Published in final edited form as:

J Am Geriatr Soc. 2015 June ; 63(6): 1112–1120. doi:10.1111/jgs.13444.

Longitudinal Analysis of Physical Performance, Functional Status, Physical Activity, and Mood in Relation to Executive Function Among Older Fallers

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Abstract

BACKGROUND—Older fallers are at risk of experiencing functional decline within 1 to 3 years; however, not all older fallers show near-term decline. Executive function (EF), which refers to the cognitive processes important for goal-oriented and controlled behavior, may be one factor that underlies resiliency against decline.

OBJECTIVES—To examine whether good EF at baseline and maintenance of EF over time predict maintenance of physical performance, functional status, physical activity, and mood over a one-year period. Conversely, to examine whether baseline functioning in these non-cognitive domains predicts maintenance of EF over the same period of time.

DESIGN—12-month prospective cohort study.

SETTING—Vancouver Falls Prevention Clinic.

PARTICIPANTS—Community-dwelling older adults ($N = 199$; mean age = 81.6; 63% female) referred to the clinic after suffering a fall.

MEASUREMENTS—At each time point, structural equation modeling created a latent EF variable from performance on five EF tasks. Physical performance (physiological falls risk and gait speed), instrumental activities of daily living (IADLs), physical activity, and depressive symptoms were also assessed at each time point.

RESULTS—Higher baseline EF predicted decreases in depressive symptoms and maintenance of IADLs from baseline to follow-up ($p < .01$). Improvements in EF correlated with increases in gait

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speed and physical activity, and with the maintenance of IADLs over the follow-up ($p < .05$). All effects were independent of demographic characteristics and global cognitive function. Baseline performance in the non-cognitive domains did not predict changes in EF.

CONCLUSION—Among older fallers, EF is a marker for resiliency in several non-cognitive domains, and therefore, should be assessed. Furthermore, interventions to improve EF should be tested among older fallers with EF deficits.

Keywords

older fallers; executive function; physical functioning; physical activity; mood

INTRODUCTION

Aging is accompanied by decline in multiple domains, including physical performance,¹ functional status,^{2, 3} physical activity (PA),⁴ and mood.⁵ Older adults who have recently fallen are at particular risk for decline in many of these domains in the near-term, i.e., within 1 to 3 years,⁶ and are more likely than non-fallers to be admitted to long-term care facilities within 3 years.⁷ However, not all fallers suffer near-term decline or require institutionalization. This suggests that there are important individual differences that lead some fallers to maintain or improve functioning (i.e., to be resilient) and others to decline. Identifying the factors that underlie resiliency is essential for assessing a faller's risk for future deterioration and for designing interventions to promote healthy aging by targeting those factors.

One possible factor is executive function (EF), which describes those cognitive processes necessary for controlled, goal-oriented behavior.⁸ Cross-sectional and prospective studies in various aged populations have found that deficits in EF predict impairment in physical performance,^{9–11} reduced performance of instrumental activities of daily living (IADLs),^{12, 13} decreased PA,¹⁴ and depression.¹⁵ More interesting, longitudinal studies have demonstrated that changes in EF predict concurrent changes in IADLs^{2, 3} and that changes in EF mediate the association between changes in memory and changes in IADLs.¹⁶ Other research suggests that EF deteriorates prior to memory¹⁷ and that cognition (including EF) declines prior to, or at the same time as, physical performance.¹⁸ These longitudinal studies suggest that maintaining EF may thwart decline in other areas of functioning, and moreover, that targeting EF with intervention strategies could have outward ripple effects such that other domains of functioning are improved indirectly.

In examining previous research, it is unclear whether associations between specific EF tasks and functioning in other domains are driven by the underlying EF construct, or instead, by sources of variation that may not be of interest (e.g., measurement error, experimenter effects, task-specific variation related to instructions or response modality). Structural equation modeling (SEM) addresses this issue by using multiple EF measures to create a latent EF variable.^{13, 19} This latent EF variable comprises the common processes shared across the EF measures, and can be used to determine whether individuals with higher latent EF (or better maintenance of latent EF over time) show resiliency in other domains of functioning.

With these issues in mind, we conducted a one-year longitudinal study of older adults who had been referred to the Vancouver Falls Prevention Clinic after experiencing a low-trauma fall. In our analyses, we used SEM to create a latent EF variable from five standard EF measures at baseline and one-year follow-up. We then examined the longitudinal associations with four non-cognitive domains: *physical performance* (physiological falls risk, gait speed), *functional status* (IADLs), *PA*, and *mood* (depressive symptoms). In these analyses, we controlled for demographic variables (age, sex, education, residential living status, and functional comorbidities) and longitudinal changes in global cognitive functioning. These analyses addressed three important questions: 1) Does baseline EF predict changes in these non-cognitive domains over one year? 2) Does baseline performance in these domains predict changes in EF over one year? 3) Is change in EF correlated with concurrent change in these domains over one year?

METHODS

Study Design and Participants

We conducted a 12-month prospective cohort study at the Vancouver Falls Prevention Clinic (www.fallclinic.com) from Spring 2010 through Fall 2013. Participants received a comprehensive assessment at the clinic at baseline and 12-months. The sample consisted of 199 older adults (63% female) referred by their general practitioner or emergency department physician to the Vancouver Falls Prevention Clinic. Community-dwelling adults who lived in the lower mainland region of British Columbia were eligible for study entry if they: 1) were 70 years of age or older; 2) were referred by a medical professional to the Falls Prevention Clinic as a result of seeking medical attention for a non-syncopal fall in the previous 12 months; 3) understood, spoke, and read English proficiently; 4) had a Physiological Profile Assessment (PPA) score of at least 1.0 standard deviation above age-normative value, Timed Up and Go Test (TUG) performance greater than 15 seconds, or one additional non-syncopal fall in the previous 12 months; 5) were expected to live greater than 12 months (based on the geriatrician's expert opinion); 6) were able to walk 3 meters with or without an assistive device; and 7) were able to provide written informed consent.

We excluded those with a formal diagnosis of neurodegenerative disease (e.g., Parkinson's disease) or dementia, patients who recently had a stroke, those with clinically significant peripheral neuropathy or severe musculoskeletal or joint disease, and anyone with a history indicative of carotid sinus sensitivity (i.e., syncopal falls). Individuals with neurodegenerative disease or dementia are referred to alternate clinics. Ethical approval was obtained from the Vancouver Coastal Health Research Institute and the University of British Columbia's Clinical Research Ethics Board (H09-02370). The study was registered at clinicaltrials.gov (NCT01022866). All participants provided written informed consent.

Measures

Covariates—Age, sex, education, residential status, and functional comorbidities (using the functional comorbidity index²⁰) were assessed at baseline. Global cognition was assessed by the Mini-Mental State Examination (MMSE) at baseline and follow-up.²¹

Executive Function—Five commonly used EF measures were included. Although these measures test different aspects of EF and require different response modalities (i.e., verbal versus written responses), they all require goal-oriented, controlled cognitive processes.⁸ The Stroop Test (Stroop I-N) is an assessment of selective attention and response inhibition.²² First, participants first read out words printed in black ink (e.g., BLUE). Second, they named the display colour of coloured-X's. Finally, they were shown a page with color-words printed in incongruent colored inks (e.g., the word "BLUE" printed in red ink). Participants were asked to name the ink color in which the words were printed (while ignoring the word itself). We recorded the time participants took to read the items in each condition and calculated the time difference between the third condition (Incongruent) and the second condition (Neutral). The Trail Making Test (TMT B-A) is an assessment of cognitive flexibility, which asks participants draw lines connecting encircled numbers sequentially (Part A) or alternating between numbers and letters (Part B).²³ The difference in time to complete Part B and Part A was calculated, with smaller difference scores indicating better cognitive flexibility. Backward digit span (Digits) is a test of working memory, which required participants to correctly reproduced verbally a progressively longer random number sequence in reverse order.²⁴ Verbal fluency was assessed with the F-A-S test,²³ which relies on language and executive abilities, including working memory.²⁵ Specifically, participants are requested to produce as many words as possible that begin with the letters F, A, and S within one minute. The Digit Symbol Substitution Test (DSST) is a test of psychomotor functioning, selective attention, and working memory,²⁶ in which participants are provided a code table with 9 distinct symbols associated with the numbers 1–9 and one minute to fill in as many symbols in a matrix of numbers below.²³

Non-Cognitive Domains—Falls risk was assessed using the Physiological Profile Assessment (PPA). The PPA computes a standardized risk score from five physiological domains: postural sway, dominant hand reaction time, quadriceps strength, proprioception, and contrast sensitivity.²⁷ Higher z scores represent greater falls risk. Walking time from a four-meter walk was used to calculate gait speed (meters per second). The IADL Scale assessed individuals' ability to telephone, shop, prepare food, housekeep, do laundry, handle finances, be responsible for taking medication, and determining mode of transportation.²⁸ PA was assessed by the self-report International Physical Activity Questionnaire (IPAQ) – short form.²⁹ The IPAQ converts time spent engaging in walking, and in moderate and vigorous activity into metabolic equivalents—minutes per week (METS-min per week). Depressive symptoms were assessed by the 15-item Geriatric Depression Scale (GDS); a score 5 indicates depression.³⁰

Statistical Analysis

Data were analyzed using SPSS 22 (IBM Corporation, 2013) and Mplus 7 (Múthen & Múthen, 2012). Distributions that departed from normality (skew > |1|) underwent log₁₀ transformation and included: PA, GDS, Digits, TMT B-A, Stroop I-N, MMSE, and IADLs. Following transformation, preliminary analyses included paired-samples *t* tests and bivariate correlations. Next, we employed SEM to determine whether the EF construct remained invariant from baseline to follow-up.³¹ This consisted of creating four progressively constrained models and determining whether further constraining the model resulted in

worse fit of the data using the χ^2 difference test. The top panel of the Figure shows the longitudinal SEM model that formed the basis for these analyses. The four progressively constrained models were as follows:

- *Model 1 (Configural invariance model)*: As shown in the Figure, the first model tested whether a unitary latent EF variable at each time point adequately fit the data; that is, this model determined whether performance on the five EF measures could be attributed to a single EF construct, which reflects the controlled, goal-oriented processes required across all five measures.
- *Model 2 (Metric invariance model)*: We constrained the factor loadings for the five EF measure to be equal across time; this model tests the assumption that the EF measures demonstrate equal relationships with the underlying EF construct over time.³²
- *Model 3 (Scalar invariance model)*: We further constrained the intercepts for each EF measure to be equal across time; this model tests the assumption that differences over time in EF are due to true change in the underlying EF construct rather than to measurement error in the EF measures.³²
- *Model 4 (Residual invariance model)*: Finally, we further constrained residual variances in the EF measures to be equal across time, which fixes the variance explained by the latent EF construct equal across time. This final and most stringent model tests the assumption that the EF construct is measured identically across time.³¹

After determining whether the EF construct was invariant over time, we examined the longitudinal associations between EF and the non-cognitive domains. Unlike the paired samples *t*-tests, which examine group level change over the time, these analyses treat individual differences in performance as interesting variation, rather than as noise in the data. The bottom panel of the Figure shows a generic example of the cross-lagged model used to explore these individual differences. To simplify the Figure, the covariates and residual covariances are not shown. The term ‘correlate’ refers generically to the non-cognitive domains. As indicated in the Figure, there are four associations of interest evaluated by each model:

- *Path A*: The baseline correlation between latent EF and the correlate, controlling for the baseline covariates.
- *Path B*: The predictive association between baseline EF and one-year correlate score, controlling for the baseline correlate score and other covariates. Because the baseline correlate score is controlled, this path determines whether baseline EF predicts individual differences in change in the non-cognitive domains over the one-year period, independent of the covariates.
- *Path C*: The predictive association between baseline correlate score and one-year EF, controlling for the baseline EF and other covariates. This path determines whether baseline performance in the non-cognitive domains predicts individual differences in change in EF over the one-year period, independent of the covariates.

- *Path D:* The correlation between the residual variance in the one-year scores that cannot be accounted for by the baseline scores or the covariates. This path determines whether individual differences in change in EF are associated with individual differences in change in the non-cognitive domains, independent of the covariates.

All models used maximum likelihood estimation with robust standard errors, thus allowing all 199 participants to be included in all analyses. Six multivariate outliers that could unduly influence the statistical results were identified across models based on Mahalanobis' Distance $p < .001$ —these six cases were excluded from the models presented below. Good model fit was indicated by Comparative Fit Index (CFI) $> .95$ and Root Mean Square Error of Approximation (RMSEA) $< .05$.³³ Standardized estimates (β), which can be interpreted as partial correlations, and standard errors are presented for these models.

RESULTS

The baseline and one-year descriptive statistics are shown in Table 1. Paired-samples *t*-tests compared the change in scores from baseline to one-year and showed that only IADL scores decreased significantly over time at the group level ($p < .001$), with no significant group-level change in any other variable ($p > .05$). Table 2 provides the correlations among the study variables and covariates (excluding the EF variables). Notably, the non-cognitive domains were modestly associated with one another, and the correlations between baseline and follow-score for each variable suggest modest stability over time ($r = .42-.78$). Together, these initial analyses suggest that there is little group-level decline in these variables, but instead, there is change at the individual level, such that some individuals show decline whereas others show performance improvement over the year.

Table 3 summarizes the models testing longitudinal invariance of EF from baseline to follow-up. The configural invariance model provided good fit to the data (see first row of data). In this model, all 5 EF tasks loaded onto a single latent EF variable at each time point, and the residual variances were allowed to correlate across time. This model indicates that a single EF construct could adequately explain performance across these 5 tasks at each time point. See the top panel of the Figure for a visual depiction of this model. Progressively constraining the structure of the model across time did not worsen model fit based on the χ^2 difference test (see the remaining rows of Table 3), suggesting that the EF construct is invariant over one year. This means that the EF construct measured at baseline is also being measured at follow-up and that change over time in the EF construct reflects true change rather than measurement error.³¹ Standardized factor loadings, variances, and covariances for the residual variance model (the most constrained model) can be found in the Appendix.

Table 4 summarizes the five models examining the longitudinal relations between EF and the non-cognitive domains (each row of data represents a separate model). Each model had good fit based on the χ^2 , CFI and RMSEA values. In all models, there was a significant baseline correlation (Path A), such that better EF performance was associated with lower falls risk ($p = .02$), higher gait speed ($p < .001$), greater amounts of PA ($p = .008$), lower depression ($p = .02$), and higher IADL scores ($p = .002$). In looking at the prospective effects,

higher baseline EF predicted reductions in depression ($p=.005$) and maintenance of IADL performance ($p=.006$) over the year (Path B). In contrast, none of the baseline non-cognitive domains predicted change in EF scores (Path C). Finally, there was a significant residual correlation at follow-up (Path D) between EF and gait speed ($p=.005$), PA ($p=.03$), and IADL scores ($p=.002$), revealing that improvements in EF correlated with improvements in gait speed, increases in PA, and maintenance of IADL performance over the follow-up period.

DISCUSSION

We found that baseline EF and/or changes in EF predicted individual differences in changes in physical performance, functional status, PA, and mood over one year in older fallers; however, baseline performance in these non-cognitive domains did not predict changes in EF over time. These findings are consistent with those of Atkinson and colleagues,¹⁸ who suggested that cognitive decline either precedes or co-occurs with decline in physical performance. Here we make an important contribution by looking beyond physical performance measures, and we show that this association holds for several aspects of functioning, with the exception of physiological falls risk, among older fallers. Also, we investigated EF specifically, rather than cognitive functioning generally, which allows us to draw more specific conclusions regarding the role of cognitive function in age-related decline. At a mechanistic level, these findings are consistent with previous research showing that EF shares neural correlates with physical functioning^{34, 35} and mood³⁶ among the elderly. At a practical level, our findings suggest that EF performance might be an important marker for decline in several important areas of functioning among older fallers.

It is particularly interesting that change in EF correlated with change in PA over the follow-up period. Previous studies^{9, 18} have speculated that the link between cognition and physical functioning might be mediated in part by changes in physical activity, and recent research has shown that EF, specifically, predicts adherence to PA in healthy older adults.^{37, 38} Here, we show evidence for this link among older fallers. EF is critical to overriding impulses to engage in activities with immediate rewards (e.g., sitting in front of the television) in favor of engaging in activities that might induce moderate discomfort but have long-term benefits (e.g., going on a vigorous walk).³⁹ Thus, the link we observed between EF and PA might be due to this important role of EF in delaying gratification in order to maintain positive health behavior. It is also interesting that IADL performance was the strongest correlate of EF, as both baseline and change in EF were significantly related to change in IADLs. Performance of IADLs requires higher-order cognitive processes in order to monitor and adapt one's behavior to complete the task at hand,¹³ which might explain this close link to EF performance. Of clinical relevance, IADLs are critical to functional independence; therefore, EF performance could be a determinant of whether older fallers are able to maintain their current level of independence over the near term.

Our study addresses an important question posed by Rosano and colleagues²⁶ regarding whether the association between EF and physical functioning is specific to certain EF tasks (e.g., TMT) or are generalized effects of goal-oriented, controlled processes. Because previous studies have linked performance on a variety of EF tasks to physical

performance^{9, 11, 26, 40} and to functional status,^{2, 3, 12, 26} one could surmise that this association reflects upon EF generally; however, only a latent variable analysis can directly test this proposition, as was performed here. The relevance of our findings to clinicians is that EF should be assessed in older fallers in order to get a general sense of the individual's underlying EF performance, and therefore, of risk of decline in other domains, including physical performance, functional status, and mood.

In light of these findings, it is worthwhile to explore methods to promote EF among older fallers, especially among those with EF deficits. A promising approach is to engage older adults in physical activity.^{41, 42} Because older fallers may have difficulty maintaining an active lifestyle, especially if they are already showing EF decline, structured exercise programs that include social support and incentives may be necessary to induce sufficient motivation to exercise. Structured programs can also ensure that the individual is exercising at sufficient duration and intensity to confer benefits to cognition.^{43, 44} More direct methods to impact EF include targeted cognitive training, via interactive computer games⁴⁵ or other activities,⁴⁶ which may translate into better maintenance of functional independence over time.⁴⁶ The results of our latent variable approach have implications for the nature of EF training. Given that we found that the underlying EF construct is related to these domains, rather than specific tasks only, interventions may be effective by targeting the core of EF—i.e., goal-oriented, controlled cognitive processes—through a variety of means and may not need to target only one specific aspect of EF (e.g., task-switching or working memory).

It is noteworthy that only IADL performance showed group-level decline over the year. The other domains showed no significant group-level change and showed only modest stability over time. These findings reveal that some individuals showed improvements whereas others showed decline. Over longer follow-up periods, we would expect group level decline in the other domains.^{4, 5, 11, 18} Also, a larger sample size would provide greater statistical power to detect group-level changes over time, for example in PA and falls risk, both of which showed trends toward decline over the year.

There are notable limitations to our study. First, although examining EF and other domains longitudinally addresses issues of directionality, these findings cannot confirm causality, e.g., that improving EF would necessarily decrease depression and increase functional independence. Instead, the current results offer specific targets and hypotheses that need to be addressed using randomized controlled trials. Another limitation is the short follow-up period, which precludes us from determining whether these effects will endure over longer periods of time. However, given that the sample encompassed older adults who had recently fallen, a shorter follow-up period is warranted due to the increased risk of near-term decline in these individuals.⁶ Moreover, the lack of group-level decline does not preclude the examination of individual differences in change. A related limitation is that the inclusion of only two time points prohibits us from characterizing the shape of change in these variables over time. Also, our cognitive battery was limited to EF measures and did not include assessments of learning and memory or of fluid intelligence. As these other domains are related to EF and are also associated with changes in functioning among older adults,^{11, 47} future longitudinal studies should include a larger battery of cognitive assessments and use SEM to tease apart the unique effects of these aspects of cognitive functioning on the

domains studied herein. Finally, the study sample was individuals who had been referred to a falls clinic, which limits our ability to generalize our results to other older populations.

These limitations notwithstanding, the major strength of our study is the longitudinal examination of EF and important non-cognitive domains in a vulnerable population of fallers. Moreover, our statistical approach is an important strength. We used a latent variable approach, which minimizes measurement error and multiple comparisons, to examine the underlying EF ability required across five standard EF tasks, and we used maximum likelihood estimation to handle missing data, which produces less biased estimates than statistical methods that remove individuals with missing data.⁴⁸ In our preliminary analyses, we found evidence for strong longitudinal invariance, which strengthens the conclusions drawn from our primary results, because the change in EF over time reflects true change in the EF construct rather than measurement error.

To conclude, because older fallers have a heightened risk for decline, it is critical to better understand key factors contributing to loss of functioning as well as to resiliency. We found that EF is a significant marker among this population. Specifically, high EF performance at baseline and gains in EF over the study period were associated with resiliency on all measures with the exception of physiological falls risk. Together, these findings suggest that EF should be tested in older fallers, and that EF-focused interventions should be designed for those with poor EF in order to promote healthy, resilient aging.

Acknowledgments

Funding: The Canadian Institutes of Health Research CIHR Emerging Team Grant (MOB-93373 to Karim Khan, TLA) provided funding for this study.

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Figure 1.

Longitudinal association between baseline and one-year EF with residual covariances among indicator variables shown (top panel) and simplified diagram of cross-lagged model testing longitudinal associations between EF and correlates (bottom panel). In the bottom panel, neither the covariates (baseline age, sex, education, residential status, functional comorbidities, and baseline and one-year mini-mental state examination scores) nor the residual covariances among the EF measures are shown. DSST = Digit-symbol Substitution Test. EF = executive function. TMT = Trail-Making Test.

Table 1

Descriptive statistics for the sample.

Variables	Baseline			One-Year		
	N	M ($\pm$ SD) or n (%)	Range	N	M ($\pm$ SD) or n (%)	Range
Age (years)	199	81.6 (6.5)	70 to 96	199	82.7 (6.5)	71 to 96
Sex	196			--		
Male		71 (36%)	--		--	--
Female		124 (63%)	--		--	--
Male/Female		1 (<1%)	--		--	--
Education	196			--		
Less than high school		20 (10%)	--		--	--
Some high school		27 (14%)	--		--	--
High school diploma		33 (17%)	--		--	--
Some college		20 (10%)	--		--	--
Post-secondary certificate		19 (10%)	--		--	--
University degree		77 (39%)	--		--	--
Residential status	189			--		
Home with others		87 (46%)	--		--	--
Home alone		80 (42%)	--		--	--
Assisted living		22 (12%)	--		--	--
Functional comorbidities (max of 21)	185	3.6 (2.2)	0 to 13		--	--
MMSE (max of 30)	199	26.6 (9.1)	16 to 30	196	26.5 (11.0)	10 to 30
PPA falls risk (z score)	196	1.7 (1.0)	-0.4 to 4.5	181	1.8 (1.1)	-0.6 to 4.9
Gait speed (m/s)	189	0.8 (0.3)	0.2 to 1.7	184	0.8 (0.3)	0.2 to 2.1
Physical activity (METs-minutes per week)	188	1332.6 (1735.0)	0 to 8748	190	1256.7 (2092.8)	0 to 14,466
GDS (max of 15)	199	3.0 (2.5)	0 to 11	196	3.0 (2.7)	0 to 15
IADLS (max of 8)	198	7.0 (1.5)	0 to 8	197	6.5 (2.0)	0 to 8
TMT (switch cost in seconds)	183	134.2 (189.0)	-7.6 to 1960.0	164	122.0 (116.0)	-6.2 to 684.9
Stroop (interference in seconds)	196	88.2 (59.6)	6.1 to 472.4	171	91.3 (67.1)	9.3 to 445.3
Backward digit span (# of items recall)	196	3.1 (2.0)	0 to 13	182	3.1 (2.0)	0 to 13
DSST	190	20.5 $\pm$ 8.1	2 to 39	171	20.2 (8.9)	2 to 41

Variables	Baseline			One-Year		
	N	M (± SD) or n (%)	Range	N	M (± SD) or n (%)	Range
Verbal Fluency	187	28.5 (14.4)	0 to 76	182	29.2 (14.9)	0 to 71

Notes: DSST = Digit-symbol Substitution Test. GDS = Geriatric Depression Scale. IADLs = Instrumental Activities of Daily Living. METS = Metabolic Equivalents. MMSE = Mini-mental State Examination. m/s = meters per second. PPA = Physiological Profile Assessment. TMT = Trail Making Test.

Table 2

Pearson product-moment correlations (except where noted otherwise) among correlates and covariates.

Measure	1	2	3	4	5	6	7	8	9	10
<i>Baseline</i>										
1. Falls risk	1.00									
2. Gait speed	-.18	1.00								
3. Physical activity	-.07	.40	1.00							
4. Depression	.06	-. 36	-. 21	1.00						
5. IADLs	-.17	.53	.32	-. 27	1.00					
<i>One-year</i>										
6. Falls risk	.49	-. 29	-. 24	.23	-. 35	1.00				
7. Gait speed	-.15	.78	.26	-. 31	.44	-. 33	1.00			
8. Physical activity	-. 21	.37	.42	-. 20	.33	-. 27	.34	1.00		
9. Depression	.09	-. 36	-. 25	.66	-. 30	.31	-. 38	-. 30	1.00	
10. IADLs	-. 26	.49	.27	-. 26	.70	-. 39	.45	.49	-. 33	1.00
<i>Covariates</i>										
Baseline Age	.29	-. 28	-.11	.10	-.17	.28	-. 25	-.09	.02	-. 25
Female ^{1,2}	-.07	.09	.08	-.12	.21	-.19	.12	.20	-.21	.24
Education ¹	-.13	.18	.13	-.05	.32	-. 24	.20	.26	-.12	.31
Baseline FCI	.04	-.17	-.07	.12	-.10	.05	-.15	-.07	.05	-.14
Residential status ¹	.14	.07	.06	-.03	.14	.07	.01	.21	-.03	.11
Baseline MMSE	-. 24	.18	.17	-.05	.42	-. 34	.21	.16	-.10	.39
One-year MMSE	-. 26	.25	.18	-.14	.35	-. 37	.22	.14	-. 21	.48

Notes. Correlations $|.20|$ ($p < .01$) are in bold. FCI = Functional Comorbidity Index.

IADLs = Instrumental Activities of Daily Living, MMSE = Mini-mental State Examination.

¹ Spearman's rho for correlations involving categorical variables.

² Participant reporting male/female was excluded from correlation analyses involving sex.

Table 3

Tests of longitudinal invariance in executive function.

Model	χ^2 (df)	$\chi^2 p$ value	CFI	RMSEA (90% CI)	BIC	χ^2 difference p value ^I
1. Configural invariance model	43.45 (29)	0.04	0.99	.05 (.01, .08)	1587.86	--
2. Metric invariance model	44.60 (33)	0.09	0.99	.04 (.00, .07)	1567.96	0.89
3. Scalar invariance model	52.32 (37)	0.05	0.99	.05 (.00, .07)	1554.63	0.10
4. Residual invariance model	57.77 (42)	0.05	0.99	.04 (.00, .07)	1533.76	0.36

Notes. BIC = Bayesian Information Criterion. CFI = Comparative Fit Index. CI = Confidence Interval.
RMSEA = Root Mean Square Error of Approximation.

^ICompares change in χ^2 model fit of current model from previous model

Summary of results from longitudinal models of executive function and non-cognitive performance.

Table 4

Model	Model Fit			Standardized path estimate (standard error)			
	χ^2/df	CFI	RMSEA (90% CI)	A	B	C	D
1. Falls risk	1.27	0.98	.04 (.01, .05)	-.21 (.09)*	-.11 (.18)	-.02 (.04)	-.16 (.16)
2. Gait speed	1.38	0.97	.04 (.03, .06)	.35 (.08)***	.02 (.12)	.03 (.04)	.43 (.15)**
3. Physical activity	1.24	0.98	.04 (.01, .05)	.23 (.09)**	.21 (.16)	-.004 (.04)	.34 (.15)*
4. Depression	1.26	0.98	.04 (.01, .05)	-.22 (.09)*	-.36 (.13)**	.01 (.04)	-.25 (.15)
5. IADLs	1.34	0.97	.04 (.02, .06)	.27 (.09)**	.31 (.11)**	.04 (.04)	.48 (.16)**

Notes: Covariates include baseline age, sex, education, residential status, functional comorbidities, and baseline and one-year general cognition scores. CFI = Comparative Fit Index. CI = Confidence Interval. IADLs = Instrumental Activities of Daily Living.

RMSEA = Root Mean Square Error of Approximation. A = Baseline residual correlation between EF and correlate.

B = Baseline EF predicting change in correlate score. C = Baseline correlate predicting change EF score.

D = Correlation between change in EF and change in correlate.

* $p < .05$.
** $p < .01$.
*** $p < .001$.

APPENDIX

Standardized parameter estimates for residual invariance model.

	Estimate (standard error)	Two-tailed <i>p</i> value
<i>Factor loading on latent EF</i>		
DSST	0.78 (.04)	<.001
Stroop I-N	−0.64 (.04)	<.001
TMT B-A	−0.66 (.04)	<.001
Fluency	0.54 (.05)	<.001
Digits	0.67 (.05)	<.001
<i>Intercepts</i>		
DSST	0.00 (.00)	--
Stroop I-N	8.72 (.35)	<.001
TMT B-A	7.89 (.32)	<.001
Fluency	−0.07 (.21)	.731
Digits	0.86 (.23)	<.001
<i>Residual Variances</i>		
DSST	0.39 (.06)	<.001
Stroop I-N	0.59 (.06)	<.001
TMT B-A	0.56 (.06)	<.001
Fluency	0.55 (.06)	<.001
Digits	0.70 (.05)	<.001
<i>Variances</i>		
Baseline latent EF	1.00 (.00)	--
1-yr latent EF	1.00 (.00)	--
<i>Residual Covariances</i>		
BL DSST with 1-yr DSST	0.65 (.06)	<.001
BL Stroop I-N with 1-yr Stroop I-N	0.45 (.07)	<.001
BL TMT B-A with 1-yr TMT B-A	0.31 (.08)	<.001
BL Digits with 1-year Digits	0.48 (.06)	<.001
BL Fluency with 1-yr Fluency	0.74 (.04)	<.001
<i>Correlation between latent variables</i>		
BL EF with 1-yr EF	0.96 (.02)	<.001

Notes. Because this model required constrained factor loadings, indicator intercepts, and residual variances to be equal at baseline and follow-up, there is no need to show these estimates separately for baseline and 1-year observed variables.

BL = baseline. DSST = Digit-symbol Substitution Test. Fluency = Verbal fluency. Stroop I-N = Stroop Incongruent Condition minus Neutral Condition. Digits = Backward Digit Span. TMT B-A = Trail Making Test Part B minus Part A.