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# Executive dysfunction and effectiveness of physical program in older adults: which association?

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## Abstract

**Background.** Little is known about the association between executive function and the magnitude of improvement from personalised exercise interventions on gait performance among older-old adults.

**Aims**. We examined whether the effectiveness of personalised intervention on gait performance is dependent on the patient's baseline dysexecutive syndrome, as assessed by the Frontal Assessment Battery.

**Method.** A total of 175 older community-dwellers (83.57 ± 5.2 years; 70.2% female) were recruited from the day centre for after-care and rehabilitation in the Nantes Ambulatory Centre of the Clinical Gerontology (France), and were followed during a pre-post intervention, single-arm retrospective design. The intervention consisted of an individual personalised rehabilitation program over a period of 7 weeks, with twice-weekly sessions (45 min each). Gait speed in four conditions (preferred, fast, and under two dual-task conditions), Timed Up & Go test, and handgrip strength test were assessed.

**Results.** Using a pre-post analysis of covariance, a significant increase in dual-task gait speed while counting (+0.10 m/s; +15%) and in dual-fluency gait speed (+0.06 m/s; +10%), and in Timed Up & Go performance (-2.9 sec; +17.8%) was observed after the rehabilitation program, regardless the baseline executive status.

**Discussion.** An individual personalized intervention is effective to improve mobility performance and the dual-task gait speed in older-old adults. The magnitude of those effects is independent of the patient's baseline characteristics including the executive function status.

**Conclusion**. Even the most deficient baseline characteristics of patients should not be viewed as clinical barrier for implementing a beneficial individual intervention in high-risk older adults.

**Keywords**: Dual-task gait performance; Executive status; Rehabilitation

## Introduction

As far as we know, the scientific literature is abundant on interventions intended to improve functional mobility, including gait, in older adults (with cognitive impairment), with solid evidence of their effectiveness [1-4]. We recently showed the positive impact of an individual personalized intervention to induce a clinically meaningful change in gait speed in older-old adults (mean age: 83.3 ± 5.1 years; *N* = 483), regardless of the baseline cognitive status (as assessed by the Mini-Mental State Examination) and fall history [5]. Little is known about the association between executive function and the magnitude of improvement from personalised exercise interventions on gait performance among older-old adults. Yet, gait regulation requires executive function that plays a key role in mediating safe ambulation [6-8] and fall risk [9-10]. Hence deficits in executive functioning generate impairment in function and activities of daily living [11-12]. In the present report, we examined whether there was a relationship between the patient's dysexecutive syndrome (assessed by the Frontal Assessment Battery [13]) and the effectiveness of personalised intervention on gait performance. One could argue that those associations between gait speed and executive function, stemming from shared brain networks [14-15], may adversely influence ability to profit from the rehabilitation programmes. We hypothesized that that the patients with an executive dysfunction at baseline were prone to benefit from personalized physical interventions as much as the healthiest patients.

## Methods

### Study design and participants

From February 2012 to June 2019, a total of 175 older community-dwellers (83.57 ± 5.2 years; 70.2% female) were recruited from the day centre for after-care and rehabilitation in the Nantes Ambulatory Centre of the Clinical Gerontology (Nantes

University Hospital, France), and were followed during a pre-post intervention, single-arm retrospective study. As a component of the current clinical care, the detailed intervention [5] consisted of an individual personalised rehabilitation program over a period of 7 weeks, with twice-weekly sessions (45 min each). Hence, according to the French Public Health Code (articles L.1121-1 paragraph 1 and R1121-2), no approval of the ethics committee was needed. Informed consent was obtained from all participants. The main sampling and data collection procedures have been described elsewhere [5].

In summary, all patients were referred for gait / balance disorders by their primary care physician to the ambulatory geriatric unit, for a comprehensive health examination, including a medical and clinical check-up, a comprehensive geriatric assessment [16]. Eligibility criteria were: to be cognitively intact (Mini-Mental State Examination [MMSE] score ≥ 24) [17] or mildly impaired (MMSE score 16-23); Considering gait performance, patients who had a preferred gait speed < 0.2 m/s (extremely fragile) or > 1.3 m/s (extremely fit) were excluded when assessing the gait speed with a 884-cm-long GAITRite Electronic Walkway (active electronic surface area 793 × 61 cm, scanning frequency 120 Hz, CIR Systems,Inc). Patients who used assistive devices were included.

Patients had baseline assessments of demographic characteristics, cognition (MMSE and the Frontal Assessment Battery [FAB] test for screening the frontal functions and executive dysfunction [13], [global score /18]), medications (number of drugs taken per day, and use of psychoactive drugs), self-report of disability related to activities of daily living (ADLs; /6]) [18] and instrumental ADLs (/8) [19]. They were also interviewed using a standardized questionnaire, gathering information on the history of falls over the past year. The baseline characteristics of the patients were summarized in Table 1 using means and standard deviations, of frequencies and percentages, as appropriate.

**Physical performance measures**

*Gait measures*. The preferred ("walk at normal pace from a starting point") and fast (walk as fast as safely possible") gait speed were determined when the patients walked over about 10-m course using the GAITRite walkway. Gait speed was also assessed under two dual task gait conditions: to walk at the preferred pace while (1) counting backward from 50 by ones, and (2) naming animals (category fluency). Likewise, patients were asked to perform the Timed Up & Go test (TUG) [20].

*Handgrip strength*. The maximal isometric voluntary contraction strength of the hand was measured for the dominant hand (elbow held at 90°, upper arm held tight against the trunk) as the maximum value achieved across three trials using a Jamar hydraulic hand dynamometer.

All those assessments specified above were conducted twice, first during the outpatient clinic visit for eligibility and consent for the proposed rehabilitation program, and second during the final clinic visit following the rehabilitation program end.

**The personalised rehabilitation program at a glance**

In face to face only with the physiotherapist, each session lasted 45 minutes. First, 5 minutes for warmups Then 10-minute muscular exercises were composed of one or three series of 10 repetitions of sit-to-stand transfer, with specific instructions on the use of visual information. The following exercises intended to improve postural balance were performed for about 15 minutes, by modifying or reducing the sensorial (visual, vestibular, proprioceptive) inputs, to target specific deficits and increase the reweighting processes. Likewise, other exercises with more attentional demands consisted of reducing the contact surfaces, by standing on specific apparatus that elicited sensory perturbations (foams with different density, unstable platform). To further improve mobility and gait performance, we aimed to increase the gait speed by controlling the step length, cadence, changes of direction (turns, half-turns) and reducing the gait-related fatigue (endurance gain) for about 15 minutes. In addition, to increase the gait-related attentional cost, patient-specific walking routes were constructed of obstacles (varying in width/height) with unstable surfaces (portions with foam). The repetition of courses, the progression in difficulty, the addition of attentional dual tasks (walking while talking, extending arms, counting, playing with a ball…) were parameters for meeting the fixed therapeutic targets.

**Data analysis and statistics**

*Executive performance*. The executive status of patients was based on the FAB score (mean baseline score: 12.3 ± 4.05; quartiles were 10, 13, 15 respectively), considering patients with a baseline FAB score lower than the normality-cutoff of 13 as patients with abnormal executive performance [21] (N = 96; 54.9%; mean score: 9.4 ± 3.05). For the group with FAB score > 13 (N = 79), mean score was 15.85 ± 1.47.

*Statistics*. Comparisons of baseline clinical characteristics between patients with abnormal executive performance and those with normal executive performance were made using $\chi^2$ or t-tests as deemed appropriate (Table 1). Characteristics that significantly differed between groups were used as covariates (MMSE and iADL scores) in the subsequent analyses for all the physical performance measures, considering time [pre- and post-rehabilitation] as a within-subject factor.

## Results

Baseline characteristics show a main effect of executive status on MMSE and iADL score ($p < 0.001$), with the highest performances found for the group with FAB score >13. Regarding the baseline gait speed in all conditions, only a difference between groups was observed for the initial dual-fluency gait speed, with the highest gait speed for the group with FAB score > 13 (0.64 ± 0.2 *vs*. 0.59 ± 0.17 m/s) (Table 1).

Second using a pre-post analysis of covariance, controlling for MMSE and iADL scores, any main effect of Group or interaction involving this factor was observed, whatever the physical measures. Significant effects of Time were shown for the gait speed while counting backward ($p < 0.03$; +0.10 cm/s; +15%), and the dual-fluency gait speed ($p < 0.03$; +0.06 cm/s; +10%). Overall, a significant increase in dual-gait speed was observed after the rehabilitation program, regardless the baseline executive status (Table 2).

For the TUG performance and the maximal handgrip force, no effect of main factor nor interaction was revealed by ANCOVAs. It is noteworthy that a main effect of Time was found for the TUG performance as the baseline dual-fluency gait speed was included in the ANCOVA, evidencing a significant improvement of TUG performance after the rehabilitation program, regardless of the executive status ($p < 0.05$; -2.9 sec; +17,8%) (Table 2).

## Discussion

Our objective was to determine whether the presence of executive dysfunction in older-old people might affect the effectiveness of an individual personalized intervention aiming at improving mobility and gait speed. In line with previous works [5], we confirm the effectiveness of a rehabilitation program in older patients, irrespective of their baseline characteristics (see Table 1) and in particular the executive status. Even for the frailest patients with abnormal executive performance (FAB score ≤ 13), substantial meaningful changes in dual-task gait speed were observed. The magnitude of these changes was identical for both groups (i.e. normal vs. abnormal executive function).

While robust findings targeting the association between cognitive decline and adverse changes in postural performance [22], and between baseline executive functions' capacities and gait control[7] or the risk of future falls [9] in older adults are well established in the literature, there is less evidence whether the exercise training effect on motor deficits is affected by moderators including cognitive status,[23] falls history,[5] and executive dysfunction. In this respect, the current results are of special interest for fundamental or clinical purposes. First, the lack of dose-response relationships between the current exercise program and patient's baseline executive characteristics reaffirms the relevance of intervention's personalised contents in everyday clinical practice for patients older than 70 years. Even the frailest patients benefit from the uniqueness of rehabilitation program (see details here[5]). Second, main results revealed the positive effects of the personalised intervention on the dual-task (counting and categorial fluency) gait speed, highlighting a likely improvement of gait control. A meaningful exercise-induced shift from an attentional gait control to more automatic gait control can be stressed, even if no executive measure has been recorded after the rehabilitation program. We cannot exclude the assumption that executive function at baseline did not preclude improvement in gait parameters because it also improved with the rehabilitation. However, all other things being equal, recent meta-analyses[24-25] examined the effects of exercise training interventions on executive function in older adults. Overall, the effects size related to small beneficial effect of exercise training on executive function was similar concerning the EF sub-domain moderators (inhibition, updating, and shifting), but different regarding the cognitive status, with larger magnitude of effects for participants with cognitively normal functionning.[24] Considering this point a limitation of current findings, looking at the association between exercise-induced gait improvement and executive subdomains is warranted, particularly as the rehabilitation program primarily aimed at improving functional balance and gait disorders in older-old people.

Taken together, the results suggest that the magnitude of personalised rehabilitation effect might be affected by specific gait-related moderators including the walking speed reserve[26] and baseline spatio-temporal parameters of (dual-task) gait.[27] Precisely, assessed as the difference between the fast gait speed and preferred gait speed, the walking speed reserve was found to be associated with cognitive stage of older people, with a smaller functional reserve for the people with poorer cognitive stage. In this sense, we could argue the positive rehabilitation effect on mobility performance in older-old people depends more on the patient's functional ability to increase speed and walk quickly. Smaller walking speed reserve would be robust indicator of probable difficulties for the patient to really benefit from the rehabilitation program, despite its uniqueness.[5] In the same vein, initial parameters of gait variability, such as the stride time variability (identified as a fall predictor in older inpatients[27]), calculated in all single and dual-task gait conditions with the GAITRite walkway, could be associated with the positive response to the individual, personalized rehabilitation program. Hence these assumptions required specific examination in large sample before considering the resulting moderators of beneficial effect of rehabilitation program as a robust clinical tool for targeted therapeutic decision.

## Declarations

### Compliance with Ethical Standards

### Funding

N/A

### Conflict of interest

All authors declare no conflict of interest.

### Ethical approval

As a component of the current clinical care, the detailed intervention consisted of an individual personalised rehabilitation program over a period of 7 weeks, with twice-weekly sessions (45 min each). Hence, according to the French Public Health Code (articles L.1121-1 paragraph 1 and R1121-2), no approval of the ethics committee was needed.

### Informed consent

Informed consent was obtained from all participants included in the study.

### Availability of data and material

There are no linked research data sets for this paper. Data will be made available on request.

### Author Contributions

Conception and design of the experiments: GR, CC.

Collection, assembly, analysis and interpretation of data: GR, CC, TD

Drafting the article (CC, GR, TD) and revising it critically for important intellectual content: GC, MMO, GB.

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**Table 1.** Baseline characteristics of participants, as a function of Frontal Assessment Battery's score (N = 175).

| | Total | FAB score ≤ 13 | FAB score > 13 |
|---|---|---|---|
| | N = 175 | N = 96 | N = 79 |
| Age (years), mean ± SD [ns] | 83.6 ± 5.2 | 83.5 ± 4.9 | 83.5 ± 5.7 |
| Female gender, n (%) [ns] | 123 (70.2) | 69 (71.8) | 54 (68.3) |
| Falls in previous year, n (%) | | | |
| *Non-fallers* [ns] | 34 (19.4) | 15 (15.6) | 19 (24) |
| *Fallers (1)* [ns] | 43 (24.6) | 25 (26.1) | 18 (22.8) |
| *Fallers (2 or more)* [ns] | 98 (56) | 56 (58.3) | 42 (53.2) |
| Mini-Mental State Examination (/30), mean ± SD [a] | 25.7 ± 3.5 | 24.1 ± 3.5 | 27.5 ± 2.4 |
| Body mass index ($kg/m^2$), mean ± SD [ns] | 25.4 ± 4.7 | 25.4 ± 4.6 | 25.4 ± 4.8 |
| Medications (total number/day), mean ± SD [ns] | 5.7 ± 3.1 | 5.9 ± 3.0 | 5.6 ± 3.3 |
| Use of psychoactive drugs (yes), n (%) [ns] | 90 (52.3) | 53 (56.4) | 37 (47.7) |
| Activities of Daily Living (/6), mean ± SD [ns] | 5.3 ± 0.9 | 5.3 ± 0.9 | 5.4 ± 1.0 |
| Instrumental ADL (/8), mean ± SD [a] | 5.4 ± 2.2 | 4.8 ± 2.3 | 6.1 ± 1.9 |
| Gait speed (m/s), mean ± SD | | | |
| *Preferred gait speed* | | | |
| **Pre** [ns] | 0.67 ± 0.2 | 0.65 ± 0.19 | 0.69 ± 0.21 |
| **Post** [ns] | 0.8 ± 0.2 | 0.77 ± 0.18 | 0.83 ± 0.22 |
| *Fast gait speed* [ns] | | | |
| **Pre** [ns] | 0.93 ± 0.3 | 0.88 ± 0.27 | 0.98 ± 0.34 |
| **Post** [ns] | 1.06 ± 0.3 | 1.00 ± 0.26 | 1.12 ± 0.33 |
| *Dual task – counting* [ns] | | | |
| **Pre** [ns] | 0.66 ± 0.2 | 0.64 ± 0.17 | 0.68 ± 0.23 |
| **Post** [ns] | 0.76 ± 0.22 | 0.73 ± 0.2 | 0.79 ± 0.24 |
| *Dual task – categorial fluency* [ns] | | | |
| **Pre** [b] | 0.61 ± 0.2 | 0.59 ± 0.17 | 0.64 ± 0.22 |
| **Post** [ns] | 0.67 ± 0.21 | 0.64 ± 0.18 | 0.70 ± 0.23 |

| | Total | FAB score ≤ 13 | FAB score > 13 |
|---|---|---|---|
| | N = 175 | N = 96 | N = 79 |
| Timed Up and Go (sec), mean ± SD ns | | | |
| **Pre** ns | 16.3 ± 6.6 | 16.7 ± 6.3 | 16.0 ± 6.9 |
| **Post** ns | 13.4 ± 5.4 | 13.9 ± 5.6 | 12.8 ± 5.2 |
| Maximal Handgrip Strength (kg), mean ± SD ns | | | |
| **Pre** ns | 19.9 ± 7.1 | 19.5 ± 7.1 | 20.4 ± 7.2 |
| **Post** ns | 21.1 ± 7.2 | 20.8 ± 6.8 | 21.5 ± 7.8 |

*Note*. [a] Main effect of executive status (from t-tests or $\chi^2$ test as appropriate). [b] Main effect of executive status (from ANCOVA with MMSE and iADL as covariates). ns: non-significant.

**Table 2.** Pre- and post-rehabilitation values for the gait speed, the Timed Up and Go test, and the maximal handgrip strength, as a function of Frontal Assessment Battery's score (N = 175).

| | **Total** | **FAB score ≤ 13** | **FAB score > 13** |
|---|---|---|---|
| | N = 175 | N = 96 | N = 79 |
| Gait speed (m/s), mean ± SD | | | |
| *Preferred gait speed* | | | |
| **Pre** | 0.67 ± 0.2 | 0.65 ± 0.19 | 0.69 ± 0.21 |
| **Post** | 0.8 ± 0.2 | 0.77 ± 0.18 | 0.83 ± 0.22 |
| *Fast gait speed* | | | |
| **Pre** | 0.93 ± 0.3 | 0.88 ± 0.27 | 0.98 ± 0.34 |
| **Post** | 1.06 ± 0.3 | 1.00 ± 0.26 | 1.12 ± 0.33 |
| *Dual task – counting* | | | |
| **Pre** | 0.66 ± 0.2 | 0.64 ± 0.17 | 0.68 ± 0.23 |
| **Post** | 0.76 ± 0.22 | 0.73 ± 0.2 | 0.79 ± 0.24 |
| *Dual task – categorial fluency* | | | |
| **Pre** | 0.61 ± 0.2 | 0.59 ± 0.17 | 0.64 ± 0.22 |
| **Post** | 0.67 ± 0.21 | 0.64 ± 0.18 | 0.70 ± 0.23 |
| Timed Up and Go (sec), mean ± SD | | | |
| **Pre** | 16.3 ± 6.6 | 16.7 ± 6.3 | 16.0 ± 6.9 |
| **Post** | 13.4 ± 5.4 | 13.9 ± 5.6 | 12.8 ± 5.2 |
| Maximal Handgrip Strength (kg), mean ± SD | | | |
| **Pre** | 19.9 ± 7.1 | 19.5 ± 7.1 | 20.4 ± 7.2 |
| **Post** | 21.1 ± 7.2 | 20.8 ± 6.8 | 21.5 ± 7.8 |