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Moving towards an understanding of disability in older US stroke survivors

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Abstract

Objectives—We test a comprehensive model of disability in older stroke survivors, and determine the relative contribution of neighborhood, economic, psychological and medical factors to disability.

Methods—The sample consisted of 728 stroke survivors from the National Health and Aging Trends Study (NHATS), who were 65 years and older living in community settings or residential care. Confirmatory factor analysis and structural equation modeling were used to test relationships between neighborhood, socioeconomic, psychological and medical factors and disability.

Results—Economic and medical context were associated with disability directly and indirectly through physical impairment. Neighborhood context was associated with disability, but was only marginally statistically significant ($p=0.05$). The effect of economic and neighborhood factors was small compared to that of medical factors.

Discussion—Neighborhood and economic factors account for a portion of the variance in disability among older stroke survivors beyond that of medical factors.

Keywords

Disability; stroke survivors; neighborhood; socioeconomic status; structural equation modeling

Stroke is a leading cause of disability among older adults in the United States. Up to 30% of stroke survivors are unable to walk without assistance, 25-75% require help or are fully dependent in activities of daily living (ADL), and many experience limitations in social participation (Hartman-Maeir, Soroker, Ring, Avni, & Katz, 2007; Miller et al., 2010; Ostwald, Davis, Hersch, Kelley, & Godwin, 2008; Patel et al., 2006; Skolarus, Burke, Brown, & Freedman, 2014). Stroke is unique in that it has a sudden and potentially

Additional materials related to this research can be accessed by contacting the corresponding author.

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unexpected effect on individual's physical and cognitive functioning and communication, which influence participation in a range of activities and quality of life post-stroke {Mayo, 2002 #4}. In addition to its impact on the quality of life, disability results in significant physical, psychological and economic burdens on the stroke-survivor, family and community; as well as a substantial financial burden on the health care system (Cameron, Tsoi, & Marsella, 2008; Ostwald, et al., 2008). The societal impact of stroke is heightened as it also exacerbates racial and ethnic disparities in health. The incidence of stroke is higher and stroke results in greater post-stroke disability for Black and Hispanic Americans compared to Whites (Burke et al., 2014; Ellis et al., 2015), suggesting that minority stroke survivors, families, and communities may experience a disproportionate share of this physical, psychological and financial burden.

Given the impact of post-stroke disability, and the potential for recovery (Miller, et al., 2010), it is critical to identify a comprehensive set of risk and protective factors related to disability in older, community dwelling stroke survivors in order to intervene to optimize health. Medical factors including stroke severity, treatment, and rehabilitation during the acute and post-acute stages of stroke care are associated with post-stroke disability (Outpatient Service, 2004; Trialists'Collaboration, 1997) and the risk of recurrent stroke (Jørgensen, 1997), but these factors do not function in isolation from the economic, social and community context. Disablement models depict disability as a function of a health condition (e.g., stroke), body functions and structures, and contextual factors extrinsic (e.g., physical environment) and intrinsic (e.g., race/ethnicity) to the individual (Freedman, 2009; World Health Organization, 2001; Verbrugge & Jette, 1994). Disablement models have been used extensively in understanding the causes of disability and how to best intervene to reduce disability and related health outcomes (Clarke, Ailshire, & Lantz, 2009; Clarke & George, 2005; Hammel et al., 2015; Lien, Guo, Chang, Lin, & Kuan, 2014). These models, however, have not been widely or systematically applied to post-stroke disability. Developing a more comprehensive model of disability in stroke survivors would be useful to inform the design of interventions and policies to reduce disability experienced post-stroke.

Researchers have established the importance of environmental, psychosocial and socioeconomic factors in the causal mechanisms of chronic diseases, morbidity, and mortality (Diez Roux et al., 2001; House, Landis, & Umberson, 1988; Link & Phelan, 1996). Although researchers have not yet examined multi-factorial models of post-stroke disability, there is evidence that neighborhood, psychosocial, and economic factors influence disability in the general population (Coppin et al., 2006; de Leon, Glass, & Berkman, 2003; Freedman, Grafova, Schoeni, & Rogowski, 2008; Nusselder, Looman, & Mackenbach, 2005; T. E. Seeman, Unger, McAvay, & de Leon, 1999). Research on post-stroke disability, however, has primarily focused on medical and health correlates such as age, comorbidities and lower extremity functioning (Johanne Desrosiers et al., 2006; J Desrosiers, Noreau, Rochette, Bravo, & Boutin, 2002; Kwakkel, Wagenaar, Kollen, & Lankhorst, 1996).

Although researchers have begun to establish associations between neighborhood context and disability (Balfour & Kaplan, 2002; Botticello, Rohrbach, & Cobbald, 2014; Clarke, et al., 2009; Freedman, et al., 2008), it has not been integrated into a larger conceptual model including intra- and interpersonal factors, and the causal mechanisms remain unknown

(Pruchno, Wilson-Genderson, & Cartwright, 2011). The residential neighborhood environment may be particularly salient for older adults with disability, as they are more likely to spend more time close to home, less likely to drive, and more likely to be socially isolated (Glass & Balfour, 2003; Verbrugge & Jette, 1994). We hypothesize that neighborhood factors influence post-stroke disability above and beyond individual-level socioeconomic resources, through their impact on individuals' physical functioning. For example, neighborhoods with physical disorder (e.g., litter, graffiti) may have more crime and violence, or may be perceived as less safe. This could result in less time spent outside of the home and fewer opportunities for physical activity and social engagement for stroke survivors. Additionally, physically disordered neighborhoods also may have more structural problems including broken sidewalks, or may lack safe road crossings (de Leon et al., 2009; Ross & Mirowsky, 2001), which may discourage walking and other forms of physical activity that are imperative for rehabilitation and wellbeing post-stroke. Physical disorder may also erode community social support/cohesion (Taylor, Repetti, & Seeman, 1997) and health care resources, resulting in suboptimal access to rehabilitation and care for stroke survivors. Researchers have found that living in neighborhoods with multiple problems such as excessive noise and litter increases the risk of physical impairment twofold in older adults (Balfour & Kaplan, 2002).

There is less evidence to support a causal mechanism between psychosocial factors and disability, although substantial research supports connections between social factors and chronic disease incidence, including stroke (T. E. Seeman, 1996; Venna & McCullough, 2011). Psychosocial factors have not been tested as a risk factor for disability in stroke survivors, and only a handful of studies have included them as risk factors for disability in the general population. Limited research has found associations between social support/isolation, social engagement (de Leon, et al., 2003), self-efficacy (de Leon, Seeman, Baker, Richardson, & Tinetti, 1996; T. E. Seeman, et al., 1999), locus of control (Nusselder, et al., 2005) and psychological functioning and disability among older adults (Bruce, Seeman, Merrill, & Blazer, 1994). In a review of the literature, researchers concluded that depression/depressive symptoms and having limited social contacts were among the most influential risk factors for disability (Stuck et al., 1999). Severe depressed mood after stroke was associated with close to three times the odds of being severely disabled up to two years post-stroke (Willey et al., 2010). Based on existing evidence, we hypothesize that psychological factors will exert an effect on disability through functional decline associated with decreases in physical activity and rehabilitation, and increases in social isolation.

Researchers have also established associations between socioeconomic status (SES) and disability (Bettger et al., 2014; Chen et al., 2015; Minkler, Fuller-Thomson, & Guralnik, 2006; G. A. van den Bos, J. P. Smits, G. P. Westert, & A. van Straten, 2002). In a recent study, researchers found that adults who perceived themselves to have inadequate income before age 70, and those who were retired or unemployed/homemakers pre-stroke, had increased odds of disability three months post stroke (Bettger, et al., 2014). Due to the large financial burden suddenly incurred by older adults who suffer a stroke, economic resources are likely to directly and indirectly contribute to disability. Individuals with more economic resources can more easily afford formal help and caregiving (Skolarus, Burke, & Freedman, 2014) to facilitate daily activities, transportation to access to medical care, medications

(Levine et al., 2007), as well as home modifications and/or repairs such as installing ramps and grab bars, which also reduce disability (Gitlin, 2003; Szanton et al., 2015).

In light of the scarcity of research on the mechanisms connecting environmental factors to post-stroke disability, we will examine a multi-factorial model of physical disability in elderly stroke survivors. We hypothesize that the neighborhood, economic, and psychological context, along with current health status, will be associated with post-stroke disability through direct and indirect pathways (Figure 2). These factors are likely to be correlated, as we would expect individuals' economic context to influence medical factors; and economic context to be associated with the neighborhood. Thus, by simultaneously considering all of these factors and their correlations using structural equation modeling, we will capture the inter-relatedness of these constructs and address a potentially important limitation of prior work where single factors are considered in isolation. We will also determine the relative contribution of neighborhood, psychological, and socioeconomic influences on physical disability compared to medical influences in this population. The goal of this work is to ultimately identify factors that may be included in interventions to improve post-stroke function. For example, while the benefits of rehabilitation for well-being post-stroke are well established (Outpatient Service, 2004), access to rehabilitation varies by residence (Newhouse & Garber, 2013), psychosocial capacity and economic factors (Cook, Stickley, Ramey, & Knotts, 2005; Ottenbacher & Graham, 2007). Therefore, it is critical to identify non-medical factors related to disability on which to intervene, as well as factors that might help target sub-populations of stroke survivors at greatest risk for experiencing more severe disability.

Methods

Data and measures

Data are from the National Health and Aging Trends Study (NHATS), a nationally representative longitudinal study of the health and well-being of 8,245 Medicare recipients ages 65 and older in the United States (Kasper & Freedman, 2015). NHATS was designed to assess later life functioning within a broad aging and disability. NHATS used age-stratified random sampling to obtain a representative sample of Medicare recipients in which black and the oldest adults were oversampled (Montaquila, Freedman, & Kasper, 2012a). Baseline interviews were conducted in 2011 to collect data on disability, physical capacity, health, assistive device use, sociodemographic and neighborhood factors. Information related to the home and neighborhood environment was also collected via interviewer observation. For this study we examined a subset of stroke survivors living in the community or in a residential care facility (not a nursing home), and who completed a baseline interview (N=892). Stroke survivors were self-identified based on the following question: "Has a doctor ever told you that you had a stroke?" Participants with non-missing data for the primary variables were included in the final models (N=728).

Dependent variables and mediator—Disability was measured by difficulty with self-care activities and mobility. NHATS includes detailed assessment of these items by assessing difficulty completing the activity in relation to using assistive devices and help

from others. Our self-care measure was adapted from Freedman et al. (2011), and includes: eating, dressing, toileting, bathing/washing. Individuals were categorized into fully able, successful accommodation with a device, reductions in activities, high difficulty, and needs assistance disability groups. The “fully able” category was assigned a 1, and the subsequent categories were labeled accordingly with “needs assistance” assigned a 5 to reflect the highest degree of difficulty with the activity. The four items were summed to create a final self-care difficulty score for stroke survivors, where higher values denote more disability (range=4-20). We also included three measures of mobility: difficulty getting out of bed (transferring), getting around inside and getting around outside. Mobility was also assessed in relation to difficulty, device use, and assistance, and then categorized into the same five levels of difficulty with mobility where higher values correspond to more difficulty (range=1-5). Models included the summed self-care difficulty score, and the three separate measures of mobility.

Physical impairment was assessed by an expanded version of the Short Physical Performance Battery (SPPB) (Vasunilashorn et al., 2009), a reliable measure of lower extremity functioning that is predictive of mobility, disability and mortality (Guralnik et al., 1994). NHATS' expanded SPPB assesses gait speed over a 3 meter walk, balance in several standing positions, time to rise rapidly from a chair, grip strength and peak air flow (Kasper, Freedman, & Niefeld, 2012). NHATS used an established scoring approach where scores from each of the five activities are summed, with higher scores reflecting higher functioning (range = 0-20) (Guralnik, et al., 1994). We created a physical impairment measure by reverse coding the SPPB score so that higher values correspond to more impairment. A moderate amount of missing data (13%) was generated in the performance measures if participants were not able to perform the activities due to constraints in their home (e.g. not enough space for the walk). Participants with missing SPPB scores were more likely to be female, non-White, lower income, have worse self-rated health and more self-care difficulty.

Medical factors—Chronic disease burden was included as a sum of multiple comorbid conditions. Participants were asked to report whether a doctor diagnosed them with any of nine chronic conditions in the past year (heart attack, heart disease, hypertension, cancer, lung disease, osteoporosis, dementia, arthritis, diabetes). The first question (SF-1) from the SF-36 was used to assess perceived or self-rated general health in NHATS (Ware & Sherbourne, 1992). Participants rated their health on a 5-point scale of “excellent” to “poor” and responses ranging from “excellent” to “good” were combined. The final self-rated health measure ranges from 1 (good) to 3 (poor). An indicator of multiple past year hospital stays was created based on participants' reports of the number of times they had a separate, overnight hospital stay in the past year. Participants who reported two or more hospital stays in the past year were assigned a 1 and were otherwise assigned a 0 for the indicator. Number of past year surgeries was included as a continuous variable based on a count of hip, back/spine, cataract and heart surgeries. Participants also reported on whether they fell down in the past 30 days or had broken or fractured their hip since the age of 50, and indicators of past month falls and broken hip were created. Body mass index (BMI, lbs/in²) was created by multiplying participants' current weight by a scaling factor (703) and then dividing by their squared height in inches. BMI was included in models as a continuous variable.

Economic factors—Educational attainment was assessed using nine categories and then collapsed into: less than high school, high school graduate/equivalent, and beyond high school. Total family income from all income and assets of the sample person and spouse was reported. Income information was obtained for 69% of the sample and NHATS conducted an imputation using cylindrical hot deck imputation methods to create five imputed values for total income (31%) (Montaquila, Freedman, & Kasper, 2012b). To operationalize the imputed income values, a median over the five imputed datasets was computed for individuals with missing income data. Due to a highly skewed distribution, a natural log transformation of income was used in the analysis. Occupation was assessed by asking participants to report the type of work they did most of their life and coded using the 2010 Census Occupational Classification (<http://www.bls.gov/cps/cenocc.pdf>). A professional/managerial occupation indicator was created by combining professional, managerial, business and financial categories. Participants were asked to report how financially well off their family was when they were growing up, and a 5-level ordinal measure of childhood socioeconomic position (SEP) was created that ranged from poor to well-off. An indicator of whether participants received any financial help/gifts from family in the past year was included as an additional measure of financial strain.

Psychological factors—Depressive and anxiety symptoms were assessed in NHATS using the PHQ-2 and GAD-2 (Kroenke, Spitzer, Williams, & Löwe, 2009). Participants were asked how often over the past month they experienced the following: had little interest/pleasure in doing things; felt down, depressed or hopeless; felt nervous, anxious or on edge; and were unable to stop or control worrying. Response options ranged from 1=not at all to 4=nearly every day. Depressive and anxiety symptoms were created by taking the mean of the two items, and higher values correspond to more depressive/anxiety symptoms (range for both scales=0-3).

Neighborhood factors—The immediate neighborhood environment outside of participants' homes was assessed by interviewer reports on the presence of litter, graffiti, vacant houses and foreclosure signs. Interviewers were asked: "when standing in front of the sample person's home/building, and looking around in every direction, how much of the following did you see?" Response options ranged included none, a little, some or a lot. An ordinal measure of neighborhood items ranged from 0-4, where higher values correspond to more neighborhood physical disorder. Participants reported on social aspects of their community including: whether people know each other well; whether people are willing to help each other; and whether people can be trusted. Response options ranged from 1=agree a lot to 3= do not agree, where higher values denote less social cohesion.

Covariates—Gender, age and race were included as covariates in the structural models. Age was available in NHATS as a 5-level categorical variable. These categories were collapsed into three for the current analysis: 65-74, 75-84, 85 and higher. The youngest age group was used as the reference category. Participants self-reported their primary race and ethnicity and an indicator of minority status (non-White vs. White) was created to use as a covariate in the models. Physical activity was assessed by a question about whether

participants engaged in any vigorous activity that caused them to sweat or breathe heavily over the past 30 days (yes/no).

Analysis

We used the two-step approach to develop a model of disability among stroke survivors (Anderson & Gerbing, 1988). In the first stage we first validated our measurement model using a confirmatory factor analysis (CFA) of *a priori* neighborhood, economic and medical factors we identified in NHATS that supported our hypothesized model of risk factors of disability among older stroke survivors (Appendix 1). We allowed for correlations between all constructs and validity and appropriateness of the measurement model was evaluated based on a combination of goodness of fit indices, strength of factor loadings (moderate=0.2-0.5; strong $\geq$ 0.50), modification indices and theory (Anderson & Gerbing, 1988; Kline, 2005). In the second stage we tested our hypothesized structural model, which included age category and gender as demographic covariates of physical impairment and disability, and directional structural paths from the medical, psychological and economic latent constructs to disability. We also included indirect paths to disability through physical impairment, as we hypothesized that some of the effect of the medical, economic and neighborhood context influenced disability through physical impairment. Minority status was then added to the structural model to account for the effect of race on associations between the latent factors and physical impairment and disability. Lastly, physical activity was added as a covariate with a direct path to physical impairment and disability, based on the potential for several of the latent factors to influence physical activity and the importance of physical activity to physical impairment and disability.

Several indicators in the model were categorical so the diagonally weighted least squares (DWLS) estimator was used (Jöreskog, 1990). The CFA and SEM models were fit to the covariance matrix (Appendix 2). Model fit was evaluated using the chi-square test statistic, the Root Mean Square Error Approximation (RMSEA), The Comparative Fit Index (CFI), Tucker Lewis Index (TLI), and Weighted Root Mean Square Residual (WRMSR). We used the following criterion for evaluating adequate model fit: RMSEA 0.05, CFI 0.95, TLI 0.95 and WRMSR 1 (Yu, 2002). Additionally, standardized path coefficients, covariances, and R^2 for the latent constructs were evaluated and reported for each model. Our sample size was adequate to test for a close-fitting model for the measurement model based on 71 degrees of freedom, a desired power of 0.80, a null RMSEA of 0.05 and an alternative of 0.08 (MacCallum, Browne, & Sugawara, 1996).

Data management was performed in Stata (StataCorp, 2015). The EFA/CFA and SEM were conducted using the lavaan package in R (Rosseel, 2012). NHATS uses multi-stage survey sampling, which typically requires survey methods to correctly adjust statistical analyses. The lavaan package does not allow for application of survey methods with the DWLS estimator, however, and thus the analyses were not adjusted for survey weights. Our results will therefore not be nationally representative, and instead represent results for NHATS stroke survivors (Korn & Graubard, 1991). Sensitivity analyses were performed to assess whether the model results were sensitive to survey weights by testing a model in which the neighborhood latent construct was omitted, and indicators in the medical latent construct

were specified as continuous. Survey methods were used to estimate the modified SEM and the results of this model were compared to an identical model run without the survey weights. Coefficients from both models were similar and the substantive conclusions were the same.

Results

Descriptive results for the sample are presented in Table 1. Approximately 44% of the sample was between ages 75 and 84, and 26% were 85 years or older. Of the 728 participants with non-missing data, 44% were male and 33% were non-White. Difficulty with self-care activities was relatively low (mean=8.33, interquartile range (IQR)=3), as 40% of participants reported no difficulty (with or without assistive devices) on all four activities of daily living. The average degree of physical impairment assessed using the SPPB, however, was moderate and corresponds to a level that is indicative of risk for developing mobility difficulty (Guralnik, et al., 1994)(mean=12.16, IQR=8).

Measurement model

Indicators of the latent constructs were tested using a confirmatory factor analysis (Appendix 1). Prior to initial model evaluation the graffiti neighborhood indicator of was dropped from the model because of numerous empty cells. The hypothesized five factor model fit the model poorly (X^2 (degrees of freedom, DF) = 697.93(242), $p < 0.01$; RMSEA=0.05 (0.047,0.056); CFI=0.91; TLI=0.90; WRMR=1.49) and several indicators had low factor loadings.

We re-specified the model by first dropping indicators with low factor loadings (less than 0.3; past year surgeries, BMI, financial help, childhood SEP) and re-examined the measurement model. The fit of this model was improved, but was still not a good fitting model. Based on examination of the modification indices, theoretical considerations, and a goal of retaining the best fitting and most parsimonious model, we removed the neighborhood social cohesion items and retained the more objective physical disorder items from interviewer observation. The indicators had moderate to high loadings on their respective factors, and minimal cross-loadings with other factors (Figure 1). Loadings were generally high (>0.50) except for multiple hospital stays, which was retained for theoretical rationale. Latent constructs were generally moderately to highly correlated except for the correlations between neighborhood context with psychological and medical factors; and disability. Our final measurement model fit the data well (Table 2; $X^2 = 159.65(109)$, $p < 0.01$; RMSEA=0.02 (0.015,0.027); CFI=0.99; TLI=0.98; WRMR=0.99).

Structural model

Age and gender were included as covariates in the structural model for associations between neighborhood, economic, psychological and medical factors and disability (Appendix 3). The model resulted in an adequate fit of the data ($X^2 = 280.50(170)$, $p < 0.01$; RMSEA=0.03 (0.024,0.036); CFI=0.98; TLI=0.97; WRMR=1.09; Table 2). Economic and medical factors were directly associated with disability (Standardized regression coefficient (β_{std})=0.13, $p > 0.01$; β_{std} =0.50, $p < 0.01$ respectively), and were indirectly associated through physical

impairment, although effect sizes were small ($\beta_{\text{std}} = -0.04$, $p=0.02$; $\beta_{\text{std}} = 0.17$, $p<0.01$ respectively; Table 2). Psychological factors were not associated with physical impairment or disability and neighborhood factors were marginally associated with physical impairment, although effects were small ($\beta_{\text{std}} = 0.11$, $p=0.05$). As expected, physical impairment was associated with disability ($\beta_{\text{std}} = 0.42$, $p<0.01$). Membership in the middle and oldest age group was associated with more physical impairment, and being in the oldest age group was associated with more disability (not shown). Men had more physical impairment than women, but there was no difference in disability by gender. The structural model (Appendix 4) was then adjusted for minority status in the regression models for physical impairment and disability. The model fit declined from the previous model ($X^2 = 480.53(186)$, $p<0.01$; RMSEA=0.05 (0.042, 0.052); CFI=0.94; TLI=0.92; WRMR=1.38), although the regression coefficients; covariance, variance and R-squared estimates; and indirect and total effects remained largely unchanged (Table 2-3). Minority race was associated with more physical impairment ($\beta_{\text{std}} = 0.20$, $p<0.01$) and more disability ($\beta_{\text{std}} = 0.09$, $p=0.01$). A measure of vigorous activity was then added to the final model on physical impairment and disability. Vigorous activity was negatively associated with physical impairment ($\beta_{\text{std}} = -0.22$, $p<0.01$) but was not associated with disability (Table 3).

The addition of vigorous activity attenuated the association between economic context and physical impairment to non-significance, and slightly increased the strength of the association between neighborhood context and impairment (Table 3). The final structural model explained approximately 51% of the variance (R^2) in physical impairment and 66% in the latent disability construct. Variance estimates for the economic, psychological and medical latent constructs were moderate (0.53, 0.47 and 0.58 respectively), indicating that approximately half of the total variance remained unexplained by the indicators. The variance for the neighborhood latent construct was large; approximately 67% of the variance in this construct was not explained by the physical disorder indicators of the neighborhood. The latent factors were associated with disability primarily through direct pathways and only minimally through physical impairment. The total indirect effects are almost fully accounted for by the indirect pathway between medical factors and disability, and while the indirect paths between economic and neighborhood factors are significant, they are small (see decomposition of effects in Table 2).

Alternative Models

Three plausible equivalent models were evaluated using the recommended methods of the replacing rule (Lee & Hershberger, 1990). Based on theory we tested the possibility of reverse causation where physical impairment causes an individual's neighborhood, economic, psychological and medical context. We also tested a model of medical causation where an individual's health status causes their neighborhood and economic context; and finally a model of economic causation where an individual's socioeconomic status causes their neighborhood, psychological and medical context. The medical causation model resulted in the closest fit to our final hypothesized model, but it fit the data slightly worse ($X^2 = 533.65(204)$, $p<0.01$; RMSEA=0.05 (0.042, 0.052); CFI=0.93; TLI=0.91; WRMR=1.40) and it is unlikely that current medical state is responsible for causing

individuals' economic context given that educational attainment and primary occupation typically preceded their health status.

Discussion

This study is the first to test a multi-factorial model of disability in elderly stroke survivors, and to determine the relationships between factors and their relative contribution to disability. The final model explained 66% of the variance in disability, which suggests that the constructs included in our model contribute to the mechanisms through which stroke survivors experience disability. Our results provide some evidence that neighborhood and economic factors are associated with disability, and account for a portion of its variance among elderly stroke survivors beyond that of medical factors. We found that while the economic and neighborhood context were associated with physical impairment and disability among stroke survivors, their contribution was small compared to that of medical factors.

We found that stroke survivors with lower SES had worse physical impairment, which is consistent with previous research (Coppin, et al., 2006). This association, however, was reduced to non-significance when we accounted for past month vigorous activity, suggesting that physical activity plays a role in stroke survivors' physical impairment, and may confound the association between socioeconomic context and impairment. A recent theory-driven data mining study found that physical activity was the strongest correlate of disability in stroke survivors {Yoon, 2016 #1218}. Economic factors were also associated with disability, and not affected by accounting for physical activity. The association, however, is negative; lower SES is associated with less disability, independently of impairment, which is in contrast to the few other studies of SES and disability in stroke survivors (Bettger, et al., 2014; Chen, et al., 2015; Grube et al., 2012; G. Van Den Bos, J. Smits, G. Westert, & A. Van Straten, 2002). Associations between SES and disability vary, however, by individual characteristics such as gender, pre-stroke health status, stroke type and assessment time since stroke (Chen, et al., 2015; Putman et al., 2007; G. A. M. van den Bos, J. P. J. M. Smits, G. P. Westert, & A. van Straten, 2002). The effect of SES on post-stroke disability also may diminish over time (Putman, et al., 2007; G. A. van den Bos, et al., 2002), so it is possible that our results represent a more long-term relationship between SES and post-stroke disability. There is also a possibility that stroke survivors with the most disability are under-represented in our sample, and that the most disabled individuals who are in the sample are higher SES. Higher SES stroke survivors are more able to buy help and other assistance to function with disabilities in the community, allowing them to remain in our sample. This selection bias could account for the unexpected relationship between more economic resources and higher disability. We interpret our results with caution because of the small effect size for the association between economic factors and disability. Future research could further investigate the mechanisms through which SES influences disability in stroke survivors, as these relationships are likely to be complex and may include interactions with health behaviors; access to/utilization of healthcare services; and the use of assistive devices and caregiving.

Elderly stroke survivors living in the community are unique in that they suddenly and simultaneously experience physical, communication, and cognitive limitations that together make it difficult to navigate their physical and social environments. Stroke survivors have been found to have more participation restrictions than demographic- and comorbidity-matched non-stroke survivors (Skolarus, Burke, Brown, et al., 2014), which provides further evidence of the vulnerability of this population. We found limited evidence that the neighborhood context was associated with physical impairment in stroke survivors. Although the association did not reach statistical significance, the relative size of the effect was close to that of the economic-physical impairment association, which suggests that the neighborhood may still play a role in physical impairment for stroke survivors. After accounting for vigorous activity, the association between neighborhood context and physical impairment increased slightly. This provides more evidence that even after accounting for physical activity, neighborhoods may influence post-stroke disability, and thus research that further investigates which aspects of the neighborhood are most influential would be beneficial. We were limited in our measurement of the neighborhood by data and modeling constraints — as only 28% of the neighborhood latent construct was explained by existing data. Thus, it is possible that a more comprehensive neighborhood construct that includes more objective measures of economic context, racial/ethnic composition, and crime; would result in a stronger association with physical impairment. Only one other study has addressed the neighborhood environment as a source of risk for physical impairment/disability in stroke survivors, and this study was limited in size (N=51), and representativeness (did not include racial minorities), as well as in measurement of disability. Exploratory work related to how the neighborhood context influences disability in elderly stroke-survivors would be useful for developing more accurate and comprehensive models. Although results from our model indicated that the neighborhood had only a small influence on impairment among stroke survivors, in the context of more general evidence that the neighborhood is associated with disability and physical impairment (Balfour & Kaplan, 2002; Clarke, et al., 2009; Freedman, et al., 2008), future research in stroke survivors is warranted. This is particularly critical given that neighborhood factors may be modifiable or point to modifiable strategies to reduce disability.

Stroke has been identified as a risk factor for depression (Whyte, Mulsant, Vanderbilt, Dodge, & Ganguli, 2004), and individuals with depressive symptoms may have reduced capacity to engage in physical activity and rehabilitation, which are important for maintaining and improving physical function and disability (Hackett & Anderson, 2005). We did not find evidence to support associations between psychological factors and physical impairment or disability in our sample of stroke survivors. Results of previous research are mixed (Bruce, et al., 1994; LeBrasseur, Sayers, Ouellette, & Fielding, 2006; Lenze et al.; Penninx, Leveille, Ferrucci, Van Eijk, & Guralnik, 1999; T. Seeman & Chen, 2002; Whyte, et al., 2004). It is possible, however, that disability precedes depression in stroke survivors or that a bi-directional association exists (Hackett & Anderson, 2005). In sensitivity analyses we examined a model of reverse causation and found that both disability and physical impairment were strongly associated with depression, although the model fit was poor. Psychological attributes such as self-efficacy, mastery and sense of control may be more strongly associated with physical functioning, impairment, and with disability (Kempen, van

Sonderen, & Ormel, 1999; T. Seeman & Chen, 2002; T. E. Seeman, et al., 1999), and thus a broader latent construct of psychological context may better address how these factors influence disability among stroke survivors. Better elucidation of the temporal relationship between depression and disability in stroke survivors may also inform initiatives to reduce disability.

Medical factors were strongly associated with disability directly and through physical impairment. Although much of the research on disability post-stroke focuses on health and medical causes (Johanne Desrosiers, et al., 2006; Kwakkel, et al., 1996), the results from our model suggest that health/medical factors are inter-connected with other aspects of stroke survivors' built, economic and psychological environments. Medical factors were, in fact, correlated with neighborhood, economic and psychological factors in our final model. Disablement models have long recognized the contribution of environmental factors to disability more broadly (World Health Organization, 2001; Verbrugge & Jette, 1994), despite the absence of them in the post-stroke disability literature. Given the intricate relationships between neighborhood, economic, psychological and medical factors and disability; it is likely that the effect of these factors on disability are interdependent, which was accounted for, but not tested in our model. For example, although the direct association between neighborhood context and disability was small, it is possible that there is a larger indirect of neighborhood on disability via psychological, economic or medical factors. Given the potential for intervening on aspects of the neighborhood or psychological factors, research that further probes these complex relationships is warranted.

Our results also indicate that the neighborhood and economic context is associated with disability primarily through pathways that are independent of physical impairment, which is notable given that physical impairment/functioning is typically perceived as a precursor of disability (Latham, 2014; World Health Organization, 2001). It is possible that this applies to a more traditional medical model of disability, but that environmental and economic factors influence disability directly or through other mediators such as physical activity and rehabilitation. Disablement models also hypothesize that environmental factors interact with physical impairment to influence disability (World Health Organization, 2001), and thus future research could also investigate how these factors modify the relationship between physical impairment and disability. Overall, our results suggest that in order to most effectively intervene on disability in stroke survivors, it may be necessary to consider the effect of the neighborhood, and economic and psychological characteristics of individuals in addition to their current health and medical context. Given that stroke is an interesting model disease for disablement due to its potential to result in sudden and severe acute disablement, results from this research may be generalized to other severe acute disabling conditions (e.g. MI-related disability). This may be an important area for future disability research.

A major limitation of this study was the omission of several important indicators of the neighborhood, social and psychological context. While NHATS includes unique, rich data on physical functioning and disability, NHATS does not measure all potential conceptually relevant factors contributing to disability, including aspects of the psychosocial and neighborhood context. Having a more comprehensive set of indicators to assess each latent construct may change our results in favor of a stronger effect of non-medical factors on

physical impairment and disability, particularly for neighborhood factors where existing data incompletely captured the latent construct. Nonetheless, our study is the first to assess multiple contributors to disability post-stroke based on disablement models. Additionally, we are limited by the cross-sectional nature of the data, which does not permit causal inference or directional conclusions. Our results may also be biased by differential selection into our sample of community living stroke survivors, as was noted previously. Additionally, restricting our analyses to a community sample may introduce some selection bias.

This research is also affected by some of the limitations inherent to structural equation models. One such limitation is that while a model with adequate fit statistics is indicative that the model fits the data well, this does not provide definitive evidence that the model is a correct representation of the data (Kline, 2005). In our sensitivity analyses we considered several alternative models, however, which help support the plausibility of our proposed model. Future research that uses longitudinal data would be beneficial in further substantiating the model examined in this study. The missing SPPB data was not missing at random and may have biased our results. In sensitivity analyses we also examined a model that included a self-report physical impairment scale with less missingness – which we have used in previous research and is described in detail elsewhere (Skolarus, Burke, Brown, et al., 2014; Skolarus, Burke, & Freedman, 2014) – and the substantive conclusions from the model and model fit did not change. Lastly, although elderly individuals may not reliably self-report previous strokes, research indicates high agreement between medical record diagnoses and self-report of stroke (Okura, Urban, Mahoney, Jacobsen, & Rodeheffer, 2004).

Despite these limitations, a comprehensive framework of post-stroke disability was tested by simultaneously modeling and accounting for multiple correlated constructs that are likely to influence disability in elderly stroke survivors. While limited research has addressed specific relationships between a potential causal factor and disability after stroke, this study is progress towards developing a more complete understanding of the array of environmental and medical factors that influence disability in older stroke survivors. Although we were limited in the measurement of certain constructs, our analysis benefited from the thorough and previously validated measurement of physical impairment and disability. We included an objective, performance based measure of physical impairment that has been established as a predictor of mobility; and a novel and multi-faceted measures of disability that is sensitive to interactions between individuals' difficulty performing activities in the context of their environment (Freedman, et al., 2011).

Elderly stroke survivors are particularly vulnerable to their physical, psychosocial and economic environment because of the suddenness of the onset of their physical impairments and disability as well as their potentially extensive cognitive, physical and communication deficits. Thus identifying a comprehensive set of factors that contribute to their disability post-stroke is critical for identifying those stroke survivors at greatest risk for disability, and developing effective interventions to reduce disability. Medical factors are significant contributors to disability in this population, yet it is often difficult to intervene on these factors. By determining factors extrinsic to the individual such as the neighborhood or

psychological context, on which it is possible to intervene, it is possible to reduce disability for older stroke survivors and improve their quality of life.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Standardized regression coefficients for the fully adjusted structural model with controls for age, gender, minority status and vigorous activity. Significant ($\alpha > 0.05$) regression coefficients and correlations are indicated in bold font.

Figure 2. Retained measurement model including standardized factor loading of indicators on the respective latent constructs and correlations between factors. Non-significant relationships ($\alpha = 0.05$) denoted as NS.

Table 1
Description of stroke survivors in the National Health and Aging Trends Study (NHATS)
included in the final structural equation model, N=728

	Mean (SD)/%	Range
Age (%)		
65-74	30.48	
75-84	43.81	
85 and older	25.71	
Male (%)	44.22	
Minority (%)	32.65	
Self-care difficulty	8.33 (4.83)	4-20
Mobility difficulty		
Transferring	2.42 (1.50)	1-5
Indoor	2.51 (1.55)	1-5
Outdoor	2.68 (1.66)	1-5
Physical impairment	12.16 (4.35)	0-20
Chronic disease burden	4.21 (1.60)	1-9
Self-rated health (%)		
Good	53.74	
Fair	30.07	
Poor	16.19	
Multiple hospital stays in past year (%)	13.88	
Falls in past month (%)	17.14	
Depressive symptoms	0.77 (0.85)	0-3
Anxiety symptoms	0.71 (0.86)	0-3
Education (%)		
< High school	33.61	
High school diploma/GED	52.52	
Beyond high school	13.88	
Total family income (\$10,000) ^a	3.20 (3.40)	0-23.07
Professional/managerial occupation (%)	27.76	
Neighborhood disorder (%)		
Litter	13.47	
Vacancy	8.30	
Foreclosure	3.54	
Vigorous activity	21.1	

Note. NHATS = National Health and Aging Trends Study

^aNatural log transformed income was used in all analyses

Table 2

Fit indexes (χ^2 , Root Mean Square Error Approximation (RMSEA), Comparative Fit Index (CFI), Tucker Lewis Index (TLI), Weighted Root Mean Square Residual (WRMSR)) and decomposition of effects for the measurement and structural models.

	χ^2 (DF)	RMSEA	CFI	TLI	WRMR	ID Econ	ID Med	ID Total	Total
Final measurement model	159.65 (109)	0.02	0.99	0.98	0.99				
Structural model w/ adjustment for age and sex	280.50 (170)	0.03 (0.02,0.04)	0.98	0.97	1.09	-0.04	0.17	0.14	0.83
Structural model w/ adjustment for minority status	480.53 (186)	0.05 (0.02,0.05)	0.94	0.92	1.38	-0.04	0.17	0.13	0.80
Fully adjusted structural model (adjustment for vigorous activity)	496.01 (202)	0.05 (0.04,0.05)	0.94	0.92	1.35	-0.02 (NS)	0.16	0.15	0.81

ID = Indirect effects; Total = Sum of total indirect and direct effects; NS=Non significant

Note: Indirect effects for Psychological context not included because they were non-significant for all models

Table 3
Standardized parameter estimates for the relationships between the latent constructs, minority status and vigorous activity with physical impairment (SPPB) and disability

	Structural model w/ adjustment for age and sex	Structural model w/ adjustment for minority status	Fully adjusted structural model (adjustment for vigorous activity)
Neigh → SPPB	0.114 *	0.092 *	0.099 *
Econ → SPPB	-0.106 ***	-0.095 ***	-0.052
Psych → SPPB	0.014	0.011	0.006
Medical → SPPB	0.417 ***	0.409 ***	0.406 ***
Minority → SPPB		0.201 ***	0.163 ***
Vigorous activity → SPPB			-0.244 ***
Econ → Disability	0.125 ***	0.108 ***	0.108 ***
Psych → Disability	0.069	0.072	0.076
Medical → Disability	0.504 ***	0.485 ***	0.478 ***
SPPB → Disability	0.417 ***	0.411 ***	0.402 ***
Minority → Disability		0.086 **	0.077 **
Vigorous activity → Disability			-0.058

*
p<0.10,

**
p<0.05,

p<0.1