−1.6 (−3.5 to 0.4)	.11	0.2 (2.2)	−0.4 (4.7)	. . .	. . .	. . .	. . .
Stride length variability, %CV	4.8 (3.9)	4.2 (3.1)	−1.6 (3.9)	0.2 (1.6)	−1.4 (−2.3 to −0.6)	<.002	0.4 (1.3)	−0.9 (1.9)	. . .	<.001	<.01	. . .

Abbreviations: CI, confidence interval; CV, coefficient of variation.
[a] Changes were calculated as 6-month follow-up minus baseline.
[b] Changes were calculated as 12-month follow-up minus 6-month follow-up.
[c] Analyses of covariance on change in measures with the baseline value as covariate.
[d] Crossover analysis of variance on change in measures using a specific procedure dealing with the analysis of crossover experiments, which provides significance values for respectively sequence, period, intervention, and carryover effects. Ellipses represent nonsignificant values.
[e] One subject under the dual-task condition had to be excluded from the analysis due to technical failure of GAITRite; CIR Systems Inc, Havertown, Pennsylvania.

the control group. This remained significant after adjustment for baseline covariates. When comparing the 2 groups using an Andersen-Gill model, the unadjusted hazard ratio of 0.46 (95% CI, 0.27 to 0.78; P=.004) remained significant after multiple adjustment.

Using a crossover analysis of variance, we found significant carryover effects for some outcomes, indicating that several changes in the early intervention group had been maintained at 12-month follow-up (Table 2 and Table 3). The improvement in gait variability under dual-task condition was retained 6 months after the intervention had ended, as were improvements in 1-legged stance duration and in Tinetti performance. At the 12-month follow-up, when both groups had taken part in the intervention program, the crossover analysis revealed improvements in stride length and stride length variability under the single-task condition and stride length variability under the dual-task condition, as well as in 1-legged stance duration and Tinetti test performance.

Between 6 and 12 months, 56 participants in each group were followed up for falls. Sixteen subjects (29%) in the early intervention group had at least 1 fall and 4 (7%) had fallen repeatedly, with 20 reported falls. The incidence of falls, proportion of subjects with 1 or more falls and those with multiple falls in this group did not differ between the intervention and the follow-up period (P=.63, P=.64, and P=.71, respectively). During the same period, while the intervention was dispensed, 19 subjects (34%) of the former delayed intervention group had at least 1 fall, of whom 6 (11%) had fallen repeatedly, with 28 reported falls. The incidence of falls was significantly reduced during this period of intervention compared with the first 6 months (P=.02), as was the proportion of participants with multiple falls (P=.01). The reduction in the proportion of subjects with 1 or more falls failed to reach significance (P=.06).

COMMENT

To our knowledge, this is the first evidence of a reversibility in age-dependent increase of gait variability under cognitive-motor dual-task condition in older adults. Indeed, dual-task gait performance improved in the music-based multitask exercise program group, with reduction in stride length variability, regardless of gait velocity modification. All statistical analyses showed similar results, which confirm the robustness of our findings. Few studies to date have demonstrated an improvement of dual-task gait performance with training, including studies in patients with stroke, Parkinson disease, or dementia or in older adults, but most of their sample sizes were small.[43-47] Our study also indicates that gait variability may be improved under a single-task condition, as was pre-

Table 3. Change in Balance and Functional Outcomes

Outcomes	Mean (SD) Baseline — Early Intervention (n=66)	Mean (SD) Baseline — Delayed Intervention (n=68)	Mean (SD) Changes at 6 mo[a] — Early Intervention (n=66)	Mean (SD) Changes at 6 mo[a] — Delayed Intervention (n=68)	Adjusted Between-Group Mean Difference (95% CI)	P Value[c]	Mean (SD) Changes at 12 mo[b] — Early Intervention (n=66)	Mean (SD) Changes at 12 mo[b] — Delayed Intervention (n=68)	Effect,[d] P Value — Sequence	Effect,[d] P Value — Intervention	Effect,[d] P Value — Carryover	Effect,[d] P Value — Period
One-legged stance task												
Displacement M-L, degrees	4.0 (2.9)	5.1 (3.4)	0.2 (2.9)	0.5 (3.1)	–0.6 (–1.6 to 0.3)	.20	–0.1 (3.0)	–0.8 (3.5)	...	...	...	...
Angular velocity M-L, degrees/s	14.6 (13.2)	16.6 (11.9)	–1.6 (12.7)	1.4 (14.5)	–4.6 (–8.6 to –0.6)	.02	–1.2 (8.2)	–3.7 (12.7)	...	...	...	...
Displacement A-P, degrees	3.6 (2.3)	4.1 (2.3)	0.6 (2.5)	0.9 (3.1)	–0.5 (–1.4 to 0.5)	.33	0.0 (2.1)	–0.6 (3.1)	...	...	...	<.01
Angular velocity A-P, degrees/s	10.8 (7.0)	12.4 (5.9)	1.2 (7.7)	3.2 (15.7)	–2.9 (–7.2 to 1.4)	.19	0.2 (9.3)	–3.1 (15.6)	...	...	...	<.01
Duration, s	7.3 (3.4)	7.4 (3.1)	0.9 (2.3)	–0.1 (1.7)	0.9 (0.3 to 1.6)	.006	–0.3 (1.4)	0.4 (2.2)	...	<.01	<.05	...
Two-legged stance task												
Displacement M-L, degrees	0.4 (0.3)	0.3 (0.2)	0.04 (0.3)	0.05 (0.2)	0.00 (–0.1 to 0.1)	.90	0.0 (0.3)	0.0 (0.2)	...	...	...	...
Angular velocity M-L, degrees/s	0.6 (0.3)	0.6 (0.3)	0.01 (0.3)	0.02 (0.2)	0.00 (–0.1 to 0.1)	.93	0.0 (0.3)	0.0 (0.2)	...	...	...	...
Displacement A-P, degrees	1.3 (0.6)	1.2 (0.5)	0.01 (0.6)	0.00 (0.5)	–0.01 (–0.2 to 0.2)	.94	0.1 (0.7)	0.1 (0.5)	...	...	...	...
Angular velocity A-P, degrees/s	1.7 (0.6)	1.7 (0.7)	0.02 (0.7)	0.02 (0.4)	0.00 (–0.2 to 0.2)	.99	0.0 (0.8)	0.1 (0.4)	...	...	...	...
Dynamic task												
Displacement M-L, degrees	4.1 (1.9)	4.1 (2.3)	–0.1 (1.7)	–0.01 (1.8)	–0.1 (–0.7 to 0.5)	.71	0.1 (1.5)	–0.2 (2.4)	...	...	...	...
Angular velocity M-L, degrees/s	9.1 (3.8)	9.4 (4.1)	–0.1 (2.7)	–0.9 (2.8)	0.7 (–0.2 to 1.5)	.11	0.0 (3.0)	0.0 (3.3)	...	...	...	...
Displacement A-P, degrees	30.6 (7.3)	29.2 (9.1)	–3.0 (6.1)	–2.4 (5.5)	0.0 (–1.8 to 1.9)	.97	0.6 (4.9)	–0.5 (5.3)	...	...	...	<.01
Angular velocity A-P, degrees/s	79.3 (16.4)	77.4 (21.8)	–4.6 (18.7)	–5.5 (13.1)	2.0 (–3.1 to 7.2)	.43	–4.8 (15.1)	–5.2 (14.6)	...	...	...	<.01
Functional tests												
Timed Up & Go test, s	10.4 (2.8)	10.8 (2.7)	–0.5 (1.6)	–0.2 (1.2)	–0.5 (–0.9 to –0.1)	.02	0.1 (1.2)	–0.3 (1.5)	...	...	...	...
Simplified Tinetti test, score	1.2 (1.3)	1.1 (1.3)	–0.6 (0.8)	–0.03 (0.6)	–0.6 (–0.8 to –0.3)	<.001	0.2 (0.6)	–0.2 (0.6)	...	<.001	<.001	<.01

Abbreviations: CI, confidence interval; A-P, body sway in anteroposterior direction; M-L, body sway in mediolateral direction.
[a] Changes were calculated as 6-month follow-up minus baseline.
[b] Changes were calculated as 12-month follow-up minus 6-month follow-up.
[c] Analyses of covariance on change in measures with the baseline value as covariate.
[d] Crossover analysis of variance on change in measures using a specific procedure dealing with the analysis of crossover experiments, which provides significance values for respectively sequence, period, intervention, and carryover effects. Ellipses represent nonsignificant values.

viously suggested in older adults, in particular after training or pharmacological interventions.[48-52] The same finding was also recently reported in healthy older adults after 6 weeks of intense balance training.[53]

We can only speculate on the factors responsible for the detected improvements in dual-task gait variability: they could be related to more automated tasks, to task coordination skills development, or to both.[46,54] The intervention effect under other dual-task conditions (eg, motor interference tasks) needs to be further explored. Also, the intervention may involve increased gait performance by improving attention and executive function.[55-58] An association between gait variability and executive function, particularly during dual tasking, has been reported in elderly fallers (those with ≥1 fall).[59] Further work is needed to fully assess the impact of this program on cognitive performances, using a comprehensive neuropsychological battery for executive functions.

The current findings extend the existing knowledge of the efficacy of physical exercise interventions to improve gait, balance, and functional capacity in elderly people.[8,60] The improvement observed in gait velocity is consistent with a meta-analysis that reported a success rate of 57% after exercise training to improve usual gait speed.[60] This finding may have an important practical im-
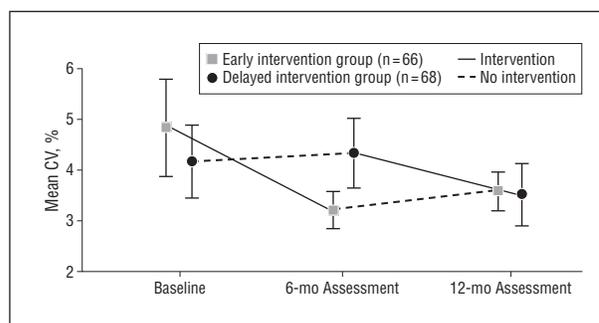
Figure 2. Stride length variability under the dual-task condition for both groups. Values represent means using last observation carried forward. Error bars represent 95% confidence intervals.

plication for older adults, since a low gait speed was found to be a consistent risk factor for disability, institutionalization, and mortality.[61] An increase in self-confidence may explain these findings.[62] An improvement of balance in 1-legged stance is also consistent with previous reports of improved 1-legged stance time following a wide range of exercise programs.[63] These changes were also accompanied by small but significant gains in functional performances. Modifications in the Tinetti score after the intervention were mainly due to an improve-

Table 4. Falls at the 6-Month Follow-up

Outcomes	Early Intervention (n=66)	Delayed Intervention (n=68)	Unadjusted	Adjusted[a]	Method
Falls, rate[b]	24 (0.7)	54 (1.6)			
IRR (95% CI)			0.46 (0.27-0.79)[d]	0.49 (0.27-0.91)[c]	Negative binomial regression model
Participants with ≥1 fall, No. (%)	19 (28.8)	32 (47.1)			
RR (95% CI)			0.61 (0.39-0.96)[c]	0.69 (0.44-1.07)	Log-binomial regression model
Participants with multiple (≥2) falls, No. (%)	3 (4.6)	16 (23.5)			
RR (95% CI)			0.19 (0.06-0.63)[d]	0.21 (0.06-0.67)[d]	Log-binomial regression model
Survival analysis					
HR (95% CI)			0.53 (0.30-0.94)[c]	0.55 (0.31-0.99)[c]	Cox proportional hazards model
HR (95% CI)			0.46 (0.27-0.78)[d]	0.46 (0.27-0.79)[d]	Andersen-Gill model

Abbreviations: CI, confidence interval; HR, hazard ratio; IRR, incidence rate ratio; RR, relative risk.
[a] Adjusted for age, history of falls over the previous 12 months, simplified Tinetti test performance, and total number of frailty criteria (according to Fried et al[21]) met.
[b] Fall rates per person per year.
[c] $P < .05$.
[d] $P < .01$.

ment in the performance of the 1-legged stance task. Unexpectedly, there were no differences in sway parameters in the 2-legged stance task and the dynamic task of sitting to standing. The latter task mainly requires greater lower extremity strength, which was only a small training component of the program.

Although the study was not powered to detect between-group differences in falls, a reduction in the incidence of falls, and in the risk of falling was found. While comparisons between trials are difficult when there are differences in study design, core components of the interventions, population targeted, intervention duration, or assessments of falls, the 54% reduction in falls observed in our study compares favorably with the rates observed in the most effective exercise-based interventions reported so far, with a meta-analysis demonstrating an overall fall reduction of 37% for Tai Chi interventions.[7,8] Our results are in agreement with another meta-analysis, which showed that interventions involving a large balance component are the most effective for preventing falls among older people.[8] The fall risk reduction in our trial may have been related to the multimodal nature of the intervention and to improvements in major risk factors for falls, such as gait variability.[1,13,17,64]

Jaques-Dalcroze eurhythmics seems to be able to change patterns of physical activity in elderly people by providing a strong motivation for the initiation and maintenance of exercise behavior, especially in women (96% of the participants in this trial) who are often less physically active than men.[65,66] The adherence to the intervention program was high (78%), compared with the mean rate of 63% reported in a review that examined exercise adherence in elderly people,[67] possibly in relation to the music component, which has been shown to facilitate exercise adherence in older adults.[68] Fifty-six percent of participants have registered in new fee paying sessions after the study.

Our study had some limitations. First, the nature of the intervention precluded blinding participants, which may have resulted in reporting bias. Second, the results should be interpreted in light of the eligibility criteria and with regard to the gender imbalance in the study population. The overwhelming predominance of women recruited may be partly explained by demographic factors (ie, in Switzerland, women 65 years and older outnumber men by approximately 1.35 to 1) and movement to music activities being more attractive for women. In addition, the participants who enrolled in this trial probably had a greater interest in health issues than the general population of elderly people. This might have resulted in the inadvertent selection of more motivated individuals. Third, there was no attention control group. Fourth, the number of withdrawals could be a limitation, but it was taken into account in the power calculation. Finally, there was only 1 class instructor and the outcomes achieved took place at 1 center. Therefore, further studies are needed to confirm the generalization potential of this program.

In conclusion, this randomized controlled trial is the first, to our knowledge, to show that participation in music-based multitask exercise classes once a week over a 6-month period can improve gait performance under single and cognitive-motor, dual-task conditions, as well as improve balance, and reduce both the rate of falls and the risk of falling in at-risk elderly community-dwelling adults. Our findings suggest that this program may be useful for fall prevention and rehabilitation in community-based settings such as senior centers.

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REFERENCES

1. Hausdorff JM, Rios DA, Edelberg HK. Gait variability and fall risk in community-living older adults: a 1-year prospective study. *Arch Phys Med Rehabil*. 2001; 82(8):1050-1056.
2. Kannus P, Parkkari J, Koskinen S, et al. Fall-induced injuries and deaths among older adults. *JAMA*. 1999;281(20):1895-1899.
3. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med*. 1988;319(26):1701-1707.
4. Sattin RW. Falls among older persons: a public health perspective. *Annu Rev Public Health*. 1992;13:489-508.
5. Nevitt MC, Cummings SR, Kidd S, Black D. Risk factors for recurrent nonsyncopal falls: a prospective study. *JAMA*. 1989;261(18):2663-2668.
6. Population Division, DESA, United Nations. World Population Ageing 1950-2050: Executive Summary. http://www.un.org/esa/population/publications /worldageing19502050/pdf/62executivesummary_english.pdf. Accessed June 2, 2010.
7. Gillespie LD, Robertson MC, Gillespie WJ, et al. Interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev*. 2009; (2):CD007146.
8. Sherrington C, Whitney JC, Lord SR, Herbert RD, Cumming RG, Close JC. Effective exercise for the prevention of falls: a systematic review and meta-analysis. *J Am Geriatr Soc*. 2008;56(12):2234-2243.
9. Berg WP, Alessio HM, Mills EM, Tong C. Circumstances and consequences of falls in independent community-dwelling older adults. *Age Ageing*. 1997;26 (4):261-268.
10. Niino N, Tsuzuku S, Ando F, Shimokata H. Frequencies and circumstances of falls in the National Institute for Longevity Sciences, Longitudinal Study of Aging (NILS-LSA). *J Epidemiol*. 2000;10(1)(suppl):S90-S94.
11. Bloem BR, Valkenburg VV, Slabbekoorn M, Willemsen MD. The Multiple Tasks Test: development and normal strategies. *Gait Posture*. 2001;14(3):191-202.
12. Bergland A, Pettersen AM, Laake K. Falls reported among elderly Norwegians living at home. *Physiother Res Int*. 1998;3(3):164-174.
13. Maki BE. Gait changes in older adults: predictors of falls or indicators of fear. *J Am Geriatr Soc*. 1997;45(3):313-320.
14. Hausdorff JM. Gait variability: methods, modeling and meaning. *J Neuroeng Rehabil*. 2005;2(1):19. doi:10.1186/1743-0003-2-19.
15. Priest AW, Salamon KB, Hollman JH. Age-related differences in dual task walking: a cross sectional study [published online November 14, 2008]. *J Neuroeng Rehabil*. 2008;5:29. doi:10.1186/1743-0003-5-29.
16. Brach JS, Studenski SA, Perera S, VanSwearingen JM, Newman AB. Gait variability and the risk of incident mobility disability in community-dwelling older adults. *J Gerontol A Biol Sci Med Sci*. 2007;62(9):983-988.
17. Verghese J, Holtzer R, Lipton RB, Wang C. Quantitative gait markers and incident fall risk in older adults. *J Gerontol A Biol Sci Med Sci*. 2009;64(8):896-901.
18. Jaques-Dalcroze É. *Rhythm, Music & Education*. Rev ed. London, England: Dalcroze Society; 1967.
19. Kressig RW, Allali G, Beauchet O. Long-term practice of Jaques-Dalcroze eurhythmics prevents age-related increase of gait variability under a dual task. *J Am Geriatr Soc*. 2005;53(4):728-729.
20. Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc*. 1986;34(2):119-126.
21. Fried LP, Tangen CM, Walston J, et al; Cardiovascular Health Study Collaborative Research Group. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci*. 2001;56(3):M146-M156.
22. Wahli-Delbos M. *La Rythmique Jaques-Dalcroze, un atout pour les seniors.* Geneva, Switzerland: Editions Papillon; 2010.
23. Guigoz Y. The Mini Nutritional Assessment (MNA) review of the literature—what does it tell us? *J Nutr Health Aging*. 2006;10(6):466-487.
24. Richardson MT, Leon AS, Jacobs DR Jr, Ainsworth BE, Serfass R. Comprehensive evaluation of the Minnesota Leisure Time Physical Activity Questionnaire. *J Clin Epidemiol*. 1994;47(3):271-281.
25. Manos PJ, Wu R. The ten point clock test: a quick screen and grading method for cognitive impairment in medical and surgical patients. *Int J Psychiatry Med*. 1994;24(3):229-244.
26. Dubois B, Slachevsky A, Litvan I, Pillon B. The FAB: a Frontal Assessment Battery at bedside. *Neurology*. 2000;55(11):1621-1626.
27. Folstein MF, Folstein SE, McHugh PR. "Mini-Mental State": a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975; 12(3):189-198.
28. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. *Acta Psychiatr Scand*. 1983;67(6):361-370.
29. Gandek B, Ware JE, Aaronson NK, et al. Cross-validation of item selection and scoring for the SF-12 Health Survey in nine countries: results from the IQOLA Project: International Quality of Life Assessment. *J Clin Epidemiol*. 1998;51 (11):1171-1178.
30. Kressig RW, Beauchet O; European GAITRite Network Group. Guidelines for clinical applications of spatio-temporal gait analysis in older adults. *Aging Clin Exp Res*. 2006;18(2):174-176.
31. Allum JH, Carpenter MG. A speedy solution for balance and gait analysis: angular velocity measured at the centre of body mass. *Curr Opin Neurol*. 2005;18 (1):15-21.
32. Bischoff-Ferrari HA, Conzelmann M, Stähelin HB, et al. Is fall prevention by vitamin D mediated by a change in postural or dynamic balance? *Osteoporos Int*. 2006;17(5):656-663.
33. Gill J, Allum JH, Carpenter MG, et al. Trunk sway measures of postural stability during clinical balance tests: effects of age. *J Gerontol A Biol Sci Med Sci*. 2001; 56(7):M438-M447.
34. Bohannon RW. Reference values for the timed up and go test: a descriptive meta-analysis. *J Geriatr Phys Ther*. 2006;29(2):64-68.
35. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*. 1991;39(2):142-148.
36. Lin MR, Hwang HF, Hu MH, Wu HD, Wang YW, Huang FC. Psychometric comparisons of the timed up and go, one-leg stand, functional reach, and Tinetti balance measures in community-dwelling older people. *J Am Geriatr Soc*. 2004; 52(8):1343-1348.

37. Lamb SE, Jørstad-Stein EC, Hauer K, Becker C; Prevention of Falls Network Europe and Outcomes Consensus Group. Development of a common outcome data set for fall injury prevention trials: the Prevention of Falls Network Europe consensus. *J Am Geriatr Soc*. 2005;53(9):1618-1622.

38. Beauchet O, Annweiler C, Lecordroch Y, et al. Walking speed-related changes in stride time variability: effects of decreased speed. *J Neuroeng Rehabil*. 2009; 6(1):32. doi:10.1186/1743-0003-6-32.

39. Moe-Nilssen R. Test-retest reliability of trunk accelerometry during standing and walking. *Arch Phys Med Rehabil*. 1998;79(11):1377-1385.

40. Moe-Nilssen R, Helbostad JL. Estimation of gait cycle characteristics by trunk accelerometry. *J Biomech*. 2004;37(1):121-126.

41. Donaldson MG, Sobolev B, Cook WL, Janssen PA, Khan KM. Analysis of recurrent events: a systematic review of randomised controlled trials of interventions to prevent falls. *Age Ageing*. 2009;38(2):151-155.

42. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373-383.

43. Schwenk M, Zieschang T, Oster P, Hauer K. Dual-task performances can be improved in patients with dementia: a randomized controlled trial. *Neurology*. 2010; 74(24):1961-1968.

44. Yang YR, Wang RY, Chen YC, Kao MJ. Dual-task exercise improves walking ability in chronic stroke: a randomized controlled trial. *Arch Phys Med Rehabil*. 2007; 88(10):1236-1240.

45. Toulotte C, Thevenon A, Fabre C. Effects of training and detraining on the static and dynamic balance in elderly fallers and non-fallers: a pilot study. *Disabil Rehabil*. 2006;28(2):125-133.

46. Silsupadol P, Lugade V, Shumway-Cook A, et al. Training-related changes in dual-task walking performance of elderly persons with balance impairment: a double-blind, randomized controlled trial. *Gait Posture*. 2009;29(4):634-639.

47. Brauer SG, Morris ME. Can people with Parkinson's disease improve dual tasking when walking? *Gait Posture*. 2010;31(2):229-233.

48. Hausdorff JM, Nelson ME, Kaliton D, et al. Etiology and modification of gait instability in older adults: a randomized controlled trial of exercise. *J Appl Physiol*. 2001;90(6):2117-2129.

49. Galica AM, Kang HG, Priplata AA, et al. Subsensory vibrations to the feet reduce gait variability in elderly fallers. *Gait Posture*. 2009;30(3):383-387.

50. Hausdorff JM, Lowenthal J, Herman T, Gruendlinger L, Peretz C, Giladi N. Rhythmic auditory stimulation modulates gait variability in Parkinson's disease. *Eur J Neurosci*. 2007;26(8):2369-2375.

51. Baezner H, Oster M, Henning O, Cohen S, Hennerici MG. Amantadine increases gait steadiness in frontal gait disorder due to subcortical vascular encephalopathy: a double-blind randomized placebo-controlled trial based on quantitative gait analysis. *Cerebrovasc Dis*. 2001;11(3):235-244.

52. Ben-Itzhak R, Giladi N, Gruendlinger L, Hausdorff JM. Can methylphenidate reduce fall risk in community-living older adults? a double-blind, single-dose crossover study. *J Am Geriatr Soc*. 2008;56(4):695-700.

53. Granacher U, Muehlbauer T, Bridenbaugh S, Bleiker E, Wehrle A, Kressig RW. Balance training and multi-task performance in seniors. *Int J Sports Med*. 2010; 31(5):353-358.

54. Silsupadol P, Shumway-Cook A, Lugade V, et al. Effects of single-task versus dual-task training on balance performance in older adults: a double-blind, randomized controlled trial. *Arch Phys Med Rehabil*. 2009;90(3):381-387.

55. Yogev-Seligmann G, Hausdorff JM, Giladi N. The role of executive function and attention in gait. *Mov Disord*. 2008;23(3):329-342.

56. van Iersel MB, Kessels RP, Bloem BR, Verbeek AL, Olde Rikkert MG. Executive functions are associated with gait and balance in community-living elderly people. *J Gerontol A Biol Sci Med Sci*. 2008;63(12):1344-1349.

57. Hausdorff JM, Schweiger A, Herman T, Yogev-Seligmann G, Giladi N. Dual-task decrements in gait: contributing factors among healthy older adults. *J Gerontol A Biol Sci Med Sci*. 2008;63(12):1335-1343.

58. Herman T, Mirelman A, Giladi N, Schweiger A, Hausdorff JM. Executive control deficits as a prodrome to falls in healthy older adults: a prospective study linking thinking, walking, and falling. *J Gerontol A Biol Sci Med Sci*. 2010;65(10): 1086-1092. doi:10.1093/gerona/glq077.

59. Springer S, Giladi N, Peretz C, Yogev G, Simon ES, Hausdorff JM. Dual-tasking effects on gait variability: the role of aging, falls, and executive function. *Mov Disord*. 2006;21(7):950-957.

60. Lopopolo RB, Greco M, Sullivan D, Craik RL, Mangione KK. Effect of therapeutic exercise on gait speed in community-dwelling elderly people: a meta-analysis. *Phys Ther*. 2006;86(4):520-540.

61. Abellan van Kan G, Rolland Y, Andrieu S, et al. Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people an International Academy on Nutrition and Aging (IANA) Task Force. *J Nutr Health Aging*. 2009;13(10):881-889.

62. Reelick MF, van Iersel MB, Kessels RP, Rikkert MG. The influence of fear of falling on gait and balance in older people. *Age Ageing*. 2009;38(4):435-440.

63. Michikawa T, Nishiwaki Y, Takebayashi T, Toyama Y. One-leg standing test for elderly populations. *J Orthop Sci*. 2009;14(5):675-685.

64. Kressig RW, Herrmann FR, Grandjean R, Michel JP, Beauchet O. Gait variability while dual-tasking: fall predictor in older inpatients? *Aging Clin Exp Res*. 2008; 20(2):123-130.

65. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc*. 2002; 34(12):1996-2001.

66. Vertinsky P. Old age, gender and physical activity: the biomedicalization of aging. *J Sport Hist*. 1991;18(1):64-80.

67. Martin K, Sinden A. Who will stay and who will go? a review of older adults' adherence to randomized controlled trials of exercise. *J Aging Phys Act*. 2001; 9(1):91-114.

68. Johnson G, Otto D, Clair AA. The effect of instrumental and vocal music on adherence to a physical rehabilitation exercise program with persons who are elderly. *J Music Ther*. 2001;38(2):82-96.