Research Article

Diminished Locomotor Control Is Associated With Reduced Neurovascular Coupling in Older Adults

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Abstract

Background: Walking, especially while dual-tasking, requires functional activation of cognitive brain regions and their connected neural networks. This study examined the relationship between neurovascular coupling (NVC), as measured by the change in cerebral blood flow in response to performing a cognitive executive task, and dual-task walking performance.

Methods: Seventy community-dwelling older adults aged 84 ± 5 years within the Maintenance of Balance, Independent Living, Intellect and Zest in the Elderly (MOBILIZE) Boston Study were divided into LOW ($n = 35$) and HIGH ($n = 35$) NVC. NVC was quantified by transcranial Doppler ultrasound and stratified by the median change in cerebral blood flow velocity of the middle cerebral artery induced by the performance of the n -back task of executive function. Walking metrics included walking speed, step width, stride length, stride time, stride time variability, and double-support time from single- and dual-task walking conditions, as well as the “cost” of dual-tasking.

Results: During both single- and dual-task walking, older adults with LOW NVC displayed narrower step width ($p = .02$ and $p = .02$), shorter stride length ($p = .01$ and $p = .02$), and longer double-support time ($p = .03$ and $p = .002$) when compared with the HIGH group. During single-task walking only, LOW NVC was also linked to slower walking speed ($p = .02$). These associations were independent of age, height, hypertension, atrial fibrillation, and assistive device. The LOW and HIGH NVC groups did not differ in dual-task costs to walking performance.

Conclusion: In older adults, diminished capacity to regulate cerebral blood flow in response to an executive function task is linked to worse walking performance under both single- and dual-task conditions, but not necessarily dual-task costs.

Keywords: Temporospatial parameters, Gait, Cerebral blood flow velocity, Dual-tasking

Walking is often completed while performing multiple tasks simultaneously, which is known as “dual-tasking.” Dual-tasking frequently disrupts locomotor control and identifying such “costs” aid in the understanding of both brain health and mobility in older adults. Dual-task costs to walking performance increase with advancing age and cognitive decline (1,2) and are predictive of future falls (3,4).

The observation that performing a cognitive task can interfere with locomotor control suggests that the two tasks call upon and potentially compete for shared brain resources. Moreover, it suggests that the ability to walk, especially while dual-tasking, requires functional activation of a distributed network of brain regions subserving cognitive function (5), as well as the capacity to redistribute blood flow to these networks as metabolic demands increase (6,7). The change in

cerebral blood flow (CBF) velocity in response to the performance of the *n*-back test of executive function, termed “neurovascular coupling” (NVC), reflects an important aspect of brain function critical to one’s capacity to walk safely, especially when performing a cognitive dual-task. Sorond and colleagues examined NVC within the bilateral middle cerebral arteries (MCA) in a population-based cohort of community-dwelling older adults from the Maintenance of Balance, Independent Living, Intellect and Zest in the Elderly (MOBILIZE) Boston Study (MBS). Participants within the fastest quartile of walking speed, compared with the lowest, exhibited greater NVC marked by, on average, a 6.5% greater increase in CBF in response to the *n*-back task (6). More recently, Jor’dan and colleagues reported that older adults with greater NVC in response to the *n*-back task demonstrated greater brain activation within the frontoparietal executive control network during performance of this same task, as measured by BOLD fMRI (7). Still, these studies only examined the relationship between NVC and walking speed under a “single-task” condition. We therefore performed a secondary analysis of the MBS that examined the relationships between NVC and additional meaningful metrics of walking performance during both single- and dual-task conditions. We focused on specific temporospatial metrics of locomotor control that have been linked to brain abnormalities, cognition, depression, and/or fall risk (8–11). We hypothesized that older adults with lower NVC would display worse walking performance, particularly within dual-task conditions, and that executive function would mediate these associations.

Methods

Participants

The MBS is a longitudinal population-based study that was launched in 2005 to identify novel risk factors for falls in older adults. Inclusion criteria included age greater than 70 years (or age > 65 if living with an already-enrolled MBS participant), the ability to understand and communicate in English, plans to live in the area for at least 2 years, and the ability to walk 20 feet without personal assistance. Exclusion criteria included terminal disease, severe vision or hearing deficits, and significant cognitive impairment defined by a Mini-Mental State Exam score of less than 18. A full description of the study protocol has been published elsewhere (12). Due to the present study’s CBF recording protocol, members of the MBS cohort were also excluded if they had an inadequate temporal bone window for transcranial Doppler ultrasound (TCD) insonation. Research procedures were conducted within the Clinical Research Laboratory at Hebrew SeniorLife, and all participants provided written informed consent as approved by the Institutional Review Board.

Protocol

Walking protocol

Participants completed two trials each of single- and dual-task walking in randomized order over a 16-foot GAITRite mat (CIR Systems Inc., Havertown, PA). Each walking trial consisted of three passes over the mat during one bout of continuous walking. Of note, turns were completed off the GAITRite mat and were not included in the data collection. Participants started four feet before the mat in a standing position and were given standardized verbal instructions just before each trial began. For single-task walking, participants were asked to walk at their “normal pace, as if they were walking down the sidewalk to go to the store and not in a hurry.” For dual-task walking, participants were asked to walk, again at their normal pace, while verbally subtracting by either 3, 5, or 1 from

500, as determined in a serial subtraction familiarization session (see the following paragraph). Participants were encouraged to continue walking during the trial, and not stop, while performing the serial subtraction task, even if the participants forgot their place while subtracting. If the participant forgot, they were instructed to continue subtracting from the last number result that they remembered. If needed, a rest period was given after each trial.

Prior to the walking protocol, participants were asked to perform serial subtractions while seated to best determine which serial subtraction they would be able to perform. During a 5-second practice trial, participants were asked to subtract by 3’s starting from 100. If they provided three to four correct responses, participants then completed one 30-second trial. Following this same procedure, those who were unable to subtract by 3 were instead asked to subtract by 5, and those who were unable to subtract by 5 were instead asked to subtract by 1. Walking aids (ie, walkers and canes) were allowed and encouraged if the participant and/or study staff felt it would be unsafe for the participant to walk without assistance.

TCD ultrasound protocol

NVC was assessed with TCD (DWL Transcranial Doppler Systems, San Juan Capistrano, CA) to record CBF velocity (6,7) with the participant in a supine position. Small, flat TCD probes were positioned over the temporal bone to insonate the left and right MCA territories. The MCA is the largest branch of the internal carotid artery and supplies portion of the frontal, parietal, and temporal lobes including cortical and deep areas of the brain involved in locomotor and cognition (13). CBF velocities were first recorded during 5 minutes of rest and then for 6 minutes during performance of the *n*-back task of executive function. Eighteen letters, projected onto a screen 1.5 m above the participant, were presented one at a time for 3 seconds with a 2-second delay. Four 90-second blocks of testing included two Identify X (IdX; ie, zero-back, control condition) and two 2-back (ie, experimental condition) tasks. Testing began with IdX and alternated with the two-back condition. During the IdX, participants were instructed to press the left key on a custom keypad when the target letter (“X”) was presented and the right computer key when it was not. During the two-back task, participants were instructed to press the left key if the presented letter was seen two positions back and the right computer key if it was not.

Data Analysis

Walking parameters

Walking speed, step width, stride length, stride time, stride time variability, and double-support time were computed. Walking speed reflects health and functional status and has been linked to survival among older adults (14,15). In addition, step width, stride length, stride time, and double-support time are temporospatial parameters that have been implicated in atypical brain structure (ie, subclinical brain infarcts and white matter hyperintensities) (8,16), cognitive decline (9), depression (10), preexisting fear of falling (17), and/or increased fall risk (18,19). Last, stride time variability was specifically explored as it predicts falls, functional status, and even mental health in older adults (20).

Average walking speed (meter per second) was computed by dividing distance by time. Step width (meter) was calculated as the distance between the midpoints of two successive foot placements. Stride length (meter) was calculated as the distance between two successive heel strikes of the same foot. Stride time (second) was calculated as the time between the contact of two successive footfalls of the same foot (right and left), and then the average was taken of right and left. Stride time variability was calculated

as the coefficient of variation of stride time. Double-support time (%) was calculated as the percentage of stride time that both feet were on the ground at the same time. Each walking parameter was quantified from each full step/stride that occurred during three passes over the GAITRite mat within each trial. For the single- and dual-task conditions, outcomes were averaged across the three passes within each trial and then averaged across like trials. Dual-task costs to temporospatial parameters of walking were calculated separately for each walking metric as the percent change from single- to dual-task condition, that is $(\text{Mean walking metric}_{\text{single}} - \text{Mean walking metric}_{\text{dual-task}}) / \text{Mean walking metric}_{\text{single}} \times 100$ (21).

NVC protocol

Instantaneous CBF velocity (centimeter per second) within the left and right MCA was recorded by TCD during the aforementioned *n*-back paradigm. The mean CBF was determined per condition and averaged across like blocks. NVC was then quantified by calculating the percent change in mean CBF velocity of the MCA between the IdX and the two-back conditions, averaging across both the left and right MCA territories (6).

Statistical Analysis

Participants with NVC below the median were grouped within the “LOW” NVC group, whereas those who were above the median were considered the “HIGH” NVC group. Student’s *t*-tests or Pearson’s chi-square tests were used to compare group demographics and clinical characteristics as appropriate.

Analysis of covariance was used to test the hypothesis that when compared with participants within the HIGH NVC group, those within the LOW group would exhibit worse dual-task walking performance. The dependent variables were measures of walking speed, step width, stride length, stride time, stride time variability, and double-support time during single- or dual-task walking, as well as the dual-task cost to these temporospatial walking metrics. Separate models were conducted for each dependent variable. The independent variable was NVC group (LOW, HIGH). Models were adjusted for age, height, hypertension, atrial fibrillation, and use of an assistive device. For stride time variability, models were further adjusted for walking speed.

To further examine whether the association between NVC and each metric of walking performance was stronger during dual-task conditions when compared with single-task conditions, β coefficients were compared between single- and dual-task conditions of significant models. A difference of greater than 20% of the β between the single- and dual-task walking measure was used to indicate a significant difference in strength of association (22).

To test our secondary hypothesis that executive function may mediate the association between NVC and locomotor control, we conducted a mediation analysis using multiple regression to determine whether executive function, as measured by Trails B performance, influenced observed correlations between NVC and metrics of gait. We defined significant mediation as a reduction in the β coefficient greater than 10% when Trails B was included in the regression model (23–25).

Significance level was set at *p* value less than .05. Due to the planned and scientifically sensible comparisons, no mathematical correction was made for multiple comparisons. All analyses were performed using JMP software (SAS Institute, Cary, NC).

Results

Participant Characteristics

Seventy participants completed the study procedures. The LOW and HIGH NVC groups were similar in demographic, clinical, and

cognitive measures. Unexpectedly, the LOW group had a lower percentage of individuals with a self-reported history of atrial fibrillation when compared with the HIGH group ($p = .01$; Table 1).

N-back task performance

The LOW and HIGH NVC group did not significantly differ in the percent correct on the IdX task (LOW, 86% vs. HIGH, 92%; $p = .23$) or the two-back task (LOW, 70% vs. HIGH 74%; $p = .57$).

Dual-task serial subtraction task

Within the LOW NVC group, 86% performed serial subtraction by 3’s, 6% subtracted by 5’s, and the remaining 8% subtracted by 1’s while walking. For the HIGH NVC group, 91% performed serial subtraction by 3’s, 9% subtracted by 5’s, and no participants subtracted by 1’s while walking. The LOW NVC group made more serial subtraction errors, on average, compared with the HIGH NVC group (1.4 vs. 0.6 errors, $p = .03$) independent of serial subtraction task.

Relationships Between NVC and Walking Performance

Analysis of covariance models indicated that when compared with the HIGH group, the LOW NVC group displayed slower walking speed during the single-task condition ($p = .02$) and trended toward significance during the dual-task condition ($p = .06$; Table 2). During both single- and dual-task walking, the LOW NVC group displayed narrower step width ($p = .02$ and $p = .02$, respectively), shorter stride length ($p = .01$ and $p = .02$, respectively), and longer time spent in double support ($p = .03$ and $p = .002$, respectively), when compared with the HIGH NVC group. The LOW and HIGH NVC group did not differ in single- or dual-task stride time or stride time variability ($p > .11$).

The LOW and HIGH NVC group did not differ in the dual-task cost to any gait measure ($p > .22$; Table 2).

Table 1. Demographic and Clinical Characteristics by LOW Versus HIGH NVC

Characteristic	LOW NVC < 1.5%	HIGH NVC > 1.5%
N	35	35
Age (y)	85 (6)	84 (4)
% Female	63	57
Height (m)	1.6 (0.1)	1.6 (0.1)
% Assistive device	29	14
Mini-Mental State Exam	27 (3)	27 (2)
Trails A (s)	50 (20)	43 (20)
Trails B (s)	115 (47)	97 (51)
Trails B adjusted (s)	69 (42)	57 (40)
% Type 2 diabetes	9	6
% Hypertension	63	71
% Hyperlipidemia	56	49
% Atrial fibrillation	9	37
% Pacemaker	13	6
NVC (%)	−0.7 (1.6)	4.2 (2.0)
Mean CBF IdX (cm/s)	50.6 (14)	52.4 (11.3)
Mean CBF two-back (cm/s)	50.3 (13.9)	54.5 (12.0)

Notes: CBF = cerebral blood flow; IdX = Identify X task; NVC = neurovascular coupling. Data are presented as mean (SD). Nonsignificant differences existed between groups, except for atrial fibrillation ($p = .01$) and NVC ($p < .001$).

Table 2. Walking Metrics During Single- and Dual-Task Walking and the Associated Dual-Task Cost by LOW Versus HIGH NVC

	LOW NVC	HIGH NVC	β	CI	<i>P</i>
Gait speed					
Single (m/s)	0.90 $\pm$ 0.04	1.03 $\pm$ 0.04	0.22	0.010, 0.113	.02*
Dual-task (m/s)	0.69 $\pm$ 0.04	0.79 $\pm$ 0.04	0.20	-0.001, 0.101	.06
Dual-task cost (%)	23.9 $\pm$ 2.7	21.7 $\pm$ 2.6	-0.09	-4.304, 2.099	.49
Step width					
Single (m)	0.55 $\pm$ 0.02	0.60 $\pm$ 0.02	0.23	0.004, 0.045	.02*
Dual-task (m)	0.50 $\pm$ 0.02	0.55 $\pm$ 0.02	0.24	0.004, 0.045	.02*
Dual-task cost (%)	9.2 $\pm$ 1.5	8.6 $\pm$ 1.4	-0.05	-2.050, 1.436	.73
Stride length					
Single (m)	1.05 $\pm$ 0.04	1.16 $\pm$ 0.04	0.24	0.011, 0.098	.01*
Dual-task (m)	0.94 $\pm$ 0.04	1.05 $\pm$ 0.04	0.25	0.010, 0.099	.02*
Dual-task cost (%)	10.9 $\pm$ 1.6	9.6 $\pm$ 1.6	-0.09	-2.545, 1.329	.53
Stride time					
Single (s)	1.23 $\pm$ 0.03	1.17 $\pm$ 0.03	-0.18	-0.067, 0.007	.11
Dual-task (s)	1.48 $\pm$ 0.06	1.39 $\pm$ 0.06	-0.16	-0.115, 0.024	.19
Dual-task cost (%)	19.6 $\pm$ 3.7	18.8 $\pm$ 3.5	-0.02	-4.766, 3.972	.86
Stride time variability [†]					
Single (s)	3.91 $\pm$ 0.37	4.10 $\pm$ 0.33	0.06	-0.330, 0.526	.65
Dual-task (s)	5.51 $\pm$ 0.57	5.68 $\pm$ 0.51	0.03	-0.565, 0.735	.79
Dual-task cost (%)	74.42 $\pm$ 20.8	64.06 $\pm$ 19.9	-0.06	-29.703, 19.348	.67
Double-support time					
Single (%)	37.6 $\pm$ 1.3	34.2 $\pm$ 1.3	-0.23	-3.261, -0.163	.03*
Dual-task (%)	40.9 $\pm$ 1.3	36.0 $\pm$ 1.2	-0.32	-3.931, -0.911	.002*
Dual-task cost (%)	10.6 $\pm$ 2.5	6.9 $\pm$ 2.4	-0.16	-4.806, 1.1322	.22

Notes: CI = confidence interval (lower, upper); NVC = neurovascular coupling. Data are presented as least square mean $\pm$ SE.

* $p < .05$ after adjustment for age, height, hypertension, atrial fibrillation, and use of an assistive device or †aforementioned covariates + walking speed per condition (Model 1).

Differences in the Strength of Relationship Between NVC and Walking Performance in Single- and Dual-Task Conditions

The difference in NVC β coefficients for double-support time was 39% greater during the dual-task condition compared with the single-task condition, which suggested a stronger correlation between NVC and double-support time during the dual-task condition. The difference in the β was less than 9% for walking speed, step width, and stride length.

Effect of Executive Function on the Relationship Between NVC and Walking Performance

As given in Table 3, when Trails B performance was added to the regression models, the main effect of group was no longer statistically significant for both single- and dual-task walking speed, step width, and stride length ($p > .06$). For double-support time, the main effect of group was no longer statistically significant for single-task walking only ($p = .07$). The addition of Trails B attenuated NVC β by 14%–50% and 28%–64% for walking metrics during single- and dual-task, respectively (Table 3).

Discussion

Community-dwelling older adults with a lower capacity to regulate CBF in response to the *n*-back task of executive function (NVC), demonstrated worse walking performance. Specifically, those with LOW NVC had slower walking speed, narrower step width, shorter stride length, and longer time spent in double support during both single- and dual-task walking, when compared with those with HIGH NVC. Moreover, associations between NVC and double-support

time were stronger during dual-task walking when compared with single-task walking. Executive function, as determined by Trails B performance, may mediate the observed association between NVC and walking performance. These results support the hypothesis that in older adults, diminished locomotor control—especially when simultaneously walking and performing a cognitive dual-task—is linked to an impaired ability to regulate CBF in response to increasing executive function-related task demands.

Previous research in our laboratory demonstrated that reduced bilateral NVC of the MCA in response to the *n*-back task of executive function was associated with slower walking speed under normal walking conditions in community-dwelling older adults (6,7). In contrast to the study by Sorond and colleagues in which participants were grouped based on the cohort median walking speed (slow vs. fast walkers), the present study participants were grouped according to the cohort median NVC (LOW vs. HIGH NVC). Our results demonstrated that those with lower NVC not only walked more slowly, but also had narrower step width, shorter stride length, and longer time spent in double support during both single- and dual-task walking. However, NVC was not associated with stride time variability, which is consistent with the recent findings that gait speed and gait variability are controlled by different networks and therefore regions, outside of the MCA territory (26). Previous studies have reported that in well-functioning older adults, abnormal gait characteristics are linked to subclinical brain abnormalities (ie, white matter hyperintensities and subcortical brain infarcts) (8) and gray matter atrophy in regions related to executive function (16), which may cause a decrement in the coupling between neural activity and the related hemodynamic response (ie, NVC). Notably, Rosano and colleagues stated that the probability of having subclinical brain abnormalities known to decrease blood flow and oxygen

Table 3. Executive Function as a Mediator of Walking Metrics During Single- and Dual-Task Walking by LOW Versus HIGH NVC

	LOW NVC	HIGH NVC	β	CI	P
Gait speed					
Single (m/s)	0.93 $\pm$ 0.05	1.04 $\pm$ 0.04	0.19	–0.003, 0.109	.06 [†]
Dual-task (m/s)	0.73 $\pm$ 0.05	0.79 $\pm$ 0.04	0.13	–0.024, 0.088	.26 [†]
Step width					
Single (m)	0.56 $\pm$ 0.02	0.60 $\pm$ 0.02	0.19	–0.002, 0.044	.08 [†]
Dual-task (m)	0.51 $\pm$ 0.02	0.55 $\pm$ 0.02	0.17	–0.005, 0.041	.13 [†]
Stride length					
Single (m)	1.07 $\pm$ 0.04	1.16 $\pm$ 0.04	0.20	–0.003, 0.094	.07 [†]
Dual-task (m)	0.97 $\pm$ 0.04	1.05 $\pm$ 0.04	0.18	–0.010, 0.089	.11 [†]
Double-support time					
Single (%)	37.5 $\pm$ 1.5	34.3 $\pm$ 1.3	–0.21	–3.303, 0.104	.07
Dual-task (%)	40.7 $\pm$ 1.5	36.3 $\pm$ 1.3	–0.29	–3.893, –0.567	.01*

Notes: CI = confidence interval (lower, upper); NVC = neurovascular coupling. Data are presented as least square mean $\pm$ SE.

* $p < .05$; Model 2 = Model 1 + Trails B performance. [†]10% change in the estimate with the inclusion of Trails B as a mediator.

levels to brain regions was more than two times greater for those older adults with slower gait speed, shorter gait stride, or longer double-support times, when compared with those older adults with the best gait performance (8). Alterations in gait performance may be due to structural and associated functional changes in the brain. Longitudinal research is warranted to determine the cause-and-effect sequence of structural changes and gait abnormalities to target and develop interventions.

Our results suggest that the link between NVC and walking performance, specifically double-support time, is stronger under the dual-task walking condition, compared with the single-task walking condition. Walking while performing a serial subtraction task requires the reallocation of cognitive resources and prioritization of tasks and therefore draws more heavily upon executive function. Based on this rationale, cognitive task prioritization could cause the participant to spend longer time in double support to regain stability before starting a new gait cycle (27). Alternatively, because executive function is necessary to shift from one motor pattern to another, its impairment could result in difficulty starting a new gait cycle.

In fact, executive function, as determined by Trails B performance, was shown to partially mediate the association between NVC and walking performance under both single- and dual-task walking conditions. These findings are supported by our previous work that determined that the task-related change in CBF (ie, NVC) is associated with the recruitment of the executive network of the brain and, moreover, that the reduced activation of this region is associated with slow gait speed under single-task walking conditions (7). Intervention-based studies targeting the executive network have shown improvements in mobility measures when stimulated by noninvasive electrical current (28) or when subjected to physical-cognitive therapy (29). Therefore, the executive function network may serve as a critical component in neurorehabilitative research.

We observed that HIGH NVC is linked to a wider step width in both single- and dual-task walking. An increase in step width is associated with aging—even in the absence of overt disease or injury—and may therefore represent a compensatory response for other neuromuscular abnormalities that destabilize gait to increase stability and avoid falls (18,30,31). A narrower step width, within the LOW NVC group, challenges medial–lateral balance control and may have a destabilizing effect (32). Therefore, the LOW NVC group may have a higher risk for sideways falls, especially during dual-tasking (33). More research is needed to understand the role

of step width in locomotor control and its link to CBF regulation in older adults.

Within our study, we included the dual-task cost to locomotor control, which is an important ability that relies on executive function and related brain network activation. However, our results did not show a link between a high dual-task cost to locomotor control and a lower capacity to regulate CBF in the brain (ie, lower NVC). This could be due, in part, to the fact that our cohort was relatively cognitively intact and may have had greater cognitive resources to compensate for the dual-task paradigm compared with those with higher cognitive impairment (34,35). Another consideration is that the dual-task cost to locomotor control may depend on the recruitment of different brain regions that are not supplied by blood flow from the MCA and thus not reflected in the NVC measure. This is supported by a previous study that used functional near-infrared spectroscopy to measure the frontal lobe's hemodynamic response to dual-tasking and found only weak correlations between blood oxygen levels and the dual-task cost to temporospatial gait (36).

Because we were interested in the relationship between executive function and gait, we utilized TCD ultrasonography to assess NVC within the MCA territory and its relationship to walking performance. However, other cerebral arteries (eg, anterior cerebral artery) have been shown to be meaningful in the delivery of oxygenated blood to specific brain regions during walking (37). Future studies are thus needed to determine the link between NVC in other cerebral territories and locomotor control. In addition, longitudinal studies with larger sample sizes are warranted to better establish the complex relationship between NVC, higher-level cognitive function and locomotor performance, as well as any thresholds. Also, because participants may prioritize gait rather than cognitive performance, subsequent studies should include a measurement of cognitive-cost by solely monitoring performance during a single cognitive task condition (eg, seated serial subtraction task).

The present study addressed attributes associated with the timing and coordination of gait, but did not assess other important neuromuscular attributes (eg, leg strength, leg power, leg range of motion) that underlie mobility skills (38). These attributes should be evaluated in a similar fashion within future studies. Answering these research questions would provide a more comprehensive picture of locomotor control with and without the performance of an

additional cognitive load and the associated “costs.” Such information would also implicate specific brain regions/networks and/or neuromuscular attributes for future neuromodulation and balance rehabilitation interventions.

In conclusion, the current findings highlight the role of blood flow regulation in the control of temporospatial walking parameters. Executive functioning may underlie the association between NVC and walking performance. Therefore, rehabilitation strategies, such as cognitive-motor interventions and neuromodulation targeting the executive function region and including complex task constraints, may prevent mobility decline in older adults.

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Conflict of Interest

None reported.

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