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ORIGINAL RESEARCH

Long-Term Exercise in Older Adults: 4-Year Outcomes of Music-Based Multitask Training

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Abstract Prospective controlled evidence supporting the efficacy of long-term exercise to prevent physical decline and reduce falls in old age is lacking. The present study aimed to assess the effects of long-term music-based multitask exercise (i.e., Jaques-Dalcroze eurhythmics) on physical function and fall risk in older adults. A 3-year follow-up extension of a 1-year randomized controlled trial (NCT01107288) was conducted in Geneva (Switzerland), in which 134 community-dwellers aged ≥65 years at increased risk of falls received a 6-month music-based multitask exercise program. Four years following original trial enrolment, 52 subjects (baseline mean ± SD age, 75 ± 8 years) who (i) have maintained exercise program participation through the 4-year follow-up visit ("long-term intervention group", $n = 23$) or (ii) have discontinued participation following original trial completion ("control group", $n = 29$) were studied. They were reassessed in a blind fashion, using the same procedures as at baseline. At 4 years, linear mixed-effects models showed significant gait (gait speed, $P = 0.006$) and balance (one-legged stance time, $P = 0.015$) improvements in the long-term intervention group, compared with the control group. Also, long-term intervention subjects did better on Timed Up & Go, Five-Times-Sit-to-Stand and handgrip strength tests, than controls ($P < 0.05$, for all comparisons). Furthermore, the exercise program reduced the risk of falling (relative risk, 0.69; 95 % confidence interval, 0.5–0.9; $P = 0.008$). These findings suggest that long-term maintenance of a music-based multitask exercise program is a promising strategy to prevent age-related physical decline in older adults. They also highlight the efficacy of sustained long-term adherence to exercise for falls prevention.

Keywords Aged · Exercise · Physical health · Falls · Detraining · Frailty

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Introduction

Population aging poses challenges for society. In many countries, the number of seniors aged 65 years and over is predicted to increase by 60 % by 2030 [1]. Physical impairments and falls are among the most common and devastating concern facing older adults, significantly contributing to disability, hospitalizations, nursing home admissions, poor quality of life, and mortality in this population [2–5].

Over one-third of community-living older adults experience physical impairments affecting daily activities (e.g., difficulty with walking or getting out of a chair) and/or falls at least once a year, this rises to almost half for those over 80 years [2, 6]. The age-related decline in physical function can predispose an individual to an increased risk of falls [7, 8]. Deficits in gait and balance, and muscle weakness, rank among the most frequent intrinsic fall-risk factors [2]. In addition, physical impairments constitute primary markers of frailty, a state of increased vulnerability to stressful events with high risk of multiple adverse outcomes [9, 10]. Evidence has previously shown that exercise is the most effective preventive strategy for counteracting the decline in age-related physical function and in turn reducing fall risk, with an effectiveness of different approaches in a variety of populations and settings [3, 5, 11, 12]. However, to date only a handful of prospective controlled studies have reported the long-term adherence and benefits of supervised exercise programs delivered beyond 2 years in older adults, with most programs lasting for 6–12 months [13]. Hence, evidence about the positive role of exercise initiated in old age and maintained over the long-term on physical or other relevant geriatric outcomes, including falls and frailty, has been limited by the observational design of most studies [7, 13, 14]. Most traditional exercise programs are not attractive enough to promote regular long-term adherence [12, 15]. After cessation of the exercise, detraining occurs and benefits are lost [16, 17].

In a previous randomized controlled trial, we promoted a new way to improve physical function and reduce falls in older people through a 6-month music-based multitask exercise program (i.e., Jaques-Dalcroze Eurhythmics) [18]. Jaques-Dalcroze eurhythmics—a music education through movement method—consists of varied multitask exercises performed to the rhythm of improvised piano music [19]. This specific exercise regimen involved multiple-task practice which highly challenged motor-, cognitive- and social-related abilities (e.g., large balance component). Trial results indicated that 6 months of once-weekly exercise classes improved gait under both single- and dual-task conditions, balance and functional performances, compared with non-exercising controls; this translated into a reduction in falls. The 6-month program also benefited cognitive function and mood [20].

In this paper, we report data from a 4-year follow-up of our previous randomized controlled, cross-over, 1-year trial [18], designed to assess if the effects on gait, balance, and falls are maintained with or without exercise continuation.

Methods

Design Overview and Participants

Original Trial

Detailed descriptions of the rationale, design, procedures and main results of the original trial have been previously published [18]. Briefly, this was a 1-year monocenter, randomized controlled trial (NCT01107288), conducted in Geneva (Switzerland) between February 2008 and December 2009, in which 134 individuals received a 6-month music-based multitask intervention, either immediately or after a 6-month delay. All enrolled participants fulfilled the following inclusion criteria: (i) aged ≥65 years, (ii) living in the community, (iii) without past experience of Jaques-Dalcroze eurhythmics, except during childhood, and (iv) at increased risk for falling. The risk of falling was based on self-reported falls after the age of 65 years, balance assessment and frailty phenotype. Following trial completion, participants had the opportunity to participate in music-based multitask exercise sessions delivered in community centres under the supervision of the research team.

Extension Study

Subjects who completed the original 1-year trial were contacted by phone to detail study procedures, assess interest and eligibility, and schedule the extended follow-up assessment visit. Both (i) participants who have maintained exercise participation through the 4-year follow-up visit (“long-term intervention group”), and (ii) participants who have discontinued participation following original trial completion (“control group”) were included into the extension study. Attendance lists were checked to verify participant’s status regarding participation in community exercise classes since the original trial completion. Participants were excluded from the follow-up assessment if they reported any major orthopedic surgery or limb fracture less than 4 months prior to enrollment into the extension study.

Intervention

A detailed description of the intervention has been detailed elsewhere [19]. Music-based multitask exercise classes for seniors were held once weekly over 45 weeks per year, at various community locations, under the supervision of certified instructors who were involved in the original trial. Each class, of 1 h duration, consisted of a warm-up followed by varied multitask exercises of progressive difficulty, sometimes involving the handling of objects (e.g., percussion instruments), performed individually, in pairs or more. Basic exercises consisted of walking following the piano music, responding directly or oppositely to changes in music’s rhythmic patterns, phrases, form or other aspects.

Extended Follow-Up Measurements

The 4-year follow-up visit included the same procedures as during the original trial. During the 4-year follow-up assessment, all outcome measures were assessed by the same multidisciplinary team who completed the baseline assessments. All team members were blind to group assignment and without access to previous scores. Gait was assessed under single- and dual-task conditions using an electronic pressure-sensitive walkway, with an active recording surface of 732 × 61 cm (GAITRite; CIR Systems Inc., Havertown, PA, USA) [18, 21]. Participants were asked to walk at their self-selected comfortable speed (one trial), as a single-task, and walk at their self-selected speed while simultaneously counting aloud backwards by ones starting from 50 (one trial), as a dual-task. They were instructed to begin and stop walking two meters from either end of the active surface to counter acceleration and deceleration effects. Coefficient of variation (CV) was used as a measure of gait variability (i.e., the stride-to-stride fluctuations in walking) for each gait parameter (CV = [SD/mean] × 100). Balance was assessed using angular velocity transducers (SwayStar; Balance International Innovations GmbH, Iseltwald, Switzerland) [18]. For functional tests, each participant underwent a Timed Up & Go test under single-task and a simplified Tinetti test (the scale contains seven items rated according to two levels—i.e., normal, abnormal—: unsteady sitting down, unable to stand on one leg unsupported, unsteady turning, unsteady after gentle push on sternum, increased trunk sway, unable to pick up walking pace and increased path deviation). Five-Times-Sit-to-Stand test was introduced at 1-year to assess functional muscle performance (strength/power) [18, 22]. Structured face-to-face interviews recorded sociodemographic characteristics, fall history, nutritional status (using the mini-nutritional assessment short-form) [23], quality of life (using the 12-Item Short Form Health Survey) [24], physical activity level [25], medications and motivations/barriers to long-term maintenance of music-based multitask exercise. Neuropsychological status was evaluated using the Hospital Anxiety and Depression Scale [26], the Mini-Mental State Examination [27] and the clock-drawing test [20, 28]. Frailty status was also determined according to Fried's frailty criteria (i.e., unintentional weight loss, exhaustion, slow walking speed, low grip strength and low physical activity level) [10]. Participants were categorized as robust (0 criteria), pre-frail (1 or 2 criteria) and frail (3 or more criteria). The number, circumstances, and consequences of falls since the last original trial visit and in the previous year were also recorded based on self-report. A fall was defined as an event where the participant unintentionally came to rest on the ground or a lower level.

Statistical Analysis

Data were analyzed using Stata version 12.1 (Stata Corp., College Station, TX, USA) statistical software. Descriptive statistics were computed as mean ± standard deviation (SD) for continuous variables or as number and percentages for categorical variables. Imbalance between groups at baseline and 1-year was examined using *t* tests or Wilcoxon rank sum tests for continuous data, and χ^2 or Fisher's exact tests for categorical data. Differences between participants who were followed-up for 4 years and those originally recruited but not enrolled into the long-term extension study were also examined using these tests.

Groups' differences in changes of outcome measures over 4 years were assessed using linear mixed-effects regression models, fitted using Stata's "xtmixed" procedure, with participant included as random effect, and with group, time (as repeated factor: baseline (i.e., original trial entry), 1-year (i.e., original trial end), 4-year), and group × time interactions entered into the models. In addition, to take into account the cross-over design of the original trial, potential sequence differences were also controlled for by entering the sequence of interventions as a covariate. Within-group changes from baseline to 4-year were also examined using linear mixed-effects models.

For fall outcomes, Wilcoxon rank sum and χ^2 tests were computed. Log-binomial regression models were used to calculate relative risks comparing both the number of participants with 1 or more falls and participants with multiple falls (≥2 falls during the study period) in both groups at year 4. The incidence rate ratios for the number of falls were analyzed using negative binomial regression models.

A two-sided *P* value less than or equal to 0.05 was considered to indicate statistical significance.

Results

Figure 1 shows the progress of participants through the stages of follow-up. Fifty-two were enrolled into the extension study, of which 23 maintained regularly participation in music-based multitask exercise classes through the 4-year follow-up and 29 discontinued participation following the original 6-month exercise program completion. Participants who were followed-up ($n = 52$) and those originally recruited but not enrolled into the extension study ($n = 82$) did not differ at baseline in any of the assessed variables ($P > 0.05$ in all cases). Most common self-reported barriers to long-term maintenance of music-based multitask exercise in control group included the cost of the exercise program (62 %) or personal factors unrelated to the program (17 %). Intercurrent illnesses represented 10 % of the cases.

The extension study population was predominantly female (98 %), had a mean baseline age of 74.6 ± 7.8 years, and had a relatively good functional status

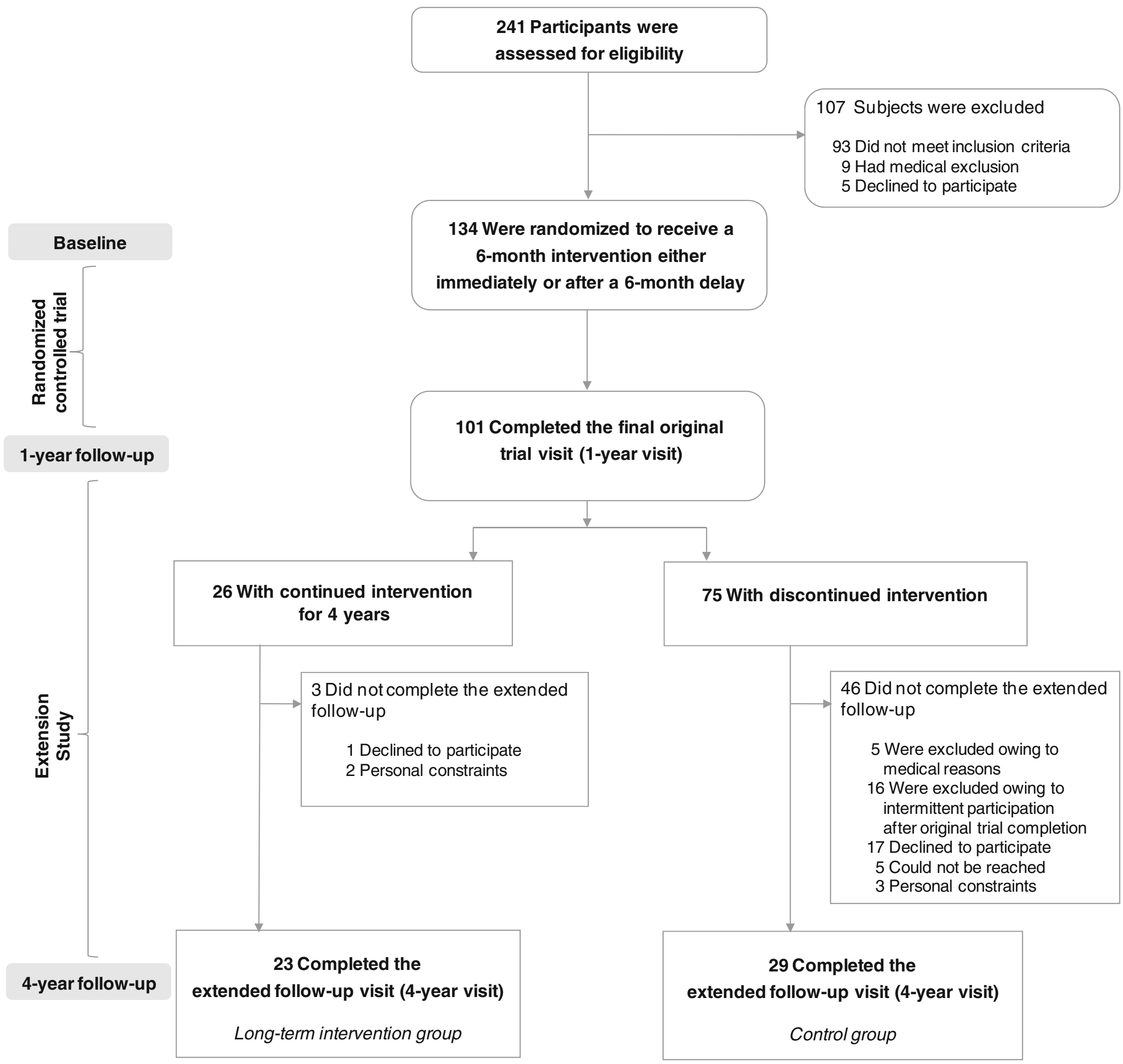


Fig. 1 Flowchart of the study

(Timed Up & Go time, 10.1 ± 2.1 s) (Tables 1, 2). There were no significant differences between the long-term intervention and the current control group at the completion of the 1-year original exercise trial, although the control participants had a significantly wider base of support while walking at self-selected comfortable speed (Table 2). Also, control participants scored significantly higher on the frailty and Tinetti scales at baseline when compared to the long-term intervention group (Tables 1, 2). The mean length of follow-up was 3.8 ± 0.2 years. No major adverse effects or health problems resulting from the exercise program were reported.

The values of gait, balance, and muscle function tests are appeared in Table 2. At 4 years, linear mixed-effects models showed significant gait and balance improvements in the long-term intervention group, compared with the control group (Table 2; Fig. 2). Under single-task condition, long-term intervention group participants increased the usual gait speed ($P = 0.006$) and stride length ($P = 0.001$), compared with the control group. Also, stance time on one-legged stance task ($P = 0.015$) improved in this group, as compared to controls. Similarly, the long-term intervention group did better in gait variability ($P = 0.033$ for stride length variability and $P = 0.016$ for step length variability), Timed Up & Go ($P = 0.008$), and handgrip strength ($P = 0.018$) tests (Table 2; Fig. 2). Between-groups differences for changes in all other outcome measures were no significant. Adjustment for change in physical activity level during the follow-up did not alter any of the results. Mixed-effects models of change in measures from 1-year revealed additional benefits of the long-term intervention for gait under

Table 1 Characteristics of study participants at baseline and at the 1- and 4-year follow-up visits

Characteristic	Baseline Original trial entry		1-year Original trial end		4-year	
	Long-term intervention group ($n = 23$)	Control group ($n = 29$)	Long-term intervention group ($n = 23$)	Control group ($n = 29$)	Long-term intervention group ($n = 23$)	Control group ($n = 29$)
Age, mean (SD), y	76 ± 6.6	73.5 ± 8.6	–	–	–	–
Sex, no. (%)						
Male	0 (0)	1 (3)	–	–	–	–
Female	23 (100)	28 (97)	–	–	–	–
Marital status, no. (%)						
Married	2 (8.7)	10 (34)	–	–	–	–
Other	21 (91.3)	19 (66)	–	–	–	–
Educational level, no. (%)						
Primary school	1 (4)	4 (14)	–	–	–	–
Middle school	12 (52)	22 (76)	–	–	–	–
High school	10 (43)	3 (10)	–	–	–	–
Home help services, no. (%)	3 (13)	7 (24)	–	–	–	–
Height, mean (SD), cm	161 ± 6.9	160 ± 5.8	161 ± 6.9	160 ± 5.8	161 ± 7.0	161 ± 5.7
Body mass index, mean (SD), kg/m^{2}[a]	25.3 ± 4.0	26.4 ± 3.5	25.1 ± 3.8	26.3 ± 4.1	24.2 ± 3.8	25.0 ± 4.9
History of falls after 65 years, no. (%)	22 (96)	24 (83)	22 (96)	26 (90)	22 (96)	27 (93)
Fall(s) in the past 12 months, no. (%)	13 (57)	17 (59)	12 (52)	19 (66)	5 (22)	14 (48)
Number of frailty components, mean (SD)[b]	0.5 (0.6)	1 (0.7)*	0.7 (0.6)	0.9 (0.6)	0.5 (0.8)	1.3 (0.8)
Frailty components, no. (%)						
Unintentional weight loss	1 (4)	6 (21)	0 (0)	0 (0)	0 (0)	1 (3)
Exhaustion	6 (26)	5 (17)	2 (9)	3 (10)	2 (9)	3 (10)
Low physical activity level	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Slow walking speed	2 (9)	4 (14)	2 (9)	2 (7)	2 (9)	10 (34)
Low grip strength	3 (13)	14 (48)*	11 (48)	20 (69)	8 (35)	23 (79)
Physical activity level, mean (SD), kcal/week	2304 ± 1010	2501 ± 1191	2312 ± 999	2586 ± 1216	2022 ± 789	2379 ± 1138
SF-12, mean (SD), score	31.4 ± 1.9	30.8 ± 2.8	31.9 ± 2.3	31.9 ± 2.2	31.8 ± 3.1	31.1 ± 2.7
MNA-short form, mean (SD), score	12.8 ± 1.3	12.6 ± 1.5	12.5 ± 1.8	12.6 ± 1.7	13.2 ± 1.2	13.1 ± 1.0
HADS, mean (SD), score	10.7 ± 5.8	10.1 ± 5.3	9.4 ± 4.9	9.3 ± 3.8	8.0 ± 4.8	8.6 ± 3.4
MMSE, mean (SD), score	27.1 ± 2.4	25.9 ± 3.1	28.0 ± 2.2	27.6 ± 1.6	27.4 ± 2.3	26.9 ± 2.3
Clock-drawing test, mean (SD), score	9.0 ± 1.7	8.8 ± 1.0	8.4 ± 1.7	8.7 ± 1.5	8.9 ± 1.4	9.2 ± 1.2
Self-rated health status, mean (SD)[c]	2.6 (0.8)	2.7 (0.8)	2.7 (0.9)	2.8 (0.8)	2.7 (0.6)	2.8 (0.6)

Table 1 continued

Characteristic	Baseline Original trial entry		1-year Original trial end		4-year	
	Long-term intervention group ($n = 23$)	Control group ($n = 29$)	Long-term intervention group ($n = 23$)	Control group ($n = 29$)	Long-term intervention group ($n = 23$)	Control group ($n = 29$)
Medications >4, no. (%)	9 (39)	10 (34)	10 (43)	13 (45)	8 (35)	5 (17)

SD standard deviation, *SF-12* 12-item short-form health survey, *MNA* mini-nutritional assessment, *HADS* hospital anxiety and depression scale, *MMSE* mini-mental state examination

[a] Calculated as weight in kilograms divided by height in meters squared

[b] According to Fried et al. [10]

[c] Five-point Likert scale from 1 (excellent) to 5 (bad)

* Significant difference between groups ($P < 0.05$)

dual-task, including gait variability ($P = 0.018$ for stride length variability and $P = 0.006$ for step length variability), speed ($P = 0.012$), and for Five-Times-Sit-to-Stand test performance ($P < 0.001$). Within-group analysis revealed significant improvements in gait and balance in the intervention group, including in gait speed under both single- and dual-task conditions ($P = 0.037$ and $P = 0.009$, respectively) and stance time on one-legged stance task ($P < 0.001$) (Table 2). In the control group, gait and balance declined, with a significant increase found in most gait variability parameters and in Timed Up & Go time ($P = 0.042$) (Table 2).

The mean numbers of falls reported by the participants in the previous year and over the 4-year follow-up period were 0.4 (0.6) and 2.0 (1.8), respectively, and ranged from 0 to 8. Compared with the control group, the long-term intervention group experienced fewer falls during the previous year (0.2 ± 0.4 vs. 0.6 ± 0.6; *t* test, $P = 0.027$). The proportion of participants with 1 or more falls was also statistically different between groups (22 vs. 48 % in long-term intervention and control groups, respectively; χ^2 test, $P = 0.048$). The incidence rate ratio for falls and the relative risk for participants with 1 or more falls failed to reach statistical significance (Table 3). Over the 4-year follow-up period, the relative risks for participants with 1 or more falls and multiple falls were lower (0.69, 95 % CI 0.53–0.91, and 0.53, 95 % CI 0.29–0.99, respectively).

At baseline, 19 participants (37 %) were robust (i.e., no criteria) and 33 (63 %) prefrail (i.e., with 1 or 2 criteria) using Fried's frailty criteria. Over the 4-year follow-up period, most participants worsened toward higher frailty scores: at 4 years, 7 (37 %) of robust participants became prefrail and 2 (11 %) frail (i.e., with 3 or more criteria). Among prefrail participants, long-term intervention participants were more likely to become robust at 4 years than controls [6/11 (55 %) vs. 2/22 (9 %); $P = 0.004$].

Discussion

This 4-year follow-up provides evidence that long-term participation to a music-based multitask exercise program can prevent physical decline and reduce falls in community-dwelling older adults. The current 4-year data set represents, to our knowledge, the longest prospective controlled follow-up supporting the efficacy of a long-term supervised exercise intervention in counteracting age-related physical decline and falls in older people.

Our results indicate that 4-year of music-based multitask training had beneficial effects for physical functioning, with sustained improvements on a number of performance measures. Within-group and between-groups analyses revealed that long-term intervention participants improved in several gait and balance outcomes over the 4-year period, while muscle and functional test performances slightly declined, but to a significantly less extent than in controls. This may have major clinical implications since physical performance measures, such as gait speed, one-legged stance, handgrip strength, Timed Up & Go or sit-to-stand, have been identified as powerful predictors of negative health outcomes, including disability, and major determinants of independence in activities of daily living or quality of life [8, 29–33]. Most pronounced benefits were for gait function, with benefits found in fall-related gait parameters, under both single- and dual-task conditions (i.e., an ecologically valid proxy of typical situations that older adults may encounter). Such improvements are likely to have a profound impact on daily functioning which requires the ability to walk safely and efficiently (e.g., reflected by reduced gait variability) in complex environments. It has been suggested that an increase of 10 cm/s in usual gait speed would result in absolute risk reduction of death of 18 % [34]. With respect to maintenance of efficacy after cessation of the short-term intervention, control

Table 2 Change in physical outcome measures from baseline to 4-year follow-up

Variable	Baseline		1-year		4-year			
	Long-term intervention group (n = 23)	Control group (n = 29)	Long-term intervention group (n = 23)	Control Group (n = 29)	Long-term intervention group (n = 23)	Control group (n = 29)	P Value[a]	P Value[b]
Gait								
Single-task condition								
Gait speed								
Gait velocity, cm/s	111.5 ± 19.4	102.1 ± 16.5	113.3 ± 19.0	108.5 ± 17.4	118.3 ± 21.1†	97.9 ± 17.4	0.006	<0.001
Stride length, cm	122.1 ± 16.4	113.9 ± 13.0	124.1 ± 15.2	115.8 ± 15.3	126.2 ± 16.4†	109.2 ± 15.6†	0.001	0.001
Cadence, steps/min	109.5 ± 7.7	107.6 ± 9.4	109.7 ± 8.7	112.5 ± 8.2	112.5 ± 10.5	108.1 ± 9.8	0.318	0.004
Dynamic balance								
Double support phase, %	22.6 ± 3.2	24.0 ± 3.4	20.5 ± 3.9	22.5 ± 3.0	25.5 ± 3.0†	29.6 ± 4.2†	0.003	0.022
Support base, cm	7.1 ± 2.5	8.4 ± 3.5*	6.7 ± 2.3	8.9 ± 3.4*	7.4 ± 3.0	9.4 ± 3.7†	0.314	0.576
Gait variability								
Stride time variability, %CV	2.2 ± 0.8	2.3 ± 1.1	2.1 ± 0.8	2.6 ± 1.1	2.3 ± 1.0	3.2 ± 1.0†	0.036	0.273
Stride length variability, %CV	2.6 ± 1.0	2.7 ± 1.1	2.5 ± 1.0	2.7 ± 1.0	2.6 ± 1.0	3.6 ± 1.4†	0.033	0.060
Step time variability, %CV	3.3 ± 1.1	3.6 ± 1.3	3.4 ± 1.3	4.1 ± 1.4	3.7 ± 1.4	5.1 ± 1.6†	0.027	0.169
Step length variability, %CV	4.1 ± 1.8	4.2 ± 1.6	4.4 ± 2.7	4.2 ± 1.6	4.1 ± 1.6	5.5 ± 2.4†	0.016	0.003
Dual-task condition								
Gait speed								
Gait velocity, cm/s	93.2 ± 27.2	78.5 ± 17.6	97.9 ± 19.5	88.1 ± 15.9	102.7 ± 22.1†	81.5 ± 18.8	0.155	0.012
Stride length, cm	117.7 ± 18.2	106.5 ± 13.8	119.0 ± 14.8	111.3 ± 13.3	119.5 ± 17.5	104.4 ± 16.7	0.164	0.009
Cadence, steps/min	93.6 ± 17.0	88.3 ± 15.2	98.4 ± 11.5	95.0 ± 11.2	103.0 ± 12.6†	93.8 ± 14.2†	0.286	0.114
Gait variability								
Stride time variability, %CV	5.4 ± 9.1	6.4 ± 8.7	3.5 ± 2.1	3.4 ± 1.9	2.8 ± 1.2	5.8 ± 2.9	0.302	0.113
Stride length variability, %CV	3.7 ± 2.9	4.7 ± 3.1	3.2 ± 1.4	2.8 ± 1.8	2.8 ± 1.2	4.2 ± 1.7	0.582	0.018
Step time variability, %CV	7.6 ± 10.9	8.8 ± 10.7	5.2 ± 2.3	5.4 ± 3.3	4.1 ± 1.5	7.9 ± 3.1	0.256	0.115
Step length variability, %CV	5.8 ± 3.7	6.6 ± 3.5	4.7 ± 2.0	4.5 ± 2.1	4.3 ± 1.8†	6.5 ± 2.5	0.126	0.006
Balance								
One-legged stance task								
Displacement M–L, degrees	4.4 ± 4.0	4.5 ± 3.0	3.6 ± 2.0	4.5 ± 2.8	3.8 ± 2.4	3.9 ± 2.5	0.903	0.417
Angular velocity M–L, degrees/s	13.4 ± 12.2	16.2 ± 13.2	10.7 ± 6.0	13.8 ± 8.0	8.6 ± 3.5†	10.4 ± 7.1†	0.750	0.669
Displacement A–P, degrees	4.0 ± 2.6	4.2 ± 2.2	4.8 ± 3.0	3.7 ± 1.9	4.0 ± 2.4	3.9 ± 2.5	0.746	0.236
Angular velocity A–P, degrees/s	11.5 ± 8.9	11.4 ± 5.9	12.9 ± 12.2	11.7 ± 5.3	8.9 ± 3.3	10.1 ± 8.9	0.575	0.295
Duration, s	7.3 ± 3.3	6.7 ± 3.4	8.8 ± 2.0	8.2 ± 2.6	9.3 ± 2.0†	6.8 ± 3.4	0.015	0.013
Functional tests								
Timed Up & Go test, s	9.7 ± 2.2	10.5 ± 2.1	9.3 ± 1.9	9.8 ± 1.8	10.0 ± 2.0	12.7 ± 3.7†	0.008	0.001

Table 2 continued

Variable	Baseline		1-year		4-year		*P* Value[a]	*P* Value[b]
	Long-term intervention group ($n = 23$)	Control group ($n = 29$)	Long-term intervention group ($n = 23$)	Control Group ($n = 29$)	Long-term intervention group ($n = 23$)	Control group ($n = 29$)		
Simplified Tinetti test, score	0.3 ± 0.5	1.0 ± 1.1*	0.0 ± 0.2	0.7 ± 1.1	0.1 ± 0.5†	1.0 ± 1.0	0.481	0.366
Five-times-sit-to-stand test, s[c]	–	–	11.8 ± 3.4	12.3 ± 2.6	11.8 ± 2.6	14.7 ± 4.1	–	<0.001

Presented as mean ± standard deviation

CV coefficient of variation, *M–L* body sway in mediolateral direction, *A–P* body sway in anteroposterior direction

[a] Linear mixed-effects analysis on change in measures from baseline to 4-year

[b] Linear mixed-effects analysis on change in measures from 1- to 4-year

[c] Added at 1-year visit

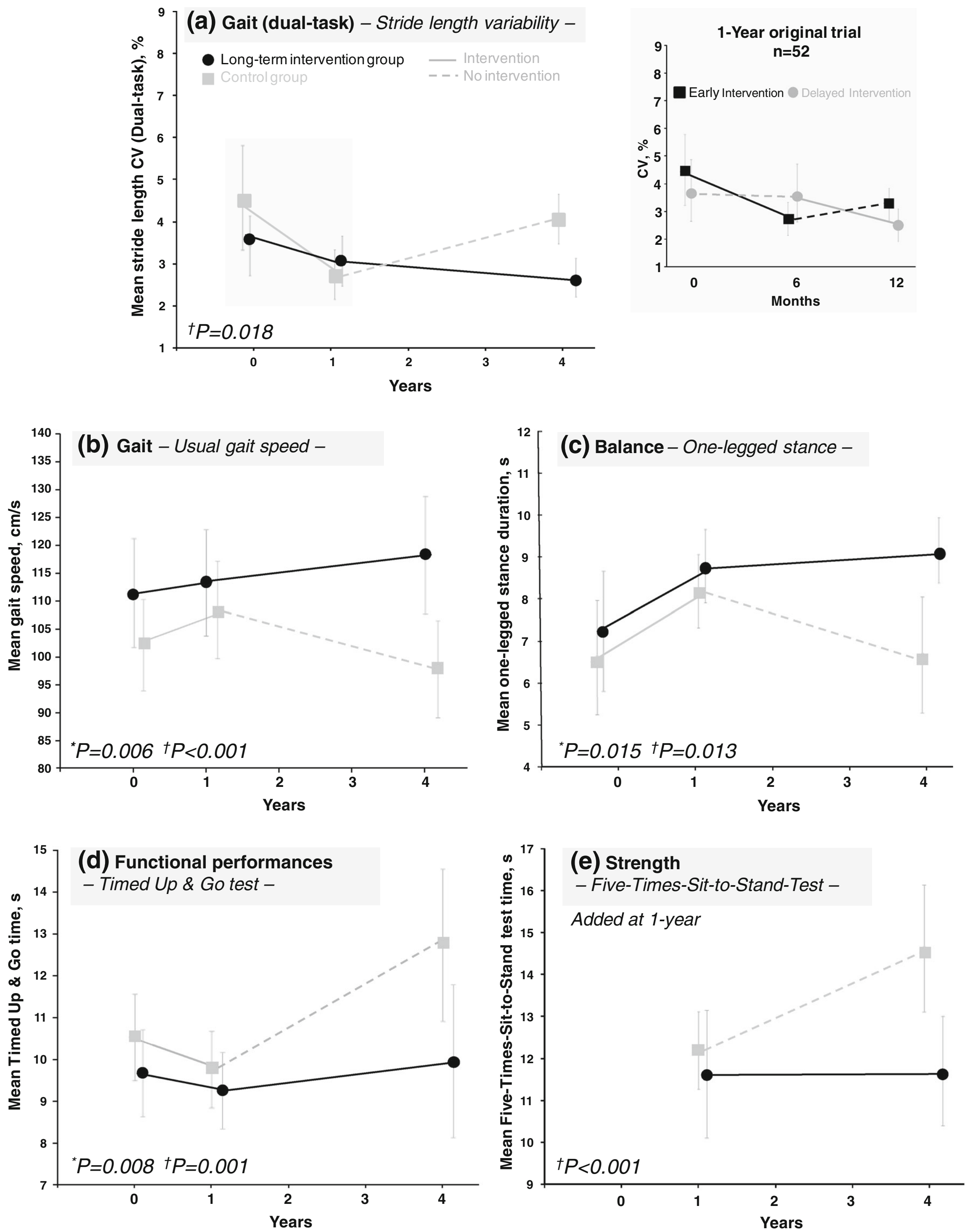
* Significant difference between groups ($P < 0.05$)

† Significant within-group change from baseline to 4-year ($P < 0.05$)

participants declined in all aspects of physical function, with benefits of the initial 6-month intervention partially to totally lost. This adds to the relatively limited literature showing detraining effects after program cessation in community-living older adults [16, 17]. Among others outcomes, gait speed declined to below 100 cm/s and Timed Up & Go test performance (i.e., time required to complete basic tasks of daily living) above 12 s in control participants at 4-year follow-up, putting these subjects at a high risk of adverse health outcomes including fractures, hospitalization and decreased survival [30, 32, 35]. Of note, the 4 % decline observed in gait speed at 4 years in controls was of lower magnitude than the rates of decline reported in the literature, including a recent large cohort study which found a 5.5 % decline over a 4-year period [36].

Despite the limited number of participants, the data showed a promising effect of a long-term exercise program on falls. While long-term engagement in exercise has been widely advocated for effects on fall rates, this relies mainly on observational studies. Although incidence rate ratios and relative risks provided should be interpreted with caution due to the small sample size, this 4-year follow-up is a relatively unique set of data supporting the efficacy of sustained long-term adherence to exercise for falls prevention. This finding should reinforce the importance to successfully implement and run long-term community-based programs for seniors. The reduction in statistical power due to decreasing sample size, and the retrospective reporting of falls events, are likely to explain the non-significant risk estimates found for the number of falls over the 4-year follow-up and for falls outcomes in the previous year.

Another salient finding of our study was the positive effect shown on frailty status. While the role of exercise on most components and adverse health outcomes of frailty have been largely investigated, there is still a lack of data regarding whether exercise can prevent worsening or reverse frailty status (i.e., defined using an operational definition of frailty [10]) [37]. The findings from this long-term follow-up suggest that 4 years of music-based multitask training may positively impact the frailty development process. Although transitions to a more severe frailty state at 4 years were more common than transitions to better state in both groups—the natural evolution of frailty [38, 39]—prefrail long-term intervention participants were more likely to become robust than controls. Transition from prefrail to robust states was likely attributable to improvements in physical performance measures. Cohort studies have highlighted that prefrail older adults are more likely than frail to improve to a state of lesser frailty, suggesting that prefrail state may be an optimal target for interventions [38].



* Groups' differences in change from baseline (original trial entry) to 4-year. Linear mixed-effects regression model with sequence of interventions as a covariate.

† Groups' differences in change from 1-year (original trial end) to 4-year. Same model.

Fig. 2 Changes in physical outcome measures in long-term intervention and control group from baseline to 4-year. *Error bars* represent 95 % CIs

While successful engagement in exercise is a significant and widespread issue in older population, to address long-term adherence has been recognized as the more daunting challenge [15, 40, 41]. Dropout rates from different exercise programs for older adults has been reported to be 26 % at 3-month and 49 % at 1-year [42]. It was encouraging to

Table 3 Falls at the 4-year follow-up

Variable	Falls in the previous year		Falls over the 4-year follow-up	
	Long-term intervention group ($n = 23$)	Control group ($n = 29$)	Long-term intervention group ($n = 23$)	Control group ($n = 29$)
Falls, no.	5	16	40	65
Mean (SD)	0.2 (0.4)	0.6 (0.6)*	1.7 (1.8)	2.2 (1.8)
Incidence rate ratio (95 % CI)	0.39 (95 % CI, 0.14–1.08) $P = 0.07$		0.78 (95 % CI, 0.47–1.28) $P = 0.320$	
Participants with ≥ 1 fall, no. (%)	5 (22)	14 (48)†	16 (70)	25 (86)
Relative risk (95 % CI)	0.45 (95 % CI, 0.19–1.07) $P = 0.07$		0.69 (95 % CI, 0.53–0.91) $P = 0.008$	
Participants with multiple (≥2) falls, no. (%)	0 (0)	2 (7)	8 (35)	19 (66)
Relative risk (95 % CI)	[a]		0.53 (95 % CI, 0.29–0.99) $P = 0.045$	

SD standard deviation, *CI* confidence interval

* $P = 0.027$

† $P = 0.048$

[a] Too few events to calculate relative risk (only 2 control participants with multiple falls)

find that 26 % of participants have maintained regular exercise program participation 3-year after the formal support from the original trial has withdrawn. Of note, this intervention was only a once weekly effort, this contrast with other supervised exercise interventions that often require at least a two weekly commitment [11, 13]. Main motivators to long-term maintenance of program reported by participants were enjoyability of the exercise classes and perceived health benefits. Jaques-Dalcroze eurhythmics, which involves strong music and social components [19], has a great potential to foster adherence in older adults; in particular, music has been widely shown to promote exercise adherence in older people [43]. In the last decade there has been a growing interest in music-based or 3D interventions, such as dance-based programs, as alternatives to improve exercise adherence in elderly subjects [40, 44]. Understanding the factors that have impeded long-term adherence in trials is a critical issue, especially because barriers connected to exercise have been revealed as more predictive of adherence than motivators [41]. The central barrier reported by participants who have discontinued participation included the cost of the program—exercise classes were provided free of charge only during the original trial period—as reported in several studies [45, 46]. This underscores the need for health policy makers and community leaders to consider minimizing budget constraints (e.g., subsidizing exercise classes memberships). Given the health benefits of the exercise program and the potential for widespread dissemination, future studies should examine whether the program is cost-effective.

Strengths of the study include (i) its design, allowing to appreciate both long-term effects of the exercise intervention and the sustainability of changes, (ii) the long-term follow-up, with objective blinded assessments carried-out over a total period of 4-year, and iii) the assessment of a "real-world" exercise program already available in the community. A number of limitations need to be considered. First, some caution must be retained given the limited sample size. However, participants whose data are reported herein did not differ significantly in any measures at original trial completion from those who did not take part to the 4-year follow-up assessment visit and the long-term extension study sample was representative of the targeted original trial population. Also, it might be argued that participants who maintained a 4-year exercise program were more likely to be healthier. While significant differences in the number of frailty components and Tinetti score were evident between groups at original trial entry, differences did not remain at original trial completion. Furthermore, because linear mixed-effects models were used, with random effects fitted, the heterogeneity of baseline scores was carefully taken into account. Second, part of falls data was collected retrospectively without validation against medical records. Retrospective falls history obtained through participants' recollection of falls in the past year and 3 years may not have been as accurate as collecting falls data through prospective methods (e.g., calendar method used during the original trial) and may have involved under-reporting of falls. Third, because long-term outcomes were secondary endpoints, no formal a priori power calculation was made for the 4-year follow-up analysis. This study may have been underpowered to detect small but significant differences and as a result some of our findings may be prone to type 2 error. Fourth, due to practical constraints, in-class attendance could not be rigorously recorded by the instructors over the entire 4-year extended follow-up period. This limited our ability to assess dose–response effects. Finally, while the original trial targeted community-dwellers at increased risk for falling, we recruited predominantly older women with relatively good physical function. Further investigations among more frail individuals or with more pronounced mobility limitations, from both genders, are required to confirm the generalization potential of the exercise program.

In conclusion, this 3-year extension of a 1-year randomized controlled trial suggests that long-term maintenance of a music-based multitask exercise program is a promising strategy to prevent age-related physical decline and falls. Community-dwelling older people should be advised on the major interest of sustained long-term participation to exercise for falls prevention.

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Conflict of Interest Mélany Hars, François R. Herrmann, Roger A. Fielding, Kieran F. Reid, René Rizzoli, and Andrea Trombetti declare that they have nothing to disclose.

Human and Animal Rights and Informed Consent This study was approved by the Geneva University Hospitals Ethics Committee (protocol PSY 10-175) and an informed consent was obtained from all participants for the extended follow-up.

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