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Association of cognitive impairment and fall risk in older adults: an analytical cross-sectional study

Abstract

Background/Objectives: Falling affects up to one-third of older adults each year and poses as a major public health concern. It is one of the main causes of morbidity and mortality in the geriatric population. Many studies have suggested that poorer cognition increases fall risks but there is currently no consensus on implementing cognitive assessment routinely for patients at risk of falls. This may be due to the existing time-consuming assessment tools or the lack of trained neuropsychological health professionals to administer such tests. Cognivue however, is a validated novel cognitive screening tool that is quick to administer and requires minimal training. This study aims to correlate fall risks as determined by abnormal postural stability on the computerized dynamic posturography with cognivue scores. Especially in clinical facilities without access to the exorbitant posturography equipment, Cognivue may hence help with fall risk assessments and improve clinicians' confidence at managing patients at risk of falls.

Methods: 34 older adults who were referred to the American Institute of Balance for dizziness were recruited in this prospective, cross-analytical pilot study. All participants had unremarkable vestibular neurodiagnostic workup and as part of a comprehensive balance assessment and undertook the computerized dynamic posturography test. An additional cognitive screening test using the Cognivue was further administered and all results including social demographics and medical history were statistically analyzed for correlation.

Results: Participants with cognitive impairment were almost 14 times more likely to have degraded postural stability on the sensory organization test. This significance remained even after adjusting for confounding variables such as age and relevant medical comorbidities. In this group of cognitively impaired individuals, there was a greater proportion of participants with polyneuropathy, fall and neurological history as compared with participants without cognitive impairment.

Conclusion: Fall risk assessments need to be expanded to included cognitive screening routinely. The inclusion of screening tools such as Cognivue should be considered to guide clinicians with managing patients at risks of falls. Further large cohort studies may be warranted and should include correlation of Cognivue with other clinical assessments such as Time-Up and Go and Dynamic Gait Index.

Keywords: Cognition, falls, balance assessment, cognitive impairment, fall risk

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Abbreviations: AIB, American Institute of Balance; KRC, Kinetic Rotatory Chair; VHIT, Video-Head Impulse Test; VEMP, Vestibular Evoked Myogenic Potential; SOT, Sensory Organisation Test; CDP, Computerized Dynamic Posturography; MOCA, Montreal Cognitive Assessment; MMSE, Mini Mental State Examination; SLUMS, St. Louis University Mental State; MEM, Memory; VSP, Visuo-Spatial Processing; PS, Processing Speed; EF, Executive Function; RT, Reaction Time; PD, Parkinson Disease; CI, Cognitive Impairment; TUG, Time-Up and Go; POMA, Performance Oriented Mobility Assessment

Introduction

Ageing is a defined by the World Health Organization (WHO) as a progressive loss of adaptive response to stress and a generalized impairment of global function.[1] Of the many problems associated with ageing, falls are one of the causes of concern. Falling affects 30% of older adults each year and is a major public health issue, as it is one of the main causes of morbidity and mortality in older adults.[2] Several studies[3-5] have linked poorer cognition with fall risk but there is no consensus on implementing cognitive assessment in the population at risk of falls. This is in part due to the differences in methods and tools used to define cognitive impairment and type of fall outcomes when quantifying risk.[6] Past studies have used global cognitive dysfunction like dementia, which is a disease specific diagnosis to evaluate fall risk.[6] However, in the absence of dementia, postural stability can also be affected by subtle changes in specific cognitive domains, such as executive function.[7] Hence, it may be crucial to evaluate different cognitive domains in defining cognitive impairment and evaluating fall risk. One such validated clinical tool that was recently developed is the Cognivue®.

Cognivue® is a Food-Drug Administration (FDA) approved clinical tool used to aid in cognitive screening. Unlike conventional cognitive screening assessments, the Cognivue® thrive is a quick 5-minute computerized assessment that looks at individual cognitive domains such as Memory (MEM), Visuo-Spatial abilities (VSP), Executive function (EF), Reaction Time (RT) and Processing Speed (PS). This study aims to correlate Cognivue scores with sensory organisation test (SOT) composite scores in the Computerized Dynamic Posturography (CDP), to see if poorer cognition is correlated with fall risk. Some authors have shown that abnormal SOT scores (especially when scores

are less than 38), increases the likelihood ratio (4.13X) of identifying repeated fallers in the past six months.[8] SOT composite scores have also been well correlated with clinical test of balance function such as the Time Up and Go (TUG) test, Performance Oriented Mobility Assessment (POMA) and Dynamic Gait Index (DGI), which are all clinical tools used to assess fall risk. Hence using SOT composite scores to predict fall risk has good validity construct9. If cognitive impairment on the Cognivue® is well correlated with fall risk on the SOT, clinicians should consider cognitive screening as part of their assessment for fall risk. In particular, when expensive instrumentation such as the CDP or trained clinicians in balance assessment may be unavailable, the Cognivue® may help better inform clinicians and patients about fall risk. The objectives are hence i) to evaluate the association of cognitive impairment on fall risk (based on SOT composite scores), ii) to explore the differences in associated co-morbidities between individuals with cognitive impairment or otherwise and iii) to determine if self-reported dizziness handicap is correlated with SOT composite or Cognivue® scores.

Methods

Study sample, inclusion and exclusion criteria

Adults who were attending a vestibular clinic at the American Institute of Balance (AIB) between January to December 2021, who were age 65 and above and at risk for age-related cognitive decline were invited to take part in this study. Participants were screened with a full balance assessment which, includes Video-Head Impulse Test (VHIT), Kinetic Rotatory Chair (KRC), Videonystagmography (with calorics), Vestibular Myogenic Evoked Potentials (VEMP) and Sensory Organisation Test (SOT) in the Computerized Dynamic Posturography (CDP). All participants had findings that were unremarkable for any active/acute or uncompensated peripheral vestibulopathy. A full detailed medical history was taken and as part of the study, participants had further undergone cognitive screening with a validated computerized program, Cognivue®. Participants with any focal neurological deficits, cerebellar signs or a history of neurodegenerative diseases were excluded from this study. All participants who were able to follow simple instructions for Cognivue testing, who could stand unassisted for more than ten minutes to perform CDP and met the age criteria were recruited.

Computerized Dynamic Posturography (CDP)

The Equitest® System (NeuroCom® International, Inc., Clackamas, OR, United States)[9] is a clinical instrument used to evaluate postural stability by measuring center of gravity sway during standing.[10] Postural stability is the ability to control the center of mass in relation to the individual's base of support, during either static or dynamic task. As part of the Equitest® System, the Sensory Organisation Test (SOT) creates sensory conflict conditions to alter visual and/or proprioceptive inputs to the brain's balance control centre. The subject's oscillations are quantified, and scores are assigned based on degree of stability (higher scores denoting greater stability). Based on the SOT scores in various sensory conflicting conditions, a sensory analysis (SA) will be provided to suggest whether postural instability is more of a vestibular, proprioceptive, or visual deficit. SOT and SA norms are provided only for age groups up to 79 years 9 and as SOT performance has been suggested to decline with age in healthy adults,[11] it may be difficult to interpret SOT scores or further correlate them with cognitive function for subjects aged 80 and above, as oscillations may or may not be physiological. A recent study, however, has determined normative data for SOT scores in the older adults up from 80-89 years.[12] The normative data from both studies are shown below (Table 1) and will be used as reference for this study in determining age-specific abnormal SOT composite scores.

Table 1

Age Group (years)	Test			
	Somatosensory	Visual	Vestibular	SOT Composite Score
20-29	100.60±2.55	82.90±5.36	76.60±11.60	79.18±4.67
30-39	99.40±2.17	78.40±9.37	71.90±11.51	76.05±7.06
40-49	100.10±1.79	75.80±13.31	68.10±10.59	72.58±6.09
50-59	97.40±2.12	73.80±9.22	68.70±9.33	73.85±6.62
60-69	99.50±1.35	76.20±5.33	70.60±8.77	75.12±4.32
70-79	95.1±7.9	85.0±0.07	67.3±10.4	72.8±5.4
80-84	96.5±3	81.8±8.0	51.8±18	69.9±8.4
85-89	97.1±3.1	76.9±11.7	31.4±27	60.7±10.3

Cognivue screening

Unlike traditional question and answer testing such as the Montreal Cognitive Assessment (MOCA) or Mini-mental state examination (MMSE), Cognivue® is a computerized clinical tool used for automated assessment of cognitive function. Automated testing circumvents problems with traditional cognitive testing, such as inconsistent test-retest reliability[13] and testing bias.[14] Furthermore, some tests require specific training and cannot be administered by non-clinicians.[14] Use of some traditional cognitive assessment tools may also be hindered by long test length and can be impractical for routine use.[14,15] The Cognivue® thrive is a quick five-minute testing protocol that assesses Memory (MEM), Visuo-Spatial (VSP), Executive Function (EF), Reaction Time (RT) and Processing Speed (PS). This program has been approved by the Food and Drug Administration (FDA) for use as an adjunctive cognitive assessment tool for subjects aged 55-95 years.[14] Cognivue classification scores were validated against traditional neuropsychological tests such as the St. Louis University Mental Status (SLUMS) examination and demonstrated good test agreement and psychometric validity. Details of the testing algorithm of Cognivue® can be found on their website.

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Definition of cognitive impairment

When quantifying fall risk, the method used to define cognitive impairment and type of fall outcomes are both important6. Cognitive impairment here is defined as a less than good rating in the average of Memory, Visuospatial and Executive Function abilities (when average score of three cognitive domain is <75) and/or a less than a good rating in either of the performance parameters: Reaction Time and Processing Speed. The normative range and cut-off scores can be found in the table below (Table 2).

Table 2

Cognitive Domain Screened	Normative Range Reference			Cognivue Cut-off Scores
Memory (MEM)	0-48 (Poor)	49-76(Moderate)	77-100 (Good)	Impaired: <51 Mildly Impaired (intermediate): 51-74 Unimpaired: >74
Visuospatial (VSP)	0-42 (Poor)	43-58 (Moderate)	59-100 (Good)	
Executive Function (EF)	0-49 (Poor)	50-74 (Moderate)	75-100 (Good)	
Reaction Time (RT)	>/=1170ms (Poor)	901ms-1169ms (Moderate)	</=900ms (Good)	
Processing Speed (PS)	>/=2500ms (Poor)	1901ms-2499ms (Moderate)	</=1900ms (Good)	

Statistical analyses

All analyses were performed with IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp. Parametric and non-parametric equivalent testing were used depending on normality of data distribution. Chi-square test of significance and bi-variate correlation matrix were performed to assess for correlation between Cognivue® and SOT scores. Univariate and multivariate regression analyses were carried out to adjust for confounding factors affecting postural stability and hence SOT composite scores.

Results

Of the 34 participants, there were 20 females (58.8%) with a mean age of 78 years (range:65-89) and 14 males (41.2%); mean age of 75 (range: 67-90). There were no significant differences in the mean age between gender (p=0.23) nor Cognivue® group (p=0.55). Two participants were excluded from analyses as they did not complete Cognivue® screening.

Correlation between Sensory Organisation Test (SOT) and cognivue scores

Chi-Square analysis revealed a good correlation between what is suggested as impairment in the Cognivue® thrive with SOT composite scores (Table 3). Participants who are cognitively impaired are 13.6X more likely to have abnormal SOT composite scores as compared to peers without cognitive impairment. When adjusted for confounding variables such as age, presence of comorbidities including polyneuropathy, history of falls, significant neurologic, orthopaedic, or non-corrected visual deficits, the odds ratio of having an abnormal SOT composite score in participants with cognitive impairment was still significant (Table 4).

Table 3 Chi-Square test of association between SOT and Cognivue scores

Chi-Square Table n=32		Abnormal SOT		
		NO	YES	Total
Cognitive Impairment	NO	8	2	10
	YES	5	17	22
Total		13	19	32
Fisher Exact P-Value	0.01, Odds Ratio: 13.6 [95% Confidence Interval: 2.15-85.9]			

Table 4 Logistic regression analyses of SOT with confounding variables

Abnormal SOT (NO)	B value	Standard Error (SE)	Significance	EXP (B)	95% Confidence Interval for EXP (B)	
Intercept	-4.66	2.02	0.02	-	-	-
Cognitive Impairment (NO)	4.04	1.76	0.02*	56.56	1.81	1772.21
Age (60-69)	1.86	1.42	0.19	6.45	0.40	104.13
Age (70-79)	1.67	1.35	0.22	5.33	0.38	75.50
Polyneuropathy (NO)	0.87	1.43	0.54	2.38	0.15	38.90
Falls (NO)	-0.33	1.23	0.79	0.72	0.06	8.07
Neurologic (NO)	-0.91	1.66	0.58	0.40	0.02	10.43
Orthopaedic (NO)	2.26	1.31	0.09	9.55	0.73	125.07
Visual (NO)	1.38	1.30	0.29	3.96	0.31	50.42

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Comparison of associated co-morbidities between Cognivue® groups

More than half of the participants (22/32; 68.8%) had abnormal cognitive scores on the Cognivue®. Of the 22 participants, more than half (59.1%) had either hypertension, hypotension and about 40.9% had significant orthopaedic medical history, including osteoarthritis, knee, or hip replacement. One-third of the participants with abnormal cognition had significant non-corrected visual deficits (31.8%) such as cataracts. About 45.5% had a fall in the previous year and approximately 36.4% had a neurologic history including stroke, transient ischemic attacks, neuropathy, Parkinson, seizures/epilepsy, and head injuries. Six participants (27.3%) had polyneuropathy while one participant (4.5%) had Diabetes Mellites. When compared with participants without cognitive impairment (CI), those with CI had a 3X (6/22, 27.3%; 1/10, 10%) greater proportion of polyneuropathy (PN), 2.5X (10/22, 45.6%; 2/10, 20%) more fallers, and 3.5X (8/22, 36.4%; 1/10, 10%) more participants with a significant neurological history (Figure 1). Although there were fewer reported orthopaedic and non-corrected visual deficits in participants with CI, these comorbidities including PN, fall and neurological history were still confounding variables that had to be adjusted for in regression analyses assessing relationship between cognition and fall risk.

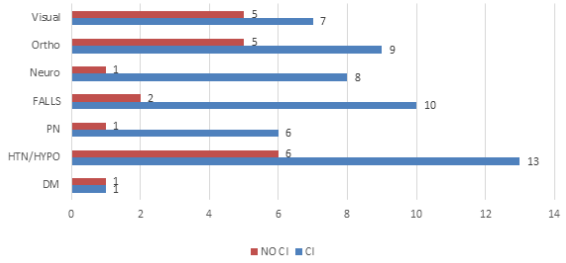

Figure 1 Comparison of associated comorbidities between abnormal (N=22) and normal congnivue group (N=10).

Dizziness Handicap Index (DHI) correlation with Sensory Organisation Test (SOT) and Cognivue scores.

Bivariate correlation matrix suggests no significant correlation between SOT and DHI individual domain or total scores. However, memory, visuo-spatial abilities and executive function appears to be negatively correlated with emotional and functional aspects of the DHI. Processing speed is further correlated with DHI functional scores. Overall, total DHI scores are negatively correlated with memory, visuo-spatial and executive function (Table 5).

Table 5 Bi-variate correlation matrix between DHI and Cognivue scores

		MEM	VSP	EF	RT	PS
DHI (Emotional)	Pearson Correlation	-0.53*	-0.44*	-0.62*	-0.04	0.28
	Sig. (2-tailed)	0.01*	0.04*	0.00*	0.88	0.19
DHI (Physical)	Pearson Correlation	-0.07	-0.06	-0.10	0.10	-0.06
	Sig. (2-tailed)	0.74	0.78	0.66	0.66	0.79
DHI (Functional)	Pearson Correlation	-0.66*	-0.57*	-0.70*	0.17	0.58*
	Sig. (2-tailed)	0.00*	0.01*	0.00*	0.44	0.00*
DHI (Total)	Pearson Correlation	-0.54*	-0.46*	-0.60*	0.10	0.35
	Sig. (2-tailed)	0.01*	0.03*	0.00*	0.64	0.10

Discussion

Participants who are cognitively impaired on Cognivue® testing are more likely to perform poorly on the SOT component of the CDP. This is suggestive that individual cognitive domains, such as Memory, Executive Function, Visuo-Spatial abilities, processing speed and reaction time affects postural stability. Postural stability has been well correlated with fall risks and hence cognitive impairment may lead to fall risk especially in the elderly population through loss of postural control. Although executive function (EF) has been studied to be the most well correlated with fall risks,[16] EF in this study did not show a greater correlation with postural instability compared to other individual cognitive domains. This could be due to the small sample size, that was not enough to detect a small change expected in the individual cognitive domains. Larger prospective cohort studies on individual cognitive domains and fall risks assessments must be undertaken to understand the specific cognitive domains involved in fall risk and better inform clinicians performing fall risk assessment. The link between cognition and fall risk can be understood from dual tasking paradigms,[4,17-18] which suggest that walking performance relies heavily on cognition. When attention and executive function are compromised with a simultaneous activity, competition for the brain cortical resources[16] will affect gait contro.[14,19]

The correlation between SOT and Cognivue® scoring is, hence, not surprising given the brain's finite cortical resources, which may have to be diverted away from postural control to assist poorer cognitive function. In individuals with Parkinson's Disease (PD), it has been further suggested that cognitive tasks are prioritise over maintenance of equilibrium while walking[20] in a "posture second" approach. Conversely, in cognitively normal adults, there is a priority of maintaining balance over other tasks ("posture-first").[21] Activities of daily living are often attention-demanding, and when cognition is affected in older adults, there is loss of "posture-first" approach, leading to an increase in postural sway, loss of dynamic gait, postural control, and consequently higher occurrences of falls.[12] Individuals with PD, MCI, dementia, and stroke have performed poorly in dual-tasking challenges, allowing it to be used as a tool to predict fall risks in mobility declining adults.[19,22]

Cognition is therefore no doubt, very important for maintaining postural stability. Past studies have correlated bed-side fall risk assessments such as the Time-Up and Go (TUG) and Performance Oriented Mobility Assessment (POMA) with cognition. To our understanding, there has been no study on direct comparison between postural stability on the SOT with a novel cognitive impairment screening tool, Cognivue®. If Cognivue® predicts postural

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stability, this five-minute test can be implemented as part of fall risk assessments, especially in clinical settings where CDP is unavailable. Cognivue® will also not require professionals trained in psychometric assessments to administer, unlike the MoCA. Limitations of this study include a small sample size that may not be sufficiently powered to detect significant small changes in individual cognitive domains. This is also an observational cross-sectional study and the odds-ratio of the relationship between cognitive impairment and SOT scores may be over-estimated. Larger controlled trials with relative risk are warranted to better establish the correlation between cognitive impairment and SOT performance and should include comparison with other fall risks assessment tools such as the dynamic gait index (DGI) for better validity construct. Although DHI had no significant relationship with SOT scores, a different outcome measure such as the Activities Specific Balance Confidence (ABC) scale should have been used instead, as that is more specific in assessing functional and physical competence with balance.

Cognivue® has been validated with other neuropsychological battery of tests, such as the St. Louis University Mental Status (SLUMS) and the Montreal Cognitive Assessment (MoCA). Although it is still unclear if the cognitive domains tested in Cognivue® is comparable with specific sub-tests of standard neuropsychological assessments, it has nevertheless been validated as a psychometric screening tool. For example, the SLUMS naming tasking for language may correlate well with the language domain of Cognivue®. However, it is believed to not be testing similar areas of the brain.[23] Furthermore, Cognivue®'s presentation is all visual, before participants are given a multiple-choice paradigm to recognize and response. This is a limitation for testing memory as it only commits the patient to short term recall.[23] Short-term recall tests are also easier than free recall of information or accessing long term memory to answer test questions.[24] Hence, Cognivue® does not assess some cognitive domains such as long-term memory, language nor abstraction. However, these cognitive domains are not salient when considering fall risk.

Conclusion

In conclusion, cognitive screening tools should never be used in isolation to diagnose neurocognitive disorders, rather, it should be used to assist clinicians in determining if further neuropsychological evaluations are necessary. Despite the limitations of Cognivue®, there are still agreements with standard neuropsychological tests. Of note, in this study cognitive impairment is correlated with an increase in postural instability and fall risks on the CDP. Clinicians should be using validated cognitive screening tools such as Cognivue® as part of a comprehensive fall risk assessment. Future large cohort studies will help to determine which Cognivue® subtests should be selected for optimal sensitivity and specificity to identify cognitive impairment and therefore fall risk.

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