Published in final edited form as:

J Neurol Sci. 2019 June 15; 401: 95–100. doi:10.1016/j.jns.2019.04.035.

Fall Risk in Stroke Survivors: Effects of Stroke Plus Dementia and Reduced Motor functional capacity

Daniel G. Whitney¹, Aviroop Dutt-Mazumder¹, Mark D. Peterson¹, and Chandramouli Krishnan^{1,2,3,4,*}

¹Department of Physical Medicine and Rehabilitation, Michigan Medicine, Ann Arbor, MI, USA

²Biomedical Engineering, University of Michigan, Ann Arbor, MI, USA

³Michigan Robotics Institute, University of Michigan, Ann Arbor, MI, USA

⁴School of Kinesiology, University of Michigan, Ann Arbor, MI, USA

Abstract

Background: Despite extensive research on falls among individuals with stroke, little is known regarding the impact of neurological conditions with comorbid diagnoses and motor functional capacity on the risk of falls in these individuals. Hence, the purpose of this study was to determine the fall risk and the contribution of reduced motor functional capacity to fall risk in individuals with stroke, dementia, and stroke plus dementia.

Methods: Data from the National Health and Aging Trends Study (NHATS), a nationally-representative sample of Medicare beneficiaries, were analyzed for this cross-sectional study. The odds of self-reported falls within the past month in three subgroups of neurological conditions [stroke (n=751), dementia (n=369), and stroke plus dementia (n=141)] were evaluated with a reference group of individuals with no stroke/dementia [i.e., controls (n=6337)] using logistic regression models.

Results: The prevalence of a recent fall was significantly higher ($P<0.05$) in the three neurological disorder groups compared with controls. After adjusting for sociodemographics, mobility device use, and other comorbidities (i.e., chronic disease, vision impairment, and major surgery), the odds of a recent fall were significantly elevated in individuals with stroke (odds ratio [OR]=1.45), dementia (OR=2.45), and stroke plus dementia (OR=2.64) compared with controls. After further adjustment for the lower motor functional capacity, the elevated odds in individuals with stroke were attenuated (OR=1.16); however, the odds remained significantly elevated in individuals with dementia (OR=1.67) and stroke plus dementia (OR=1.82).

***Address for Correspondence:** Chandramouli Krishnan, PT, PhD, Director, Neuromuscular & Rehabilitation Robotics Laboratory (NeuRRo Lab), Department of Physical Medicine and Rehabilitation, Michigan Medicine, University of Michigan, 325 E Eisenhower Parkway (Suite 3013), Ann Arbor, MI - 48108, Phone: (319) 321-0117, Fax: (734-615-1770), mouli@umich.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Declarations of Interest
None

Conclusion: Findings indicate that the odds for falls in stroke survivors are elevated in the presence of comorbid dementia. Further, lower motor functional capacity accounted for increased likelihood of a fall in individuals with stroke, but it was not sufficient to account for the increased likelihood of a fall in individuals with dementia or stroke plus dementia. Thus, interventions focusing on secondary prevention of dementia and improving motor functional capacity may reduce fall risk in individuals with stroke.

Keywords

Dementia; Falls; Motor Function; Balance; Coordination; Hemiparesis

1. Introduction

Falls are a major cause of disability and death in older adults and represent a serious public health concern in the U.S. and worldwide. Stroke survivors are at higher risk for falls, and this risk persists even years after the stroke [1–4]. Moreover, individuals with stroke are also at higher risk of dementia [5], which in itself increases the likelihood of falls [6]. Thus, it is possible that when stroke and dementia exist as comorbid diagnoses, it could lead to a greater risk of falls than stroke or dementia alone. Further, while the etiologies and resulting sequelae of stroke and dementia can differ, both conditions are associated with impairments of motor function [7], such as decreased muscle strength, difficulties with function, poor balance, etc., which are important constituent of fall risk. However, despite extensive research on falls among individuals with stroke, the impact of neurological conditions with comorbid diagnoses and motor functional capacity on the risk for falls after stroke is currently unknown. This information is critical because individuals with stroke and dementia have an accelerated rate of experiencing adverse health outcomes after a fall when compared with the general older adult population [8, 9]. Hence, this study sought to determine the fall risk (i.e., the prevalence and odds of a fall) and the contribution of reduced motor functional capacity to fall risk in individuals with stroke, dementia, and stroke plus dementia.

2. Materials and Methods

2.1. Participants

Data from the 2011 (round 1) National Health and Aging Trends Study (NHATS) were used for this study. NHATS utilized a multistage survey design, sampling Medicare beneficiaries aged 65+, with oversampling of individuals aged 90+ and non-Hispanic Black individuals. Briefly, round 1 utilized a stratified three-stage design that included (1) selection of 95 primary sampling units (i.e., individual or groups of counties), (2) selection of 655 secondary sampling units (i.e., ZIP codes or ZIP code fragments for sampled primary sampling units), and (3) selection of beneficiaries for sampled secondary sampling units. Information pertaining to NHATS study design, methodology, and survey instrumentation (e.g., methods, validation) is available from <https://www.nhats.org/>. The primary exposure variable was the presence of neurological disorder(s), which included individuals with stroke, dementia, and stroke plus dementia. Individuals without stroke or dementia served as a reference population (i.e., controls). Stroke (self-report) and dementia (42% self-report; 58% proxy-report) were determined during the in-person or telephone interview based on

whether the sampled person (or their proxy) was ever told by a doctor that they had that disorder. The prevalence of stroke and dementia in our sample was 9.7% and 4.9%, respectively, which are similar to previous national reports of similar age groups [10, 11]. Exclusion criteria were missing data on variables relating to stroke, dementia, or a recent fall within the past month (n=647). Of the 647 individuals with missing data, 468 were missing because these individuals resided in a nursing home, and the NHATS did not administer the sampled person interview in the nursing home setting. Another 168 completed the facility questionnaire, but did not complete the sampled person interview. Data were assumed to be missing at random for the remaining 11 individuals. The NHATS study protocol was approved by The Johns Hopkins University Institutional Review Board.

2.2. Outcome measure

The outcome variable was a fall (yes/no) within the past month. In the NHATS, falls were defined as “any fall, slip, or trip in which you lose your balance and land on the floor or ground or at a lower level.”

2.3. Covariates

Covariates were chosen based on their relevance to fall risk, stroke, and dementia, and their availability in NHATS. Sociodemographic variables included age (categorized as 65-74 years; 75-84 years; 85+ years), sex (male; female), race (White, non-Hispanic; Black, non-Hispanic; Hispanic; Other, non-Hispanic), weight status as determined by body mass index (categorized as underweight [$<18.5 \text{ kg/m}^2$], normal weight [$18.5\text{-}24.9 \text{ kg/m}^2$], overweight [$25.0\text{-}29.9 \text{ kg/m}^2$], and obese [$>30 \text{ kg/m}^2$], marital status (married [yes/no]), and education (less than High School; High School graduate; Beyond High School). We also adjusted for mobility device use in the past month (yes/no) and various comorbidities such as chronic disease (an indicator [yes/no] for at least one of the following conditions: heart attack, heart disease, high blood pressure, arthritis, osteoporosis, diabetes, lung disease, or cancer [not including skin cancer]), vision impairment (an indicator [yes/no] for any of the following: blind, vision aid use, or unable to see across the street), and major surgery (an indicator [yes/no] for any of the following: knee surgery, hip repair or replacement, cataract surgery, back or spine surgery, or heart surgery at any point in their life). Motor function variables included balance/coordination problems, pain, and fatigue within the past month, as well as physical capacity. The NHATS measured all of these motor function variables except the physical capacity using a YES/NO answer (i.e., presence or absence of a problem) (Table 1). The physical capacity was assessed using validated procedures, which queried individuals about their ability to perform 6 pairs of less and more challenging activities, as described previously[12]. Briefly, these activities included whether the individual could walk 3 (less challenging) or 6 (more challenging) blocks; lift and carry 10 (less challenging) or 20 (more challenging) pounds; bend over (less challenging) or kneel down (more challenging); reach up over head without holding on (less challenging) or put a heavy book on a shelf overhead (more challenging); use fingers to grasp small objects (less challenging) or open a sealed jar (more challenging). Low physical capacity was defined as those who were unable to do any of the less challenging activities. Medium physical capacity was defined as those who were able to do less challenging but not more challenging activities. High physical capacity was defined as those who were able to do all of the more challenging activities.

2.4. Statistical analysis

All participants (stroke [n=751], dementia [n=369], stroke plus dementia [n=141], and controls [n=6,337]) and data for this study were from the first round of the NHATS (2011). All analyses were performed in Statistical Analysis Software (SAS version 9.4 [SAS Institute, Inc., Cary, NC]) using sample weights according to NHATS specifications. The data were weighted to account for the complex survey design, adjust for oversampling, survey nonresponse, and post-stratification, and allow for generalizability of the survey responses to the population represented by the sample. All statistical analyses were performing with 2-sided confidence intervals (CI) and $P<0.05$ to determine statistical significance. Group differences were tested using chi-square tests. Logistic regression was used to determine the odds of a fall within the past month by group (reference: controls). Model 1 adjusted for sociodemographic variables. Model 2 adjusted for the variables in Model 1 and motor function variables. The interactions between group and sociodemographic variables were individually tested, and if not significant, were excluded from the models

3. Results

Descriptive data are presented in Table 1. Of the 1,261 individuals that had a stroke and/or dementia, 47 had missing data (assumed to be random) on at least one sociodemographic or motor function variable (<4% of the sample with a neurological disorder). Of the 6,337 controls, 157 had missing data (assumed to be random) on at least one sociodemographic or motor function variable (<3% of the control participants). Among the four groups, there were significant differences ($P<0.05$) for sociodemographic factors, mobility device use, and comorbidities (Table 1). Individuals with neurological disorders had poorer motor functional capacity compared with controls as determined by balance/coordination problems (all, $P<0.05$), fatigue (all, $P<0.05$), pain (all, $P<0.05$), and physical capacity (all, $P<0.05$). Individuals with dementia and stroke plus dementia had poorer motor functional capacity compared with individuals with stroke as determined by balance/coordination problems and physical capacity (all, $P<0.05$). Individuals with stroke plus dementia had lower physical capacity compared with individuals with dementia ($P<0.05$).

The prevalence of a fall within the past month was 17.0% for stroke, 25.5% for dementia, 31.0% for stroke plus dementia, and 8.8% for controls. The unadjusted odds were significantly elevated in all three neurological disorder groups compared with controls (odds ratio [OR]=2.12-4.67, all $P<0.05$). After adjusting for the sociodemographic variables, mobility device use, and other comorbidities (i.e., chronic disease, vision impairment, and major surgery), the odds remained significantly elevated in all three neurological disorder groups (OR=1.45-2.64, all $P<0.05$). After further adjusting for the motor function variables (model 2), the odds were attenuated in individuals with stroke (OR=1.16; 95% CI=0.88-1.53); however, the odds remained significantly elevated in individuals with dementia (OR=1.67; 95% CI=1.19-2.33) and stroke plus dementia (OR=1.82; 95% CI=1.14-2.89) (Table 2).

4. Discussion

In a large, nationally-representative sample of older adults, we found that individuals with stroke, dementia, and stroke plus dementia had an increased likelihood of a recent fall compared with individuals without neurologic disorders. Further, we found that accounting for motor functional capacity attenuated the elevated odds of a recent fall in individuals with stroke, but not among individuals with dementia or stroke plus dementia. These findings suggest that reduced motor functional capacity is an important factor contributing to the increased fall risk in individuals with stroke; however, other factors may further explain the increased likelihood of falls among individuals with dementia and stroke plus dementia. In addition to functional loss, age-related fall risk reflects a multifaceted etiology across multiple cognitive domains, including executive function, attention, visuospatial ability, and memory [13–15]. Thus, it should come as no surprise that physical function domains may not fully explain the increased likelihood of falls among individuals with cognitive impairments and dementia. The findings help to identify at-risk subpopulations and highlight the complexities of the association between neurological disorders and falls in older adults.

Our findings of an increased likelihood of falls in older adults with stroke or dementia are consistent with previous studies [6, 15–17]. There are a variety of factors that contribute to increased fall risk in the older adult population, including demographics (e.g., age, sex, race) [18, 19], medical history (e.g., prior injuries, surgeries, pain, arthritis, diabetes, neurological disorders, cognitive dysfunction) [15, 19–25], increased health care needs (e.g., medical comorbidities, medications) [17, 26], prior history of falls [18, 27–30], physical impairments [24, 29], and environmental factors [30]. Older adults with neurological disorders may have increased fall risk in part because of their complex health care needs [6, 16, 17]. However, an important constituent of fall risk is motor function, which is impaired in individuals with stroke and/or dementia [6, 7, 31, 32]. Further, older adults with neurological disorders have altered compensatory mechanisms in response to external perturbations [33]. These factors may help to explain their heightened fear of falling [32, 34], which collectively increases their fall risk. In the current study, we found that after accounting for the lower motor functional capacity, the increased odds of a recent fall were attenuated in individuals with stroke, but not among individuals with dementia or stroke plus dementia. This finding is clinically important because motor function preservation through exercise intervention has been shown to reduce falls in older adults with dementia [35, 36]; although, the effects of such exercise interventions to improve balance and falls in stroke survivors are somewhat equivocal [37–42].

To the authors' knowledge, this is the first study to show an increased likelihood of falls in older adults with both stroke and dementia. Evidence from recent studies indicate a greater prevalence of post-stroke dementia in the first year following stroke, with rates of dementia further increasing with severity of stroke and recurrent stroke [5, 43]. Thus, it is possible that the greater odds of falls in those with both stroke and dementia could be partly because of greater sensorimotor issues (e.g., physical disability, pain, fatigue, etc.) caused by a major or recurrent stroke. Unfortunately, we were not able to determine whether dementia was pre- or post-stroke or the number of strokes and its severity. Nevertheless, we found that the fully-

adjusted odds of a recent fall in individuals with dementia and stroke plus dementia were higher than stroke alone suggesting that cognitive and sensorimotor problems that are specific to dementia may contribute to the added risk. Thus, interventions focusing on improving brain health and secondary prevention of dementia are critical for reducing fall risk in individuals with stroke [44–46]. Further, interventions for fall prevention may benefit from tailored efforts based on the presence of stroke, dementia, or stroke plus dementia.

There are also some limitations to this study. First, because of the cross-sectional design, we were unable to determine causality or directionality in the exposure-outcome associations, as well as minimize unmeasured confounding. Second, it is unknown if older adults with pre-stroke dementia have a higher fall risk than post-stroke dementia. Third, data were reported by the respondent and are subject to bias or misreporting; however, most variables had a recall period of 1 month. Fourth, disease severity and age of onset, as well as the condition-specific health care needs (e.g., medications) were not available for analysis. Finally, we did not adjust for environmental factors and prior history of falls, which are significant risk factors for a recent fall [27–30]. We intentionally did not adjust for these factors because the presence of multiple falls is more prevalent in individuals with neurological conditions [47] and accounting for this factor would artificially attenuate the fall risk in these individuals. Similarly, individuals with neurological conditions, particularly those with dementia, may have greater difficulty in navigating through environmental barriers and hence, we believe that it is important not to account for these factors to completely capture how the presence of dementia increases the odds of a recent fall in stroke survivors.

Conclusions

In summary, the results of this study indicate that odds of a recent fall are elevated in stroke survivors in the presence of dementia. Further, motor functional capacity accounts for the increased likelihood of falls in individuals with stroke, but not necessarily among individuals with dementia or stroke plus dementia. Thus, interventions focusing on secondary prevention of dementia and improving motor functional capacity may reduce fall risk in individuals with stroke. The findings also emphasize the importance of clinician awareness and collaboration with advocacy groups and community stakeholders to advance community-based programs and prevention initiatives to minimize falls in older adults with neurological conditions, such as stroke and/or dementia.

Acknowledgments

This work was partly supported by the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR) (Grant # 90AR5020-0200) and National Institutes of Health (NIH) (Grant # R01 EB019834)

Abbreviations

OR	Odds Ratio
CI	Confidence Interval
NHATS	National Health and Aging Trends Study

References

- [1]. Quigley PA, Redesigned Fall and Injury Management of Patients With Stroke, *Stroke* 47(6) (2016) e92–4. [PubMed: 27118792]
- [2]. Minet LR, Peterson E, von Koch L, Ytterberg C, Occurrence and Predictors of Falls in People With Stroke: Six-Year Prospective Study, *Stroke* 46(9) (2015) 2688–90. [PubMed: 26243230]
- [3]. Kao PC, Dingwell JB, Higginson JS, Binder-Macleod S, Dynamic instability during post-stroke hemiparetic walking, *Gait Posture* 40(3) (2014) 457–63. [PubMed: 24931112]
- [4]. Morone G, Iosa M, Pratesi L, Paolucci S, Can overestimation of walking ability increase the risk of falls in people in the subacute stage after stroke on their return home?, *Gait Posture* 39(3) (2014) 965–70. [PubMed: 24440427]
- [5]. Pendlebury ST, Rothwell PM, Prevalence, incidence, and factors associated with pre-stroke and post-stroke dementia: a systematic review and meta-analysis, *Lancet Neurol* 8(11) (2009) 1006–18. [PubMed: 19782001]
- [6]. Allan LM, Ballard CG, Rowan EN, Kenny RA, Incidence and prediction of falls in dementia: a prospective study in older people, *PLoS One* 4(5) (2009) e5521. [PubMed: 19436724]
- [7]. Cotter VT, The burden of dementia, *Am J Manag Care* 13 Suppl 8 (2007) S193–7. [PubMed: 18095782]
- [8]. Coutinho ES, Bloch KV, Coeli CM, One-year mortality among elderly people after hospitalization due to fall-related fractures: comparison with a control group of matched elderly, *Cad Saude Publica* 28(4) (2012) 801–5. [PubMed: 22488325]
- [9]. Scandol JP, Toson B, Close JC, Fall-related hip fracture hospitalisations and the prevalence of dementia within older people in New South Wales, Australia: an analysis of linked data, *Injury* 44(6) (2013) 776–83. [PubMed: 23270698]
- [10]. Centers for Disease Control and Prevention (CDC), Prevalence of stroke--United States, 2006–2010, *MMWR Morb Mortal Wkly Rep* 61(20) (2012) 379–82. [PubMed: 22622094]
- [11]. Beydoun MA, Beydoun HA, Gamaldo AA, Rostant OS, Dore GA, Zonderman AB, Eid SM, Nationwide Inpatient Prevalence, Predictors, and Outcomes of Alzheimer's Disease among Older Adults in the United States, 2002–2012, *J Alzheimers Dis* 48(2) (2015) 361–75. [PubMed: 26402000]
- [12]. Freedman VA, Kasper JD, Cornman JC, Agree EM, Bandeen-Roche K, Mor V, Spillman BC, Wallace R, Wolf DA, Validation of new measures of disability and functioning in the National Health and Aging Trends Study, *J Gerontol A Biol Sci Med Sci* 66(9) (2011) 1013–21. [PubMed: 21715647]
- [13]. Amboni M, Barone P, Hausdorff JM, Cognitive contributions to gait and falls: evidence and implications, *Mov Disord* 28(11) (2013) 1520–33. [PubMed: 24132840]
- [14]. Montero-Odasso M, Oteng-Amoako A, Speechley M, Gopaul K, Beauchet O, Annweiler C, Muir-Hunter SW, The motor signature of mild cognitive impairment: results from the gait and brain study, *J Gerontol A Biol Sci Med Sci* 69(11) (2014) 1415–21. [PubMed: 25182601]
- [15]. Muir SW, Gopaul K, Montero Odasso MM, The role of cognitive impairment in fall risk among older adults: a systematic review and meta-analysis, *Age Ageing* 41(3) (2012) 299–308. [PubMed: 22374645]
- [16]. Simpson LA, Miller WC, Eng JJ, Effect of stroke on fall rate, location and predictors: a prospective comparison of older adults with and without stroke, *PLoS One* 6(4) (2011) e19431. [PubMed: 21559367]
- [17]. Bloch F, Thibaud M, Tournoux-Facon C, Breque C, Rigaud AS, Dugue B, Kemoun G, Estimation of the risk factors for falls in the elderly: can meta-analysis provide a valid answer?, *Geriatr Gerontol Int* 13(2) (2013) 250–63. [PubMed: 23185998]
- [18]. Sun DQ, Huang J, Varadhan R, Agrawal Y, Race and fall risk: data from the National Health and Aging Trends Study (NHATS), *Age Ageing* 45(1) (2016) 120–7. [PubMed: 26764401]
- [19]. Reyes-Ortiz CA, Al Snih S, Loera J, Ray LA, Markides K, Risk factors for falling in older Mexican Americans, *Ethn Dis* 14(3) (2004) 417–22. [PubMed: 15328944]
- [20]. Marshall LM, Litwack-Harrison S, Makris UE, Kado DM, Cawthon PM, Deyo RA, Carlson NL, Nevitt MC, Osteoporotic Fractures in Men Study Research, A Prospective Study of Back Pain

and Risk of Falls Among Older Community-dwelling Men, *J Gerontol A Biol Sci Med Sci* 72(9) (2017) 1264–1269. [PubMed: 27852636]

- [21]. Gokalp O, Akkaya S, Akkaya N, Buker N, Gungor HR, Ok N, Yorukoglu C, Preoperative and postoperative serial assessments of postural balance and fall risk in patients with arthroscopic anterior cruciate ligament reconstruction, *J Back Musculoskeletal Rehabil* 29(2) (2016) 343–350. [PubMed: 26836842]
- [22]. Levinger P, Menz HB, Wee E, Feller JA, Bartlett JR, Bergman NR, Physiological risk factors for falls in people with knee osteoarthritis before and early after knee replacement surgery, *Knee Surg Sports Traumatol Arthrosc* 19(7) (2011) 1082–9. [PubMed: 21107530]
- [23]. Goncalves J, Ansai JH, Masse FAA, Vale FAC, Takahashi ACM, Andrade LP, Dual-task as a predictor of falls in older people with mild cognitive impairment and mild Alzheimer's disease: a prospective cohort study, *Braz J Phys Ther* 22(5) (2018) 417–423. [PubMed: 29636306]
- [24]. Cho K, Yu J, Rhee H, Risk factors related to falling in stroke patients: a cross-sectional study, *J Phys Ther Sci* 27(6) (2015) 1751–3. [PubMed: 26180313]
- [25]. Paul SS, Thackeray A, Duncan RP, Cavanaugh JT, Ellis TD, Earhart GM, Ford MP, Foreman KB, Dibble LE, Two-Year Trajectory of Fall Risk in People With Parkinson Disease: A Latent Class Analysis, *Arch Phys Med Rehabil* 97(3) (2016) 372–379 e1. [PubMed: 26606871]
- [26]. Kropelin TF, Neyens JC, Halfens RJ, Kempen GI, Hamers JP, Fall determinants in older long-term care residents with dementia: a systematic review, *Int Psychogeriatr* 25(4) (2013) 549–63. [PubMed: 23253253]
- [27]. Deandrea S, Lucenteforte E, Bravi F, Foschi R, La Vecchia C, Negri E, Risk factors for falls in community-dwelling older people: a systematic review and meta-analysis, *Epidemiology* 21(5) (2010) 658–68. [PubMed: 20585256]
- [28]. Nevitt MC, Cummings SR, Kidd S, Black D, Risk factors for recurrent nonsyncopal falls. A prospective study, *JAMA* 261(18) (1989) 2663–8. [PubMed: 2709546]
- [29]. Gadkaree SK, Sun DQ, Huang J, Varadhan R, Agrawal Y, Comparison of simple vs. performance-based fall prediction models: data from the National Health and Aging Trends Study, *Gerontol Geriatr Med* 1 (2015).
- [30]. Wing JJ, Burke JF, Clarke PJ, Feng C, Skolarus LE, The role of the environment in falls among stroke survivors, *Arch Gerontol Geriatr* 72 (2017) 1–5. [PubMed: 28482268]
- [31]. Jeong S, Kim J, Prospective Association of Handgrip Strength with Risk of New-Onset Cognitive Dysfunction in Korean Adults: A 6-Year National Cohort Study, *Tohoku J Exp Med* 244(2) (2018) 83–91. [PubMed: 29398690]
- [32]. Vahlberg B, Cederholm T, Lindmark B, Zetterberg L, Hellstrom K, Factors related to performance-based mobility and self-reported physical activity in individuals 1–3 years after stroke: a cross-sectional cohort study, *J Stroke Cerebrovasc Dis* 22(8) (2013) e426–34. [PubMed: 23721615]
- [33]. Patel PJ, Bhatt T, Fall risk during opposing stance perturbations among healthy adults and chronic stroke survivors, *Exp Brain Res* 236(2) (2018) 619–628. [PubMed: 29279981]
- [34]. Tornbom K, Sunnerhagen KS, Danielsson A, Perceptions of physical activity and walking in an early stage after stroke or acquired brain injury, *PLoS One* 12(3) (2017) e0173463. [PubMed: 28273158]
- [35]. Ohman H, Savikko N, Strandberg T, Kautiainen H, Raivio M, Laakkonen ML, Tilvis R, Pitkala KH, Effects of Exercise on Functional Performance and Fall Rate in Subjects with Mild or Advanced Alzheimer's Disease: Secondary Analyses of a Randomized Controlled Study, *Dement Geriatr Cogn Disord* 41(3–4) (2016) 233–41. [PubMed: 27160164]
- [36]. Pitkala KH, Poysti MM, Laakkonen ML, Tilvis RS, Savikko N, Kautiainen H, Strandberg TE, Effects of the Finnish Alzheimer disease exercise trial (FINALEX): a randomized controlled trial, *JAMA Intern Med* 173(10) (2013) 894–901. [PubMed: 23589097]
- [37]. Gerards MHG, McCrum C, Mansfield A, Meijer K, Perturbation-based balance training for falls reduction among older adults: Current evidence and implications for clinical practice, *Geriatr Gerontol Int* 17(12) (2017) 2294–2303. [PubMed: 28621015]
- [38]. Mansfield A, Schinkel-Ivy A, Danells CJ, Aquil A, Aryan R, Biasin L, DePaul VG, Inness EL, Does Perturbation Training Prevent Falls after Discharge from Stroke Rehabilitation? A

- Prospective Cohort Study with Historical Control, *J Stroke Cerebrovasc Dis* 26(10) (2017) 2174–2180. [PubMed: 28579506]
- [39]. Sherrington C, Michaleff ZA, Fairhall N, Paul SS, Tiedemann A, Whitney J, Cumming RG, Herbert RD, Close JCT, Lord SR, Exercise to prevent falls in older adults: an updated systematic review and meta-analysis, *Br J Sports Med* 51(24) (2017) 1750–1758. [PubMed: 27707740]
- [40]. Verheyden GS, Weerdesteyn V, Pickering RM, Kunkel D, Lennon S, Geurts AC, Ashburn A, Interventions for preventing falls in people after stroke, *Cochrane Database Syst Rev* (5) (2013) CD008728. [PubMed: 23728680]
- [41]. Eng JJ, Chu KS, Kim CM, Dawson AS, Carswell A, Hepburn KE, A community-based group exercise program for persons with chronic stroke, *Med Sci Sports Exerc* 35(8) (2003) 1271–8. [PubMed: 12900678]
- [42]. Eng JJ, Pang MY, Ashe MC, Balance, falls, and bone health: role of exercise in reducing fracture risk after stroke, *J Rehabil Res Dev* 45(2) (2008) 297–313. [PubMed: 18566947]
- [43]. Pendlebury ST, Rothwell PM, Oxford Vascular Study, Incidence and prevalence of dementia associated with transient ischaemic attack and stroke: analysis of the population-based Oxford Vascular Study, *Lancet Neurol* 18(3) (2019) 248–258. [PubMed: 30784556]
- [44]. Liu-Ambrose T, Barha CK, Best JR, Physical activity for brain health in older adults, *Appl Physiol Nutr Metab* 43(11) (2018) 1105–1112. [PubMed: 30306793]
- [45]. McGough EL, Lin SY, Belza B, Becofsky KM, Jones DL, Liu M, Wilcox S, Logsdon RG, A Scoping Review of Physical Performance Outcome Measures Used in Exercise Interventions for Older Adults With Alzheimer Disease and Related Dementias, *J Geriatr Phys Ther* 42(1) (2019) 28–47. [PubMed: 29210934]
- [46]. McGough E, Kirk-Sanchez N, Liu-Ambrose T, Integrating Health Promotion Into Physical Therapy Practice to Improve Brain Health and Prevent Alzheimer Disease, *J Neurol Phys Ther* 41 Suppl 3 (2017) S55–S62. [PubMed: 28628597]
- [47]. Ozturk TC, Ak R, Akoglu EU, Onur O, Eroglu S, Saritemur M, Factors associated with multiple falls among elderly patients admitted to emergency department, *International Journal of Gerontology* 11(2) (2017) 85–89.

Highlights

- Effect of dementia and motor function on falls among stroke survivors is unknown
- Odds of a recent fall is elevated in stroke survivors in the presence of dementia
- Lower motor capacity accounts for increased fall risk *only* in stroke survivors
- Secondary prevention of dementia may reduce fall risk in individuals with stroke

Table 1.

Descriptive characteristics of study participants (n=7,598).

	Stroke (n=751)	Dementia (n=369)	Stroke and dementia (n=141)	Controls (n=6,337)
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Age				
65-74 years	41.4 (37.0, 45.8) ^{D,S+D,C}	16.3 (11.1, 21.6) ^{S,C}	24.3 (17.6, 31.0) ^{S,C}	56.1 (54.9, 57.3)
75-84 years	39.6 (36.2, 42.9) ^C	43.0 (37.8, 48.2) ^C	39.4 (29.6, 49.2)	32.6 (31.7, 33.6)
85+ years	19.1 (15.9, 22.2) ^{D,S+D,C}	40.6 (35.9, 45.4) ^{S,C}	36.2 (28.1, 44.4) ^{S,C}	11.2 (10.5, 12.0)
Sex				
Male	43.6 (39.3, 48.0)	35.3 (30.5, 40.0) ^C	39.2 (29.2, 49.1)	43.7 (42.1, 45.4)
Female	56.4 (52, 60.7)	64.7 (60.0, 69.5) ^C	60.8 (50.9, 70.8)	56.3 (54.6, 57.9)
Race				
White, non-Hispanic	80.2 (77.5, 82.9)	72.9 (67.7, 78.1) ^C	75.5 (68.9, 82.2)	82.0 (80.3, 83.7)
Black, non-Hispanic	9.6 (8.0, 11.3)	10.9 (8.6, 13.1)	13.7 (9.2, 18.3) ¹	7.9 (7.1, 8.7)
Hispanic	6.2 (4.1, 8.4)	11.1 (6.8, 15.3)	9.9 (4.6, 15.1)	6.6 (5.6, 7.7)
Other, non-Hispanic	3.9 (2.2, 5.7) ^{S+D}	5.2 (2.6, 7.7) ^{S+D}	0.9 (0.3, 1.5) ^{S,D,C}	3.5 (2.6, 4.4)
Weight status				
Underweight	5.2 (3.3, 7.0) ^{D,S+D}	15.1 (10.8, 19.5) ^{S,C}	13.4 (7.6, 19.2) ^{S,C}	5.2 (4.3, 6.1)
Normal weight	30.4 (26.0, 34.8) ^D	44.0 (37.2, 50.8) ^{S,C}	38.8 (30.2, 47.3)	30.4 (29.1, 31.8)
Overweight	37.7 (33.9, 41.5) ^D	24.8 (19.5, 30.0) ^{S,C}	28.1 (19.6, 36.5)	36.9 (35.5, 38.4)
Obese	26.7 (22.2, 31.2) ^D	16.1 (11.8, 20.4) ^{S,C}	19.8 (12.3, 27.2)	27.5 (26.0, 29.0)
Married				
Yes	47.2 (42.8, 51.6) ^{D,C}	37.0 (31.4, 42.6) ^{S,C}	41.6 (32.7, 50.4) ^C	56.5 (55.0, 58.0)
No	52.8 (48.4, 57.2) ^{D,C}	63.0 (57.4, 68.6) ^{S,C}	58.4 (49.6, 67.3) ^C	43.5 (42.0, 45.0)
Education				
Less than High School	29.3 (25.3, 33.3) ^C	37.3 (31.4, 43.2) ^C	39.0 (26.8, 51.2) ^C	20.1 (18.4, 21.8)
High School graduate	27.3 (23.2, 31.5)	31.4 (25.4, 37.4)	37.3 (28.5, 46.1)	27.3 (25.8, 28.8)
Beyond High School	43.3 (39.2, 47.5) ^{D,S+D,C}	31.3 (25.1, 37.4) ^{S,C}	23.8 (13.1, 34.4) ^{S,C}	52.6 (50.3, 54.9)
Chronic diseases				
Yes	97.5 (95.9, 99.0) ^C	95.0 (91.9, 98.2) ^C	98.1 (96.4, 99.8) ^C	88.9 (88.1, 89.7)
No	2.5 (1.0, 4.1) ^C	5.0 (1.8, 8.1) ^C	1.9 (0.2, 3.6) ^C	11.1 (10.3, 11.9)
Mobility device use				
Yes	44.3 (40.5, 48.1) ^{S+D,C}	53.6 (46.8, 60.5) ^{S+D,C}	72.3 (64.8, 79.8) ^{S,D,C}	20.0 (18.9, 21.0)
No	55.7 (51.9, 59.5) ^{S+D,C}	46.4 (39.5, 53.2) ^{S+D,C}	27.7 (20.2, 35.2) ^{S,D,C}	80.0 (79.0, 81.1)
Vision impairment				

	Stroke (n=751)	Dementia (n=369)	Stroke and dementia (n=141)	Controls (n=6,337)
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Yes	77.4 (73.8, 81.0) ^C	75.1 (69.1, 81.1) ^C	70.6 (62.2, 79.0) ^C	71.9 (70.9, 73.0)
No	22.6 (19.0, 26.2) ^C	24.9 (18.9, 30.9) ^C	29.4 (21.0, 37.8) ^C	28.1 (27.0, 29.1)
Major surgery				
Yes	76.3 (72.6, 79.9) ^C	67.8 (63.0, 72.6) ^{S+D,C}	80.5 (74.0, 87.0) ^{D,C}	58.3 (56.9, 59.8)
No	23.7 (20.1, 27.4) ^C	32.2 (27.4, 37.0) ^{S+D,C}	19.5 (13.0, 26.0) ^{D,C}	41.7 (40.2, 43.1)
Balance/coordination problems				
Yes	48.8 (44.3, 53.3) ^{D,S+D,C}	67.1 (62.2, 71.9) ^{S,C}	76.6 (67.3, 85.8) ^{S,C}	23.6 (22.2, 25.0)
No	51.2 (46.7, 55.7) ^{D,S+D,C}	32.9 (28.1, 37.8) ^{S,C}	23.4 (14.2, 32.7) ^{S,C}	76.4 (75.0, 77.8)
Fatigue				
Yes	62.7 (58.9, 66.5) ^C	66.9 (61.1, 72.7) ^C	71.8 (63.3, 80.4) ^C	41.0 (39.4, 42.6)
No	37.3 (33.5, 41.1) ^C	33.1 (27.3, 38.9) ^C	28.2 (19.6, 36.7) ^C	59.0 (57.4, 60.6)
Bothered by pain				
Yes	60.5 (55.7, 65.4) ^C	64.8 (59.3, 70.3) ^C	64.9 (58.2, 71.6) ^C	51.5 (49.8, 53.2)
No	39.5 (34.6, 44.3) ^C	35.2 (29.7, 40.7) ^C	35.1 (28.4, 41.8) ^C	48.5 (46.8, 50.2)
Physical capacity				
Low	60.7 (57.0, 64.5) ^{D,S+D,C}	81.5 (76.6, 86.3) ^{S+D,C}	92.8 (87.9, 97.6) ^{S,D,C}	31.8 (30.4, 33.3)
Medium	23.6 (20.5, 26.8) ^{D,S+D,C}	9.3 (5.4, 13.2) ^{S,C}	2.7 (0.0, 6.6) ^{S,C}	31.0 (29.5, 32.5)
High	15.6 (12.6, 18.7) ^{S+D,C}	9.2 (5.8, 12.7) ^C	4.5 (1.2, 7.8) ^{S,C}	37.2 (35.7, 38.6)

CI, confidence interval; chronic disease includes heart attack, heart disease, high blood pressure, arthritis, osteoporosis, diabetes, lung disease, or cancer (not including skin cancer).

^D Different compared with dementia, $P < 0.05$.

^{S+D} Different compared with stroke plus dementia, $P < 0.05$.

^S Different compared with stroke, $P < 0.05$.

^C Different compared with controls, $P < 0.05$.

Table 2.

Prevalence and multivariable logistic regression for the association with fall in the past 1 month.

	Prevalence (n=7,598)	Unadjusted (n=7,598)	Model 1 (n=7,480)	Model 2 (n=7,394)
	%	OR (95% CI)	OR (95% CI)	OR (95% CI)
Controls	8.8	Reference	Reference	Reference
Stroke	17.0	2.12 (1.70, 2.65)	1.45 (1.12, 1.87)	1.16 (0.88, 1.53)
Dementia	25.5	3.55 (2.65, 4.76)	2.45 (1.78, 3.38)	1.67 (1.19, 2.33)
Stroke and dementia	31.0	4.67 (2.92, 7.47)	2.64 (1.62, 4.30)	1.82 (1.14, 2.89)
Age				
65-74 years			Reference	Reference
75-84 years			0.96 (0.79, 1.15)	0.94 (0.78, 1.13)
85+ years			0.82 (0.61, 1.09)	0.82 (0.62, 1.09)
Sex				
Male			Reference	Reference
Female			0.89 (0.76, 1.05)	0.80 (0.68, 0.95)
Race				
White, non-Hispanic			Reference	Reference
Black, non-Hispanic			0.64 (0.53, 0.78)	0.67 (0.56, 0.81)
Hispanic			0.80 (0.55, 1.17)	0.71 (0.47, 1.05)
Other, non-Hispanic			0.88 (0.53, 1.45)	0.90 (0.54, 1.50)
Weight status				
Underweight			0.92 (0.61, 1.39)	0.90 (0.59, 1.37)
Normal weight				
Overweight			0.92 (0.70, 1.2)	0.93 (0.71, 1.23)
Obese			0.93 (0.70, 1.22)	0.87 (0.65, 1.17)
Married				
Yes			0.93 (0.77, 1.13)	1.00 (0.83, 1.21)
No				
Education				
Less than High School			Reference	Reference
High School graduate			0.74 (0.61, 0.89)	0.82 (0.67, 1.00)
Beyond High School			0.67 (0.56, 0.81)	0.78 (0.65, 0.95)
Chronic diseases				
Yes			1.48 (1.01, 2.18)	1.04 (0.71, 1.54)
No			Reference	Reference
Mobility device use				
Yes			3.14 (2.64, 3.74)	1.62 (1.26, 2.08)
No			Reference	Reference
Vision impairment				
Yes			1.2 (0.94, 1.52)	1.05 (0.82, 1.35)
No			Reference	Reference
Major surgery				

	Prevalence (n=7,598)	Unadjusted (n=7,598)	Model 1 (n=7,480)	Model 2 (n=7,394)
	%	OR (95% CI)	OR (95% CI)	OR (95% CI)
Yes			1.29 (1.03, 1.61)	1.10 (0.88, 1.38)
No			Reference	Reference
Balance/coordination problems				
Yes				3.65 (3.00, 4.43)
No				Reference
Fatigue				
Yes				1.12 (0.92, 1.37)
No				Reference
Bothered by pain				
Yes				1.49 (1.20, 1.85)
No				Reference
Physical capacity				
Low				1.41 (1.00, 1.99)
Medium				1.12 (0.83, 1.52)
High				Reference

OR, odds ratio; CI, confidence interval.

Model 1:

$$\log_e \left(\frac{fall}{1 - fall} \right) = \beta_0 + \beta_1(group) + \beta_2(age) + \beta_3(sex) + \beta_4(race) + \beta_5(weight\ status) + \beta_6(martial\ status) + \beta_7(education) + \beta_8(chronic\ disease) + \beta_9(mobility\ device) + \beta_{10}(vision\ impairment) + \beta_{11}(major\ surgery)$$

Model 2:

$$\log_e \left(\frac{fall}{1 - fall} \right) = \beta_0 + \beta_1(group) + \beta_2(age) + \beta_3(sex) + \beta_4(race) + \beta_5(weight\ status) + \beta_6(martial\ status) + \beta_7(education) + \beta_8(chronic\ disease) + \beta_9(mobility\ device) + \beta_{10}(vision\ impairment) + \beta_{11}(major\ surgery) + \beta_{12}(balance\ and\ cordination) + \beta_{13}(fatigue) + \beta_{14}(pain) + \beta_{15}(physical\ capacity)$$