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Rural–Urban Differences in Cognitive Outcomes Among Older Adults: The Roles of Falls and Depressive Symptoms

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Abstract

Background: Older adults with Alzheimer's Disease and Related Dementias (ADRD) experience a higher risk of falls. However, research lacks evidence on the effect of fall exposure on cognitive impairment and dementia. We investigated the association of falls and depressive symptoms with cognitive impairment and dementia in a nationally representative sample. **Methods:** We analyzed data from 6221 participants (age $\geq$ 65) in the Health and Retirement Study (HRS) from the 2018–2020 waves, using Multinomial logistic regression models. Measures included the HRS health status questionnaire, HRS cognition scale, and the Center for Epidemiological Studies Depression scale. **Results:** Prevalence of fall exposure across cognition levels was 44.61% for dementia, 37.76% for cognitive impairment, and 32.16% for normal cognition. Having at least one fall exposure in the last 24 months significantly increased odds of having dementia by 42%, while the relationship between fall exposure and cognitive impairment was non-significant. Depressive symptoms were also associated with cognitive impairment and dementia. The stratified analysis by residential areas revealed that having a fall exposure increased the likelihood of having cognitive impairment by 26% and dementia by 73% in urban residents. However, the association between fall exposure and cognitive outcomes was not significant in rural settings. Depressive symptoms increased the odds of cognitive impairment in both strata, with a larger effect size in rural settings (OR = 2.23, 95% CI [1.41, 3.54]). Conversely, the association between depressive symptoms and dementia was only significant in urban settings (OR = 3.20, 95% CI [1.99, 5.15]). **Conclusions:** Falls and depressive symptoms were significantly associated with the odds of cognitive impairment and dementia, with significant differential effects between rural and urban older adults.

Keywords: falls; depressive symptoms; cognitive impairment; dementia; ADRD

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1. Introduction

An estimated 6.2 million Americans aged 65 years and older suffer from Alzheimer's Disease and Related Dementias (ADRD), which comprise neurodegenerative disorders

such as Alzheimer's Disease, Lewy body, Parkinson's, and Huntington's diseases [1,2]. Alzheimer's dementia is the fifth-leading cause of death among Americans aged 65 and older, disproportionately affecting multicultural older adults living in rural areas [2,3]. The most recent studies indicate that falls may be an early indicator of ADRD as they are associated with future diagnosis of dementia [4,5]. However, research focusing on the impact of falls on cognitive impairment and dementia is still developing. The World Health Organization defines falls as "inadvertently coming to rest on the ground, floor, or other lower level, excluding intentional change in position to rest in furniture, wall, or other objects" [6]. Understanding the role of falls in the continuum of ADRD is essential to develop timely and tailored fall prevention interventions for older adults in different cognitive impairment stages, from mild cognitive impairment to severe dementia (ADRD will be referred to as dementia throughout this manuscript). Such interventions may also delay future cognitive deterioration of older adults, particularly in underserved rural areas, where the accessibility of healthcare services is limited.

1.1. Falls and Cognitive Impairment

There is a complex and reciprocal relationship between falls and cognitive impairment, with each potentially contributing to or the consequence of the other [6]. Older individuals with cognitive impairment are at greater risk of experiencing falls [1] and experience higher incidence of fall-related injuries compared to cognitively intact individuals [7]. The risk of falls and fall-related injuries are even higher among individuals with dementia due to severe gait and balance dysfunction [8,9]. Cognitive impairment in specific cognitive domains, such as executive functioning and attentional resources, has also been associated with a history of repeated falls [10]. In addition to activity-limiting physical injuries from falls, most fallers report psychosocial and behavioral effects of fall exposure that may affect their cognitive abilities [11,12]. Among older adults with mild cognitive impairment, reduced functional status, longer times on walking and dual-task assessments, and increased depressive symptoms were linked to falls [13]. In contrast, a study conducted among institutionalized older patients found that the prevalence of falls was lower among patients with cognitive decline than among cognitively intact patients [14].

A growing body of literature focuses on the deleterious effects of falls on the development of cognitive impairment and dementia. For instance, in a study with an 8-year follow-up, researchers showed that cognitively intact older adults with a high risk of falls at baseline were 74% more likely to develop cognitive impairment [15]. Results from the Korean Longitudinal Study of Aging showed an association between fall exposure and developing dementia, but not cognitive impairment [16]. In contrast, a study in the United States showed that repeated falls increased the risk of future cognitive decline two-fold [17], while another study conducted on participants of seven nationally representative aging studies (N = 20,036) revealed that multiple falls, weak hand grip, poor sleep, and hearing were associated with motor cognitive dysfunction in older adults [18]. Ordoobadi and colleagues [19] also conducted a large-scale cohort study among older adults admitted to the emergency department. They found that dementia diagnosis was more prevalent within a year of fall-related injuries (10.6%) compared to other injury mechanisms (6.1%), while their analytic results showed that falling significantly increased the risk of dementia, after controlling for demographics, comorbidities, and injury characteristics. A longitudinal population-based study conducted among 9279 community-dwelling individuals younger than 65 years old investigated whether the experience of falls in the past two years had an impact on cognitive functioning, after adjusting for all possible confounding variables [20]. The same study demonstrated that cognitive functioning scores among individuals with a

history of falling were 0.13 points lower than those of individuals without fall experience, suggesting that fall events may contribute to subsequent cognitive decline.

1.2. Rural and Urban Differences

Although these findings support the idea that falls can be a marker of cognitive impairment, evidence is inconclusive on how falls relate to cognitive impairment and dementia in different residential areas. Older adults in rural areas mostly rely on a primary care provider for diagnosis and treatment. They are less likely to receive a comprehensive neuropsychological assessment, which results in delayed dementia diagnosis and symptom management, especially in early stages [21]. Studies showed that the prevalence of Alzheimer's dementia in rural areas is at least twice as high as in metropolitan areas [3,22]. Estimates of ADRD in rural areas of the United States indicate lower prevalence, lower post-diagnosis survival rates, and higher incidence than in metropolitan counties [22]. Conversely, despite unique health challenges and limited resources, rural older adults showed better verbal memory than their urban counterparts, suggesting greater resilience in rural areas [23]. For fall-related disparities, most studies report a higher incidence and risk of falls among rural older adults compared to their urban counterparts [24,25]. A study showed that the prevalence of fall exposure was much higher (16.5%) among rural older adults than among urban older adults (10.7%) [24]. Consistent with the literature, we previously found that the odds of falling were 15% higher among rural older adults than those living in urban areas [26]. Although research independently shows higher dementia and fall risks, a gap exists on how living areas modify the relationship between falls and cognitive status.

1.3. Depressive Symptoms

Depressive symptoms were often reported as a significant correlate of falls and cognition with limited evidence on the relationship between depressive symptoms and cognitive outcomes in rural–urban areas. In a meta-analysis of 23 cohort studies, Diniz and colleagues [27] demonstrated that older adults with depression had an increased risk for all-cause dementia, vascular dementia, and AD dementia. We also showed that older adults with depression had a higher odds of developing cognitive impairment (44%) and dementia (78%) compared to cognitively intact older adults [28]. We included depressive symptoms as a covariate in this study to explore the differences in the association between depressive symptoms and cognitive outcomes in rural–urban subgroups.

In light of the reviewed literature above, it is plausible to hypothesize that fall exposure/frequency and depressive symptoms will be significantly associated with subsequent cognitive impairment and dementia among rural older adults. Therefore, the objectives of this study were (1) to examine the association of falls and depressive symptoms with cognitive outcomes and (2) to further explore whether these associations differ between rural and urban older adults. Understanding the differential effects of this relationship in rural and urban areas is crucial to developing targeted preventive interventions tailored to the needs of older adults in these settings.

2. Materials and Methods

2.1. Study Design and Sample

This cross-sectional secondary analysis involved data from 6221 participants of the Health and Retirement Study (HRS). HRS provides datasets in multiple format and files. Data for this study were drawn from the RAND HRS Longitudinal File (V1), a user-friendly version of the Health and Retirement Study (HRS) developed by the RAND Center for the Study of Aging [29]. The RAND HRS longitudinal file provides cleaned and

harmonized data with consistent variable naming conventions across all waves, model-based imputations for missing income and wealth data and comprehensive demographic, health, employment, and economic variables.

The HRS is a nationally representative ongoing longitudinal survey of U.S. adults aged 50 and their spouses, sponsored by the National Institute on Aging (grant number NIA U01AG009740) and conducted by the University of Michigan's Institute for Social Research since 1992 [30]. HRS collects data through face-to-face interviews in half of the sample and through telephone interviews in the other half, alternating the data collection mode every other wave [31,32]. For this analysis, we used falls data and covariates from the 2018 wave and cognition from the 2020 wave to establish temporal precedence. Survey weights from the 2020 wave were applied to account for the complex survey design, non-response, and attrition, ensuring that results are representative of the U.S. population in 2020 [33]. The 2020 datasets contained the most up-to-date data available at the time of this analysis. All analyses followed HRS analytic guidelines for the use of sampling weights and survey design variables. We included participants if they were 65 years or older and had completed falls and covariates data in the 2018 wave. Participants who did not complete the cognition data in 2020 were excluded. Based on these criteria, the detailed steps for participant selection are presented in the flowchart (Figure 1).

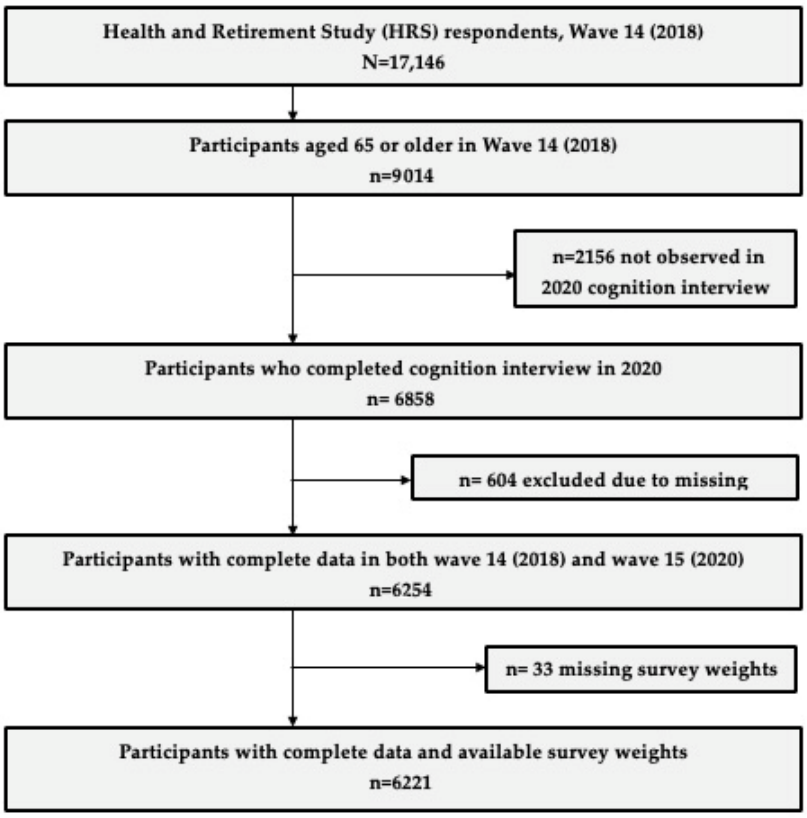


Figure 1. Flowchart of the sampling procedure. The figure shows the sample sizes at each sampling step based on inclusion/exclusion criteria, with an analytic sample of 6221 participants at the final step.

2.2. Measures

Cognition was assessed using the validated 27-item HRS Cognition Scale [34]. The scale is based on the Telephone Interview for Cognitive Status (TICS) and includes assessments for episodic memory, working memory, and reasoning domains. Cutoff values were established as follows: 0–6 for dementia, 7–11 for cognitive impairment not dementia (CIND), and 12–27 for normal cognition. The cutoffs were validated using data from the

Aging, Demographics, and Memory Study, which involved a thorough neuropsychiatric evaluation. Due to the relatively small size of minority groups and dementia cases in rural areas, we employed a diagnostic test to examine the frequencies. Due to the relatively small number of minority participants and dementia cases in rural areas, we conducted a diagnostic check of weighted cell counts to ensure that stratified analyses would have adequate sample size. Table 1 presents the unweighted counts of cognition categories by race and ethnicity for rural and urban residents.

Table 1. Frequencies of race and ethnicity across cognitive levels in residential areas.

Characteristic		Total Sample	Rural			Urban		
			Dementia	[2] CIND	Normal	Dementia	[2] CIND	Normal
		N = 6221	N = 107	N = 325	N = 1233	N = 221	N = 792	N = 3543
Race	White	4766	54	257	1096	125	514	2720
	Black	1062	40	49	91	75	206	601
	Other [1]	393	13	19	46	21	72	222
Ethnicity	Hispanic	744	16	26	49	68	156	429
	Non-Hispanic	5477	91	299	1184	153	636	3114

Notes: Unweighted Ns shown. Weighted cell counts were reviewed to assess adequacy for stratified models. [1] Other race includes American Indian, Alaska Native, Asian, or another race/ethnicity. [2] CIND: cognitive impairment-not dementia.

Falls were measured using the self-reported health questionnaire. Fall exposure was defined as reporting at least one fall during the previous two years. It was assessed via the question "Have you fallen down in the last two years?" and operationalized as a binary indicator (yes/no). Participants who reported a fall were subsequently asked to recall the number of falls, which was used to derive fall frequency. Fall frequency was modeled as a continuous variable among participants who reported at least one fall in the prior two years. To avoid collinearity, fall exposure and fall frequency were adjusted in two different models [29].

Depressive symptoms were measured using the 8-item Center for Epidemiologic Studies Depression (CES-D) scale. The scale items included feeling depressed, feeling that everything was an effort, restless sleep, happiness, loneliness, sadness, being unable to get going, and enjoying life. The overall score ranges from 0 to 8, and any score equal to or greater than 4 indicates the presence of depression [35].

Demographic Covariates included rurality [rural, urban], living arrangement [living alone, living with someone], age [≥65 in 5-year increments], gender [female, male], race [White, Black, Other race], and education [less than high school (HS), HS graduate, and more than HS].

2.3. Data Analysis

All descriptive analyses were conducted using survey-adjusted procedures to account for the complex sampling design of HRS. Categorical variables were summarized using survey-weighted frequencies and percentages, with group differences assessed using the Rao–Scott Chi-Square test. For continuous variables, because cognitive status includes three categories (normal, CIND, dementia) we used unadjusted, survey-weighted linear regression models to compare overall mean differences across cognitive groups, rather than evaluating pairwise differences. In the main multinomial models, associations between falls and cognitive outcomes were estimated using survey-weighted multinomial logistic regression with a generalized logit link. Normal cognition served as the reference category.

After analyzing unadjusted models, we built two models to test the data fit: (1) adjusted for fall exposure, demographics, and depressive symptoms; and (2) adjusted for fall frequency, demographics, and depressive symptoms. All analyses incorporated survey sampling weights provided by the HRS, with weights from the 2020 wave applied to account for the complex survey design, including unequal selection probabilities, clustering, stratification, and non-response and attrition [33], thereby ensuring nationally representative estimates of the U.S. population aged 65 years and older in 2020. Variance estimation followed HRS analytic guidelines and incorporated the survey design features.

To investigate whether the relationship between fall exposure and cognitive levels differed based on rural–urban status, we first examined an interaction term between fall exposure and rural–urban status. Although the interaction was not statistically significant, we proceeded with stratified analyses to identify potential subgroup patterns that may not have been fully captured by the interaction term alone. For each subgroup, we estimated separate multinomial logistic regression models. These stratified models used the same survey design specifications and covariates as the primary regression model. All statistical analyses were performed using SAS 9.4. by SAS Institute Inc. (Cary, NC, USA).

3. Results

3.1. Sample Characteristics

Table 2 displays participants' characteristics by cognitive status. Our sample included 6221 older adults, with a mean age of 73.36 (SD = 7.02). Most participants had normal cognition (81.72%), while the proportions of participants with cognitive impairment (CIND) and dementia were 14.41% and 3.87%, respectively. The prevalence of fall exposure was proportionally highest among participants with dementia (44.61%), followed by those with cognitive impairment (37.76%) and normal cognition (32.16%). The mean number of falls since the previous interview year has the same pattern. Almost 25.37% of the dementia cases and 16.95% of the cognitive impairment cases have depressive symptoms, while 8.31% of the cognitively intact individuals have depressive symptoms. The prevalence of dementia and CIND was higher among Black and Hispanic participants than non-Hispanic White participants. Male participants had a higher rate of cognitive impairment, while female participants had a higher rate of dementia. Participants living in rural areas and those living alone had higher rates of dementia and cognitive impairment than participants living in urban areas and those living with someone, respectively. Participants at the age of 85 and older and those between 70 and 74 had the highest percentage of dementia, 23.61% and 23.28%, respectively, while participants aged between 65 and 74 had the highest percentage of cognitive impairment (≈22%). The rate of dementia was also significantly higher among those who did not complete high school, whereas proportion of the participants with no high school education among the cognitively intact persons was only 7.21%.

Table 2. Characteristics of participants by cognitive status.

Characteristic		Total Sample	Dementia	[2] CIND	Normal	*p*-Value
		N = 6221 38,461,658 in US (100%)	N = 328 1,488,935 in US (3.87%)	N = 1117 5,541,289 in US (14.41%)	N = 4776 31,431,434 in US (81.72%)	
Fall Exposure (%)						<0.0001
	Yes	33.45%	44.61%	37.76%	32.16%	
	No	66.55%	55.39%	62.24%	67.84%	
Fall Frequency mean (SD)		1.00 (2.88)	1.43 (3.61)	1.24 (3.27)	0.91 (2.71)	0.001

Table 2. *Cont.*

Characteristic		Total Sample	Dementia	[2] CIND	Normal	*p*-Value
Depressive Symptoms (%)						<0.0001
	Depressed	10.22%	25.37%	16.95%	8.31%	
	Not depressed	89.78%	74.63%	83.05%	91.69%	
Age (%)						<0.0001
	65 ≤ AGE ≤ 69	35.41%	15.35%	21.63%	38.79%	
	70 ≤ AGE ≤ 74	27.26%	23.28%	21.83%	28.41%	
	75 ≤ AGE ≤ 79	18.31%	18.38%	19.18%	18.16%	
	80 ≤ AGE ≤ 84	11.36%	19.38%	19.25%	9.59%	
	85 ≤ AGE	7.65%	23.61%	18.10%	5.05%	
Gender (%)						<0.0001
	Female	56.05%	58.28%	54.01%	56.31%	
	Male	43.95%	41.72%	45.99%	43.69%	
Race (%)						<0.0001
	White	85.77%	60.98%	77.05%	88.48%	
	Black	8.99%	27.25%	14.89%	7.08%	
	Other [1]	5.25%	11.77%	8.06%	4.44%	
Ethnicity (%)						<0.0001
	Hispanic	8.04%	24.08%	13.13%	6.39%	
	Non-Hispanic	91.96%	75.92%	86.87%	93.61%	
Education (%)						<0.0001
	<High school	11.88%	47.55%	28.75%	7.21%	
	High School	29.23%	28.92%	35.46%	28.14%	
	>High School	58.89%	23.52%	35.79%	64.64%	
Rurality (%)						0.018
	Urban	72.26%	63.35%	68.92%	73.27%	
	Rural	27.74%	36.65%	31.08%	26.73%	
Living Arrangement (%)						<0.0001
	Living alone	25.05%	35.65%	31.93%	23.34%	
	Living with someone	74.95%	64.35%	68.07%	76.66%	

Notes: All percentages and means are weighted using HRS respondent weights. [1] Other race includes American Indian, Alaska Native, Asian, or another race/ethnicity. [2] CIND: cognitive impairment-not dementia.

3.2. Main Analysis

Table 3 shows the models from the multinomial logistic regression analysis. Fall exposure was significantly associated with developing dementia but not CIND, compared to those with no falls. Each additional fall was associated with 3% higher odds of CIND; however, the fall frequency and dementia relationship was non-significant. Participants with depressive symptoms had significantly greater odds of having CIND and dementia compared to those without depressive symptoms in both models, with a larger effect size for dementia than CIND in both models. Rurality was also significantly associated with increased odds of having CIND and dementia.

Table 3. Association of fall exposure and fall frequency with cognitive outcomes.

	Model 1 OR [95% CI]		Model 2 OR [95% CI]	
Variable	**CIND**	**Dementia**	**CIND**	**Dementia**
Fall Exposure (Ref: No Fall)	1.13 [0.94, 1.35]	1.42 [1.02, 1.97] *	----------	----------
Fall Frequency	----------	----------	1.03 [1.00, 1.06] *	1.01 [0.98, 1.05]
Depressive symptoms (Ref: no depression)	2.10 [1.60, 2.75] ***	3.02 [1.99, 4.60] ***	2.05 [1.56, 2.69] ***	3.12 [2.03, 4.79] ***
Rurality (Ref: Urbanicity)	1.25 [1.03, 1.51] *	1.91 [1.34, 2.74] ***	1.26 [1.04, 1.52] *	1.96 [1.37, 2.80] ***
Living alone (Ref: Living with someone)	1.17 [0.97, 1.41]	1.22 [0.86, 1.74]	1.18 [0.97, 1.42]	1.25 [0.88, 1.77]
Age	1.10 [1.08, 1.11] ***	1.14 [1.11, 1.16] ***	1.10 [1.08, 1.11] ***	1.14 [1.11, 1.17] ***
Gender—Male (Ref: Female)	1.39 [1.16, 1.66] ***	1.37 [1.00, 1.88]	1.40 [1.17, 1.68] ***	1.38 [1.00, 1.90] *
Race (Ref: White)				
Black	2.73 [2.16, 3.44] ***	7.66 [5.07, 11.59] ***	2.73 [2.17, 3.45] ***	7.49 [4.93, 11.38] ***
Other	1.80 [1.21, 2.67] **	2.21 [1.23, 3.98] **	1.79 [1.20, 2.66] **	2.21 [1.23, 3.98] **
Ethnicity—Hispanic (Ref: non-Hispanic)	1.38 [0.99, 1.91]	3.13 [1.97, 4.96] ***	1.38 [0.99, 1.91]	3.10 [1.94, 4.94] ***
Education (Ref: high school)				
>high school	0.50 [0.41, 0.61] ***	0.46 [0.30, 0.69] ***	0.49 [0.41, 0.60] ***	0.45 [0.29, 0.68] ***
<high school	2.64 [2.07, 3.38] ***	3.97 [2.70, 5.84] ***	2.63 [2.06, 3.36] ***	3.96 [2.69, 5.82] ***

Notes: The outcome variable: Cognition, "Normal Cognition" category is serving as the reference category. Model 1: Fall exposure + depression, rurality, living alone, age, gender, race, ethnicity, education. Model 2: Fall frequency + depression, rurality, living alone, age, gender, race, ethnicity, and education. * $p < 0.05$. ** $p \leq 0.01$. *** $p \leq 0.001$.

3.3. Stratified Analyses

Figure 2 displays the forest plot results from the stratified analyses. Although the trends of the association between fall exposure and cognitive outcomes were similar in residential areas, this association was significant only in urban areas for CIND (OR = 1.26, 95% CI [1.02, 1.55]) and dementia (OR = 1.73, 95% CI [1.17, 2.57]). Depressive symptoms were significantly associated with increased odds of CIND in rural areas (OR = 2.23, 95% CI [1.41, 3.54]) and urban areas with a smaller effect size (OR = 1.81, 95% CI [1.32, 2.47]). However, the association between depressive symptoms and dementia was only significant in urban areas (OR = 3.20, 95% CI [1.99, 5.15]). Detailed findings from the stratified analyses are presented in the Table A1.

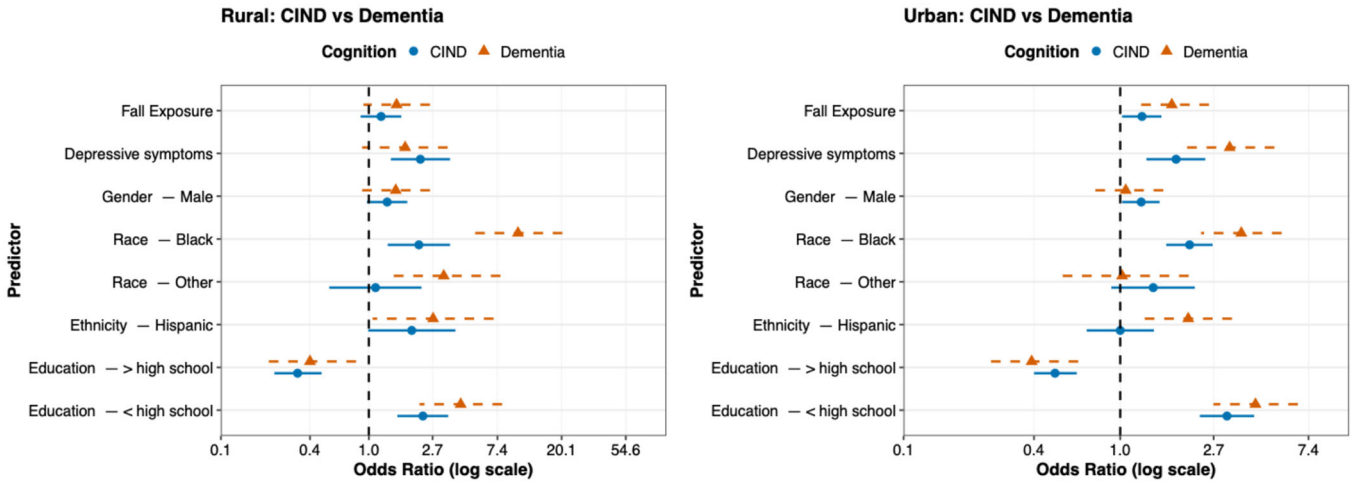


Figure 2. Forest plot for rural and urban strata. Forest plot showing the association of fall exposure and covariates with CIND and dementia in (**a**) older adults living in rural areas, and (**b**) older adults living in urban areas.

4. Discussion

This nationally representative cohort study complements the growing body of literature examining the association of falls with cognitive impairment and dementia, while providing evidence on the disparities between rural and urban older adults. To the best of our knowledge, this is the first study to explore rural–urban disparities in the association of falls with cognitive impairment and dementia.

4.1. Association of Falls with Cognitive Outcomes

Our findings demonstrate that older adults with fall exposure had significantly increased odds of having dementia but not cognitive impairment. The fall frequency was significantly associated with cognitive impairment, with a 3% decline in cognitive scores per additional fall. These findings are well aligned with emerging evidence suggesting that falls may be an indicator of future cognitive decline [5,6]. Our results are consistent with the large-scale study conducted on Medicare beneficiaries, indicating that falls were more frequently associated with dementia diagnosis within one year of the event compared to other injury mechanisms [19]. A longitudinal study conducted in South Korea also indicated an association of falls with developing dementia [16]. Another study in Sweden revealed that the risk of injurious fall incidence increased four years prior to dementia diagnoses and remained elevated for four years after dementia diagnosis [7]. Additionally, a recent systematic review conducted on seven population-based studies indicated a significant association between fall-related fractures and the incidence of subsequent dementia [36].

These findings support several potential mechanisms linking falls to subsequent cognitive impairment and dementia. One possible explanation is that older adults diagnosed with dementia after a fall exposure may have an undiagnosed cognitive impairment at the time of their fall exposure [19]. It is known that individuals with mild cognitive impairment are more susceptible to falls and have a 60–80% increased risk of falls compared to their cognitively intact peers [37]. Extensive research also showed that the rate of cognitive impairment diagnosis at earlier stages is lower than at severe stages, due to the likelihood of less exposure to healthcare systems in the early stages of ADRD [1,2,38]. In tandem with this phenomenon, the most recent research revealed that falls may be the indicator of early stage cognitive impairment such as mild cognitive impairment [39], as well as the symptom-free stage (preclinical Alzheimer's Disease) [40,41].

Another mechanism could be subtle cognitive changes that influence gait and balance, increasing older adults' risk of falling; in turn, older adults who experience falls are more likely to have subsequent cognitive decline [37]. For instance, a study with an 8-year follow-up in the United States demonstrated that cognitively intact older adults with high fall risk at baseline had a 74% greater risk of developing cognitive impairment than those with low fall risk at baseline [15]. A study in Canada revealed that older adults with mild cognitive impairment were more likely to experience injurious falls due to declining higher-level brain control involving attentional resources and functional abilities [42]. Furthermore, a systematic review of 18 studies found that individuals with mild to moderate cognitive impairment had an increased fall risk due to diminished processing speed and executive functioning, leading to instability in posture and stride [43]. Evidence shows that slowly diminishing cognitive abilities increase the risk of falls and fall-related injuries long before dementia diagnosis [44].

4.2. Rural–Urban Disparities

The stratified analysis revealed that the relationship between falls and cognitive outcomes differed between participants residing in rural and urban areas. Our findings from the descriptive (Table 2) and main analysis (Table 3) confirm the recent evidence indicating higher prevalence and risk of cognitive impairment and dementia in rural areas [45,46] and support Wiese and colleagues [3], indicating heightened risk and burden of dementia among rural older adults. In contrast to our findings, a longitudinal study [22] conducted on Medicare beneficiaries reported a lower prevalence but higher diagnostic dementia incidence among rural older adults. The effects observed in the rural and urban populations here are likely a reflection of the complex interplay between ecological, social, and economic factors. Weden and colleagues demonstrated that rural older adults were more likely to have a lower-level healthy aging profile across various domains [47]. Another study in the U.S. confirmed that older individuals living in rural counties had lower cognitive functioning than those living in urban areas, with a wider gap in counties depopulated between 1980 and 2010 [48]. In addition to social and economic challenges, rural older adults also face barriers in accessing healthcare services, especially specialists for complex health problems and emergency departments. All these barriers create additional disparities, such as underdiagnosis of cognitive impairment or misdiagnosis of dementia cases, as well as lack of opportunity to receive timely preventive interventions [3,22]. A systematic review of 38 studies revealed that rural older adults with dementia had lower visits to physicians, more hospitalizations but shorter stays, higher use of psychiatric medicine, lower use of home services, and higher admission to nursing homes [49]. Considering the sophisticated but unmet healthcare needs of rural dementia patients and their high risk for injurious falls, morbidity, and mortality, it is plausible to say that lower survival rates of rural dementia patients may have affected our results due to more dementia diagnoses in urban areas. The results from our stratified analyses showed a different trend than initially predicted; we found that falling was significantly associated with cognitive impairment and dementia among urban older adults. Although showing the same trend, this association was not significant among rural older adults. Considering the exploratory nature of the subgroup analyses, results should be replicated and rural–urban-specific factors should be included in future analyses.

4.3. Association of Depressive Symptoms with Cognitive Outcomes

Consistent with the literature [27,28], our main results showed a significant association of depressive symptoms with cognitive impairment and dementia. Contrary to our expectation, we observed that the significant association between depressive symptoms

and cognitive impairment was preserved in both strata; however, the association between depressive symptoms and dementia was significant only among older adults living in urban areas. Although literature on the mental health of older adults has mixed results [50], we confirmed the results of a systematic review conducted on a global sample, indicating that odds of developing depression were significantly higher among urban residents in developed countries; while there were no significant differences in developing countries [51]. These findings suggest that the nature of the relationship between residential area and depressive symptoms may vary across different contexts and individual characteristics of the population. Thus, comprehensive investigations focused on contextual factors are required to determine the differential effects of residential areas on health outcomes.

Findings may also reflect differences in lifestyle factors across residential settings. In rural areas, higher engagement in outdoor physical activities, stronger community cohesion, and closer connection to nature may mitigate the association between depressive symptoms and cognitive deterioration, despite more limited access to formal mental health services. Selection effects may further play a role, as older adults with more severe depression or cognitive impairment may relocate to urban areas to obtain specialized healthcare, leading to a higher concentration of vulnerable older adults in urban settings.

4.4. Implications

The results of this study highlight residential disparities, underscoring the need for targeted health promotion and integrated prevention strategies that support the cognitive and physical well-being of older adults. Nurses and physicians should also recognize the critical role of depression screening in urban older adults, as depressive symptoms showed strong associations with both cognitive impairment and dementia in the current study, with a large effect size in the urban setting. Geriatric assessments should include both cognitive and mental health screening, as well as fall risk assessment. Additionally, mobile clinics should be integrated into primary care services in under-resourced areas, offering routine cognitive screening for older adults and mental health services to help prevent underdiagnosis and misdiagnosis. Given the strong relationship between falls and dementia among urban older adults, senior centers should be supported with outreach programs for older adults with restricted mobility in cities. The development of integrated interventional programs may address both fall prevention and secondary prevention of subsequent cognitive decline in older adults. Preventive interventions should be tailored to the unique characteristics, specific needs, available resources, and socio-cultural context of communities in different settings.

The rural–urban differences identified in this study stress the need for context-based approaches to healthy aging initiatives. For instance, rural areas may benefit more from community-based participatory programs, while urban areas can utilize the city/county resources to support mental health and fall prevention programs. Physiotherapists and occupational therapists may integrate cognitive assessments into fall risk evaluations and consider tailored interventions. These can include place-based dual-task training programs that simultaneously address motor and cognitive functions, which have shown effectiveness in reducing fall risk while potentially supporting cognitive health [37]. For rural populations, telehealth cognitive screening following fall events may help overcome geographic barriers. Occupational therapists can implement modification programs that address both fall prevention and mental support, creating environments that promote safety while maintaining cognitive engagement. While this cross-sectional analysis provides important insights, future research should include longitudinal investigations, which can establish a causal relationship between falls and cognitive impairment. Education initiatives should target patients, families, and caregivers about the bidirectional relationship

between falls and cognitive decline, emphasizing that fall prevention strategies, including exercise programs, medication reviews, vision correction, and environmental modifications, may serve dual purposes in maintaining both physical mobility and cognitive health across diverse geographic settings [52,53]. Additional investigation is necessary to fully understand the nature of the rural–urban disparities observed in this study. Qualitative studies with a community-participatory approach could provide valuable insights into the context of the findings.

Findings of the current study have significant implications for aging populations worldwide, particularly in low- and middle-income countries where rural–urban disparities are often more pronounced [3]. International evidence has consistently documented a higher prevalence of cognitive impairment and dementia in rural areas [54], suggesting that rural–urban patterns in fall–cognition relationships may reflect broader global phenomena shaped by universal social determinants of health. Our findings support the need for place-based interventions that account for local infrastructure and resources. Global health initiatives should prioritize strengthening healthcare capacity, implementing community-based screening programs that integrate fall risk and cognitive assessments, and developing policies addressing social determinants of health across diverse geographic settings to promote healthy aging worldwide.

4.5. Study Limitations and Future Directions

Our findings should be interpreted in light of several limitations. This study relied on self-reported measures of falls collected through standardized Health and Retirement Study (HRS) interview questions over a two-year recall period, which may be subject to recall bias, particularly among older adults with cognitive impairment. Falls that do not result in injury may be underreported, whereas more severe falls requiring medical attention are more likely to be recalled [55]. In addition, variations in individual interpretations of what constitutes a fall, stigma associated with perceiving falls as sign of frailty, and recall errors may have contributed to conservative estimates of fall incidence in this study. To improve reporting accuracy, future research should consider shorter recall periods and prospective designs, such as fall calendars or postcards [56].

As we emphasized in the Discussion Section, many context-based risk factors were not included in this study (e.g., housing, income, and disability). Including a broader range of place-based factors may provide more accurate results on the examined relationships. Stratified analyses by rural–urban setting showed a large effect size for the association between Black individuals and dementia among rural older adults. While diagnostic checks confirmed adequate cell sizes and model stability, precision might be limited despite reasonable confidence intervals. Thus, stratified results should be interpreted cautiously and require replication in larger samples. Although we used a lagged-time approach, with predictors measured in 2018 and cognitive outcomes assessed in 2020 to strengthen temporal precedence, the results may still be affected by residual reverse causality. However, findings provide a direction for future longitudinal studies investigating causality and the underlying mechanisms of the fall–cognition relationship in different residential settings.

4.6. Conclusions

This study complements the existing research on the relationship between falls and cognitive impairment and dementia, underscoring the critical role of residential status. Our findings on the significant relationship between fall exposure and an increased risk of cognitive impairment and dementia complement the emerging literature focusing on the impact of falls on the progression of cognitive impairment in the continuum of Alzheimer's Disease and Related Dementias. Differences between rural and urban subgroups revealed

a modifying role of residential status, emphasizing the need for tailored approaches based on residential area for healthcare services and interventions.

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Abbreviations

The following abbreviations are used in this manuscript:

AD	Alzheimer's Disease
ADRD	Alzheimer's Disease and Related Dementias
HRS	Health and Retirement Study
CIND	Cognitive Impairment Not Dementia
CES-D	Center for Epidemiologic Studies Depression Scale
TICS	Telephone Interview for Cognitive Status
OR	Odds Ratio
CI	Confidence Interval
SD	Standard Deviation

Appendix A

Table A1 shows the results from stratified analysis and supplementary to Section 3.3.

Table A1. Relationship between fall exposure and cognitive status in rural and urban older adults.

	Rural OR [95% CI]		**Urban OR [95% CI]**	
Predictor	**CIND**	**Dementia**	**CIND**	**Dementia**
Fall Exposure (Ref: No Fall)	1.21 [0.88, 1.66]	1.54 [0.92, 2.59]	1.26 * [1.02, 1.55]	1.73 * [1.17, 2.57]
Depressive symptoms (Ref: no depression)	2.23 *** [1.41, 3.54]	1.76 [0.90, 3.41]	1.81 *** [1.32, 2.47]	3.20 *** [1.99, 5.15]
Gender—Male (Ref: Female)	1.33 [0.97, 1.82]	1.52 [0.90, 2.59]	1.25 * [1.02, 1.52]	1.06 [0.71, 1.58]

Table A1. *Cont.*

	Rural OR [95% CI]		Urban OR [95% CI]	
Predictor	**CIND**	**Dementia**	**CIND**	**Dementia**
Race (Ref: White)				
Black	2.18 ** [1.34, 3.54]	10.19 *** [5.10, 20.35]	2.09 *** [1.63, 2.67]	3.62 *** [2.36, 5.56]
Other	1.11 [0.54, 2.27]	3.21 ** [1.33, 7.76]	1.42 [0.91, 2.21]	1.02 [0.50, 2.07]
Ethnicity—Hispanic (Ref: non-Hispanic)	1.95 [0.99, 3.85]	2.72 * [1.06, 6.97]	1.00 [0.70, 1.43]	2.06 ** [1.29, 3.28]
Education (Ref: high school)				
>high school	0.33 *** [0.23, 0.48]	0.40 * [0.20, 0.82]	0.50 *** [0.40, 0.63]	0.39 *** [0.23, 0.64]
<high school	2.32 *** [1.56, 3.44]	4.18 *** [2.20, 7.96]	3.11 *** [2.33, 4.15]	4.21 *** [2.69, 6.61]

Notes: * $p < 0.05$. ** $p \leq 0.01$. *** $p \leq 0.001$.

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