Gait and balance one year after stroke; relationships with lesion side, subtypes of cognitive impairment and neuroimaging findings—a longitudinal, cohort study[☆]

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Abstract

Objectives The aims of this study are to investigate impairments of balance and gait in various types of dementia and cognitive impairment, and neuroimaging correlates in patients one year after first-ever stroke or transient ischemic attack.

Design This is a longitudinal cohort study.

Participants 180 participants were included and a total of 156 participated in the assessments at the one-year follow-up.

Main outcome measures Measurements of balance and gait comprised the Berg Balance Scale (BBS) and the 10 meter walk test (10 MWT). Dementia was diagnosed with the International Classification of Diseases 10th revision. Magnet Resonance Imaging assessed vascular and degenerative changes in the brain. Multivariate linear regressions were conducted regarding associations between the motoric test performances, white matter lesions, lesion of the stroke and cognition.

Results Cognitive impairment was significant associated with BBS ($\beta = -7.28$, $P = 0.005$) and MWS ($\beta = 1.89$, $P = 0.046$) in the linear regression analyses. An association between 10 MWT to living arrangements ($\beta = 1.58$, $P = 0.049$) and lesion side of the stroke ($\beta = -1.50$, $P = 0.037$) was also observed. Pairwise associations with Mann–Whitney U test showed that participants with mixed pathology differed significantly from degenerative pathology ($P = 0.04$, $z = -2.1$) with more impaired balance measured by BBS.

Conclusions Impaired balance and gait are associated with cognitive impairment, and a lesion in the right hemisphere is related to impaired gait in this cohort of stroke survivors.

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Keywords: Stroke; Gait; Balance; Dementia

Introduction

Worldwide, 15 million people suffer a stroke each year, of which one third die, and one third survive with significant disabilities. The most widely recognised impairment caused by stroke is motor impairment [1] which may significantly impact gait and balance. In addition, the prevalence of dementia one year post-stroke is estimated to be up to 40% [2], which may severely impact the quality of life for stroke survivors and their caregivers. Cognitive impairment and dif-

ficulties with mobility often co-exist and current evidence suggests a shared underlying pathophysiology [3]. The risk of poor health-related quality of life is greater in individuals with both gait and cognitive problems, while good mobility or cognition reduce or delay disability or health risks.

The correlation between motor and cognitive impairments has been of great interest to researchers and healthcare providers as it may facilitate early identification of individuals at highest risk for dementia, and generate tailored interventions to best preserve cognitive function [4]. Many etiological subtypes of dementia have demonstrated motor impairment as the disease progresses [5]. Whether this applies to people who have suffered a stroke is not known, but cognitive-motor interference during mobility has been demonstrated [6]. Assessment of cognitive impairment following stroke is complicated by impairments in language, motor and visual-spatial functions, which limit patient participation in standardized testing. Using assessments of motor functions to predict cognitive decline would bypass many of these challenges, but there is a lack of validated, evidence-based methods of motor function to assess cognitive impairment. Converging evidence points to the important role of multiple cognitive domains, especially attention and executive function in explaining the high variability in mobility performance in healthy, frail and demented older adults [7].

Widespread use of Computer Tomography (CT) and Magnetic Resonance Imaging (MRI) has demonstrated frequent cerebral small vessel disease in elderly subjects, which has been shown to be clinically associated with impairments in both cognitive function and gait. Presences of white matter lesions of probable vascular origin have been used as measures of central nervous system abnormality [8]. This correlation has not been consistently reported, and longitudinal studies and studies of participants that have suffered stroke or TIA are limited. In addition, the correlation between lesion topography and gait and balance is poorly understood, yet critical to understanding the complex relationship between higher order cortical functions and the affected anatomical structures of the brain. Damage to the primary motor cortex has consistently been reported as a major determinant of clinical outcome in stroke patients, including global impairment [9]. However, walking entails considerably more complex functions than just voluntary leg strength, and consequently is expected to involve more extensive systems than solely the corticospinal tract [10]. Accordingly, neither Jayaram *et al.* [11] nor Dawes *et al.* [12] found a significant relationship between lesion topography, corticospinal tract overlap and walking speed in the chronic stage after stroke. A recent study exploring left and right lesion relationship in chronic stroke patients with balance and gait found no difference in the performance of balance measured by center of pressure or gait parameters between the groups [13]. Damage to the putamen, insula and external capsule has been found to be related to gait asymmetry after stroke [14].

Dementia may be due to neurodegenerative disorders like Alzheimer's disease (AD) [15] or various types of vascular lesions such as cortical infarcts, lacunar infarcts and subcortical white matter disease [16]. Recent epidemiological and clinico-pathological data indicate considerable overlap between cerebrovascular disease and AD suggesting additive or synergistic effects of both pathologies [17]. There is increasing knowledge of motor impairments in relation to AD. Impaired balance has been shown to be more prevalent in AD than people without the disease [18]. Taken together, there is limited data of impaired balance and gait after stroke and structural changes of the brain. Further research on the early stages of dementia in relation to balance and gait is at an early stage. Future studies will add important knowledge on how physiotherapists and other health personnel can contribute to identifying patients at risk for cognitive decline and dementia.

This study aims characterize impairments in balance and gait in different dementia syndromes including cognitive impairment, correlating these findings with neuroimaging abnormalities in patients one year following first-ever stroke or TIA.

Methods

Participants

All patients with a first-ever stroke or transient ischaemic attack (TIA) admitted to the stroke unit of Bærum Hospital between March 2007 and July 2008 were invited to participate in the study. The Regional Committee for Medical Ethics in South East Norway approved the study and written informed consent was obtained. If the patient was not able to understand the information, the next of kin gave informed consent. All patients were participating in a study evaluating the effect of an intervention on cognitive impairment [19].

Patients with subarachnoid haemorrhage, dementia or Mild Cognitive Impairment (MCI) diagnosed before stroke onset, cognitive decline as indicated by a score >3.7 on the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE), previous stroke or TIA, patients who did not speak norwegian and patients with a remaining life expectancy of less than 1 year as estimated by the treating physician were excluded. The study used the 26-question version of the IQCODE and the IQCODE was filled in by the patient's spouse, a first-degree relative or a close friend.

At baseline

Neurological impairment was assessed using the National Institutes of Health Stroke Scale (NIHSS). Vascular risk factors were recorded and blood-samples were analyzed for the presence of the Apolipoprotein E genotype (ApoEε4). Body weight and height were measured, and Body Mass Index (BMI) calculated. Sociodemograph*i*c characteristics

included gender, age, education (more or less than nine years), living arrangements, and smoking habits. The Trial of Org 10172 in Acute Stroke Treatment classification (TOAST) was used to classify patients with ischemic stroke into five subgroups according to presumed etiological mechanism: cardioembolic disease, large vessel disease, small vessel disease, unusual causes of stroke and stroke of undetermined etiology. The TOAST subgroups were computed into two variables; "small vessel disease" and "other etiological mechanisms." In addition a stroke physician classified the participants according to the Oxfordshire Community Stroke Project classification.

Cognitive functioning was assessed by the MMSE, the Clock Drawing Test, the Trail Making Test A and B (TMT A and B) and the 10-word test (max score 40) including delayed recall from the Repeatable Battery for the Assessment of Neuro-psychological Status and figures from Alzheimer's Disease Assessment Scale-cognitive sub-scale [20]. TMT B was interrupted after 5 minute, but the authors allowed the patients to continue past 5 minute if they insisted. These assessments were performed between days three and seven after the stroke event, and admittance to the hospital.

The registrations of gait and balance were performed by the physiotherapists at the stroke unit, two to six days after the patients were admitted to the hospital [21]. Balance and mobility was assessed using the 10 metre walking test (10 MWT), which is an objective metric for walking ability and a widely used measure of balance, the Berg Balance Scale (BBS). For the 10 MWT subjects walked 10 m from a standing position and the time in seconds was registered. The command was: "Walk as fast as you can without feeling unsafe and without running." The *BBS* consists of 14 observable tasks frequently encountered in everyday life. The test rate performance on a 5- level scale from 0 (cannot perform) to 4 (normal performance) involved functional balance control, including transfer, turning, and stepping. The total score ranges from 0 to 56 [22].

12-month follow-up

Both cognitive and physical assessments were repeated. In addition, the patients underwent a standardized MRI of the brain using Siemens 1.5T MRI scanner. The MRI assessed both the stroke lesion in addition to white matter lesion and regional atrophy. The topographic location was grouped in left or right including cerebellum and brain stem lesion, due to expectations of a higher level of cognitive impairments in lesions located in the left side of the brain. The medial temporal lobe is known to be the initial site of pathological changes of AD [23]. Cerebral atrophy was measured according to the method described by Scheltens *et al.* [24]. Based on the height of the hippocampal formation and the enlargement of the surrounding cerebrospinal fluid spaces, visually assessed on T1 weighted sequences, the Medial Temporal Lobe Atrophy (MTLA) is graded from 0 to 4 (MTLA grade 0 = no atrophy; MTLA 4 = highest degree of atrophy; MTLA zero to one are considered normal values. White matter lesions were quantified on the FLAIR sequences with a semi-automated method in the Nordic lCE Basis Module as earlier described [25]. In these FLAIR images, pixel values in the white matter higher than two SD above mean pixel value of the respective slices were defined as white matter lesions. The total white matter lesions area in all slices were added together and multiplied with slice thickness to obtain total white matter lesions volume (ml). In this material 1,5 ml defined the cut-off volume separating those with minimal white matter lesions from those with moderate and severe ischaemia. This was based on the observation that patients with pencil line lesions along the ventricles and non-confluent small subcortical lesions did not have a total white matter lesions volume exceeding 1.5 ml. Moderate and severe lesions may represent subcortical ischaemic small-vessel disease [24]. Ischemic strokes were assessed by a radiologist with imaging experience blinded to all clinical data.

Diagnosis of cognitive impairment

Dementia and MCI were diagnosed in accordance with clinical practice at the Memory Clinic in our hospital. For dementia, the International Classification of Diseases 10th revision (ICD-10) criteria and for MCI the criteria outlined by Winblad *et al*. The diagnoses were based on the following information: the patient's medical history, the IQCODE, results of the routine cognitive assessments and information regarding the patient's daily functioning – all obtained at 12 months after stroke. Diagnoses were made in consensus meetings by two senior neurologists (B.F and B.T) and one senior geriatrician (A.R.Ø) [26]. Cognitive impairment includes MCI and dementia.

Etiological sub classification of dementia and MCI were made using all available information in order to separate persons with a vascular cause of MCI or dementia from those with a neurodegenerative disease. For both dementia and MCI, the subclassification used MRI findings of vascular and degenerative changes in the brain, the results of biomarkers in the Cerebrospinal fluid and the patients' clinical cognitive profile and vascular risk factors [27,28]. Findings of white matter lesions were classified as vascular disease, MTLA without white matter lesions was interpreted as being of degenerative origin and a combination of white matter lesions and MTLA was diagnosed as mixed vascular and degenerative disease [29]. Thus, the etiological sub classification was not determined by the use of standardized criteria such as the DSM-IV or ICD-10, but rather by using clinical assessments. This method is based on the assumption that post-stroke MCI must also have a defined cause since there is coexistence of vascular lesions and AD pathology in vascular cognitive impairment [29].

Table 1
Baseline characteristics (*N* = 180). Values denote *n (%) or mean [SD].

Variable	
Demographics	
Age (years)	72.1 [12.2]
Gender (female)	88 (49)*
Living arrangement (cohabitant)	122 (67)
Education (>9 years)	140 (78)
Stroke characteristics	
NIHSS	4.33 [6.5]
TOAST (small vessel)	47 (26)*
OCSP (lacunar syndromes)	42 (23)*
Lesion (right)	84 (47)*
Risk factors	
BMI (kg/m^2)	25.6 [4.2]
Current smoking (yes)	39 (22)*
Hypertension (yes)	110 (61)*
ApoEε4 (yes)	3 (2)*
Balance and walking speed	
10 MWT (*n* = 155)	8.8 [2.0]
BBS (*n* = 178)	44.5 [17.6]

N = number of participants included at baseline; mean = mean value; SD = standard deviation; age in years; NIHSS = National Institutes of Health Stroke Scale in points; TOAST = The Trial of Org 10172 in Acute Stroke Treatment classification, small vessel disease or other pathologies; OCSP = Oxfordshire Community Stroke Project, lacunar syndromes or other syndromes; BMI = Body Mass Index in (kg/m^2); ApoE4 = Apolipoprotein 4; *n* = number of participants; 10 MWT = 10 meter walk test in seconds; BBS = Berg Balance Scale in points.

Statistical analysis

Data are given with mean values and standard deviations or with number of participants and percentages. Mann–Whitney U test was conducted for measures of balance and gait comparing participants with cognitive impairment and participants with no cognitive impairment. Based on the study size, explorations of distribution curves and log transformation parametric statistics were applied except when analyzing difference between the three etiological subtypes of dementia. Due to uneven distribution in these groups Kruskal–Wallis tests were conducted [30]. Independent samples t-test was conducted to compare different groups according to structural measurements. Linear regression analyses were conducted regarding associations between the motoric test performances (dependent variables) and white matter lesions, lesion of the stroke and cognition (independent variables). First, univariate analyses were performed. Second, 14 candidate variables were analyzed as possible confounding variables, i.e. age, sex, Apo E alleles, education, vascular risk factors, etiological subtypes of ischemic stroke, and stroke in the right hemisphere (Table 4). Predictors assessed at baseline, structural findings that was assessed at the follow-up, were included in the analyses in order to evaluate the effect on the motoric outcomes of balance and gait. All explanatory variables with a *P*-value <0.20 in unadjusted analyses were included in the multivariate regression models. The authors used all data available for each analysis, which ranged

from *n* = 129 in multivariable analyses to *n* = 156 in univariable analyses. Analyses of multi collinearity were checked to detect any high level of association between independent variables and covariates. Residual plots were inspected, and if the model assumptions were violated, a sensitivity analysis was performed to test the robustness of the results. The sample size was powered to assess difference between two groups regarding cognitive impairment after stroke and TIA [19]. Statistical analyses are performed with the Statistical Package for Social Science (SPSS), version 21 (SPSS (IBM Corporation, NY)). *P*-values <0.05 were considered statistically significant and all tests were two-sided.

Results

A sample of 180 participants with first-ever stroke or TIA were included in this study. A total of 156 of these participated in the registrations 1 year later; 13 had died and 11 refused or were not able to complete the follow-up. Patient characteristics at baseline are presented in Table 1.

In all, 91 of the participants were diagnosed with cognitive impairment (MCI and dementia) at the follow-up (Table 2). Of these, 53 participants were diagnosed with mixed etiology for dementia or MCI, 26 participants with presumed pure vascular dementia or MCI and 12 participants with AD or degenerative MCI. Table 2 shows the results on the balance and gait measures in the different groups as well as for those with no cognitive impairment.

There were significant differences between participants with cognitive impairment and those without (*P* < 0.001) according to balance t = 4.5, mean difference (MD) = 8.5, 95% CI = 4.7 to 12.3, eta squared = 0.12, and gait t = −4.2, MD = −2.8, 95% CI = −4.1 to −1.5, eta squared = 0.10. The magnitude of the differences may be interpreted as moderate to high according to Cohen [31]. A Kruskal–Wallis test showed that there was a statistically significant difference between the different subgroups of dementia and mild cognitive impairment for both outcomes; BBS (X^2 (2) = 5.2, *P* = 0.04) and 10 MWT(X^2 (2) = 8.1, *P* = 0.01). The median values indicate that participants diagnosed with vascular and mixed pathology have more impaired balance compared to patients with AD or degenerative MCI. Pairwise associations in the Mann–Whitney U test proved that mixed pathology differed significantly from AD and degenerative MCI (*P* = 0.04, z = −2.1) with worse results measured by BBS, but the result was not significant in respect to vascular dementia and MCI (*P* = 0.91, z = −1.2). Mixed pathology did not differ significantly from vascular pathology according to the analyses (*P* = 0.10, z = −1.6). For 10 MWT the group with mixed pathology seemed to have the most impaired scores compared to the other groups (Table 2). Pairwise associations in the Mann–Whitney U test show mixed pathology differed significantly from vascular pathology (*P* = 0.006, z = −2.7),

Table 2
Score of BBS and 10 MWT at one year follow-up in subtypes of dementia (*N* = 156). Values denote *n* (%) or median [IQR].

Cognitive impairments	n	10 MWT Median[IQR]	BBS Median [IQR]
Cognitive impairment (all subtypes)	91/156 (58)	6.9 [6.1–10.4]	53.0 [43.0–56.0]
Alzheimer's dementia or degenerative MCI	12/156 (8)	6.9 [5.9–10.3]	54.5 [52.1–56.0]
Mixed dementia or mixed MCI	53/156(34)	7.8 [6.6–11.5]	50.5 [40.3–56.0]
Vascular dementia or vascular MCI	26/156 (17)	6.2 [5.5–6.9]	55.0 [47.0–56.0]
No cognitive impairment	65/156 (42)	5.9 [5.1–6.7]	56.0 [55.0–56.0]

n = number of participants at one-year follow up; median = median value; IQR = Interquartil Range; 10 MWT = 10 meter walk test in seconds; BBS = Berg Balance Scale in points.

Table 3
Score of BBS and 10 MWT at one year follow-up, topographic location and structural measurements (*N* = 156). Values denote *n* or mean [SD] and mean difference (MD) with 95% confidence interval of the difference.

Structural measurements	*n*	10 MWT mean [SD]	95% CI	*n*	BBS mean [SD]	95% CI
Lesion right, cerebellum and brain steam	73	8.4 [5.2]	1.19 (−0.19 to 2.57)	73	49.8 [11.8]	0.06 (−3.8 to 3.9)
Lesion, left	83	7.2 [3.0]		83	49.8 [12.9]	
MTLA, right or left (yes; 2 to 4)	71	8.7 [3.3]	−1.84 (−3.3 to −0.3)	74	46.0 [14.6]	8.2 (4.3 to 12.1)
MTLA, (no; 0 to 1)	71	6.6 [4.2]		70	54.8 [3.4]	
WMLs (yes; >1.5)	89	8.5 [4.7]	1.12 (−0.3 to 2.5)	96	48.0 [13.3]	6.5 (−10.2 to −2.7)
WMLs (no; <1.5)	49	6.3 [2.1]		48	55.0 [2.3]	

n = number of participants at one-year follow up; mean = mean value; SD = standard deviation; 10 MWT = 10 meter walk test in seconds BBS = Berg Balance Scale in points; MTLA, right or left = medial temporal lobe atrophy right side or left side given in grade 0 = no atrophy to 4 = highest degree of atrophy; WMLs = white matter lesions given in ml.

but not to AD (*P* = 0.23, z = −1.2). Vascular pathology and degenerative pathology did not differ significantly (*P* = 0.21, z = −1.2).

Table 3 illustrates scores, mean difference and 95% confidence interval of the difference, in different groups according to structural measurements of the brain. Stroke laterality showed no significant difference between the groups, with left-sided and right-sided strokes scoring equally on the 10 MWT (*P* = 0.29, MD = 1.2) or BBS (*P* = 0.46, MD = 0.1). Further participants with MTLA left or right lobe have worse performance on the outcomes compared to those with no signs of atrophy; 10 MWT (*P* < 0.001); BBS (*P* < 0.001). Participants with identified white matter lesions were significantly different on the BBS (*P* < 0.001, MD = 6.5) but not the 10 MWT (MD = 1.1).

Table 4 illustrates the results of the linear regression analyses including variables of demographic characteristics, stroke subtypes as well as topographic lesion, cognitive impairments and neuroimaging factors included in the study.

Unadjusted linear regression showed significant associations (*P* < 0.05) with both 10MWT and BBS for age, living arrangements, dementia, MTLA right and MTLA left. In addition white matter lesions, BMI, gender and education was associated with BBS in the unadjusted analyses. When subjected to multiple regression analysis, cognitive impairment was significantly associated with both BBS (*P* = 0.005) and 10 MWT (*P* = 0.046). An association between 10 MWT, living arrangements and lesion side (*P* < 0.05) were also observed (Table 3).

Discussion

The main finding of this study is that impairments in balance and gait are associated with dementia and MCI in this cohort of first-ever stroke or TIA. Lesions in the right hemisphere are related to impaired gait, however, cohabitation is associated with better performance on gait measured by 10 MWT. A diagnosis of dementia or mild cognitive impairment is the only variable that is significantly associated with balance as measured by BBS in the adjusted regression analyses. The scores of the motor tasks show that impaired motor function is associated with impaired cognitive function. Participants with AD or degenerative MCI show greater BBS scores compared to participants with mixed and vascular pathologies. This finding might relate to the current diagnostic criteria for dementia where these latter etiological subgroups have affected more regions of the brain.

The findings in this current study that lesion in the right hemisphere are related to impaired gait have not, to our knowledge, previously been reported. However, it is known that the right hemisphere integrates sensorimotor information which is critical for maintaining posture and maintaining sitting and standing positions [32], which may be relevant to our findings. Stroke laterality did not impact balance as much as walking speed, which may relate to the BBS as a relatively static measure of balance. The study by Lopes *et al.* [13], analyzing gait parameters in relation to lesion side did not detect any difference, but the small sample size (*n* = 21) may have impacted the results. The right hemisphere is more important for spatial orientation while the left hemisphere is more

Table 4
Results of unadjusted and adjusted linear regression of the structural and functional measurements and covariates associated to gait and balance one year post-stroke (*n* = 156).

Variable (baseline)	BBS		10 MWT	
	Unadjusted β (*P*)*	Adjusted# β (*P*)**	Unadjusted β (*P*)*	Adjusted# β (*P*)**
Age in years	−0.356 (≤0.001)	−0.176 (0.060)	1.803 (0.003)	0.043 (0.220)
Gender (male = 0)	−6.930 (≤0.001)	−3.183 (0.107)	1.285 (0.068)	
Education (>9 years = 0)	−6.944 (0.003)	−3.923 (0.102)	0.831 (0.355)	
BMI in kg/m² (<25 = 0)	4.093 (0.041)	1.210 (0.531)	−0.585 (0.412)	
Living arrangements (living alone = 0)	6.085 (0.005)	2.067 (0.322)	−2.118 (0.006)	−1.580 (0.049)
Smoking (yes = 0)	1.118 (0.646)		0.306 (0.723)	
Hypertension (yes = 0)	−0.791 (0.698)		−0.393 (0.586)	
TOAST (small vessel = 0)	−4.226 (0.056)	−1.209 (0.703)	0.000 (1.000)	
OCSP (Lacs = 0)	−3.265 (0.158)	−1.272 (0.700)	−0.542 (0.509)	
Lesion (right = 0)	−0.057 (0.977)		−1.190 (0.090)	−1.499 (0.037)
ApoE4 (not having = 0)	2.925 (0.688)		−0.599 (0.816)	
Cognitive impairment (no = 0)	−12.740 (≤0.001)	−7.277 (0.005)	2.636 (0.002)	1.893 (0.046)
MTLA right (<2 = 0)	−8.677 (≤0.001)	−3.344 (0.398)	2.462 (0.001)	2.099 (0.161)
MTLA left (<2 = 0)	−8.915 (≤0.001)	−0.039 (0.993)	2.159 (0.003)	1.281 (0.418)
WML (<1.5 ml = 0)	−0.380 (0.010)	−0.019 (0.895)	0.084 (0.105)	−0.009 (0.875)

BBS = Berg Balance Scale in points; 10 MWT = 10 meter walk test in seconds; BMI = Body Mass Index in numbers; TOAST = The Trial of Org 10172 in Acute Stroke Treatment classification; OCSP = Oxfordshire Community Stroke Project; lesion = affected side of the brain; ApoE4 = Apolipoprotein e4 allele; MTLA = medial temporal lobe atrophy in grade; WML = white matter lesions; β (p) = unstandaridized beta and *P* = level of significance based on univariate regression analyses; β (*P*)** = unstandaridized beta and P = level of significance based on multivariate regression analyses; unadj. = unadjusted analyses; adjust. = adjusted analyses.

important for motor control [33]. In addition, right hemisphere lesions can have significant clinical impact, including body schema alterations, neglect, altered postural alignment and visuomotor impairment [13]. Hemiparetic patients have also shown to compensate for a lack of balance with smaller steps and a slower gait [34]. In this study, both right and left MTLA were significantly associated with worse outcomes measured by BBS and 10 MWT in the unadjusted analyses.

Although the findings were not significant in the multiple regression analyses, the participants with significant white matter lesions had worse mean scores for balance and walking, indicating that there might still be an association that this present study was not able resolve. Earlier studies have shown that white matter ischemic lesions particularly involving the frontal lobe are associated with gait impairment [35]. More specifically, damage to the superior longitudinal fasciculus has been linked to decreased postural stability and widebased gait in elderly subjects [36]. Damage to the uncinate fasciculus, which connects the anterior part of the frontal lobe to the medial and lateral temporal cortex, has been linked to decreased step length and walking velocity, as well as gait apraxia in older individuals [36]. It is known that walking involves a variety of supraspinal areas. The putamen, a node in the subcortical motor loop, is involved in movement initiation, and in the implicit learning and execution of well learned sequences (i.e., procedural memory) including walking and balance, accounting for its apparent role in relearning to walk after stroke [36].

Marriage and living with a partner appears to have a positive effect on overall health outcomes in hospitalized patients, including mental health, and AD [37]. This positive effect may be due to the constant social interaction between partners which can be beneficial for the brain. This is further emphasized by the reported association between a rich social network and lower risk of cognitive impairment and dementia [38]. These findings may also relate to an unknown variable, not included in the data collection, which may have produced a spurious relation between living arrangements and impairment. Nevertheless, in clinical practice health care providers should be aware of people living alone, since they might be extra vulnerable following a stroke or TIA.

This study has several limitations. Since a very select clinical population was recruited, our findings may not be generalizable to other groups not affected by a first-ever stroke or TIA. While the selected measures of balance and gait could be debated, the BBS has been identified as the most commonly used assessment tool across the continuum from acute care to community-based care [39], and there is a strong tradition of using the Berg Balance Scale in our hospital. Excluding patients with pre-stroke cognitive impairment and including patients suffering from TIA and only first-ever stroke patients may have influenced and limited the generalizability of the results. The strength of the study includes the thorough diagnostics related to cognition and motoric performance as well as the longitudinal design [26]. The finding that vascular dementia and MCI might be more affected due to balance may impact clinical evaluation, and increased knowledge of clinical signs may be a valuable contribution to clinical practice. Updated knowledge of clinical findings in persons affected by cognitive impairment or dementia is important for early and accurate diagnosis, and to initiate an early prevention strategy that may delay the onset of cogni-

tive impairments and dementia [40]. The early identification will be of significant importance to the individual and their families.

Measures of balance and mobility may be valuable contributions in identifying patients at risk for impaired cognition at an early stage post-stroke. Research on the different components of physical function such as balance and mobility, and their association with different etiological subtypes of dementia and cognitive impairment may contribute to existing knowledge regarding low-cost tools for assessment of prognosis, prevention and non-pharmacological interventions. Limited research has focused on relationships between the included constructs of balance, gait and cognition, which may be of great importance for the ability to live independently. Stroke survivors, caregivers, health professionals and researchers recently agreed their top ten priorities for future research. Seven of the top ten priorities were related to post-stroke impairments, among them problems with both cognitive function and mobility [41]. More research on these issues is needed since impaired balance and gait can lead to consequences such as falls. We also believe that increased knowledge will lead to better rehabilitation of these patients.

In conclusion, performance on measures of balance and gait are significantly associated with dementia and cognitive impairment in this cohort of first-ever stroke or TIA, and persons diagnosed with vascular and mixed dementia are more impaired on measures of balance compared to AD and degenerative MCI. Some brain regions are involved in both gait and cognition and interventions for one problem may impact the other; exercise has been shown to improve gait and cognition in cohorts of older adults. This group is in need of individually tailored physical activity programs with supportive strategies to counteract emerging cognitive dysfunction. Confirmation of our results should be explored in larger prospective studies including patients with all etiological subtypes of cognitive impairment and dementia. Randomised controlled trials evaluating the benefit of interventions seeking to improve balance and gait and thereby its impact on cognition, is needed, and of interest to those affected as well as healthcare providers.

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