

# Association Rule Analysis of Cognitive Frailty Subtypes in Community-Dwelling Older Adults

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**Purpose:** In order to provide a foundation for identification and intervention strategies, this study intends to investigate the influencing factors and associative patterns of two subtypes of reversible cognitive frailty (RCF) and potential reversible cognitive frailty (PRCF) in older adults with cognitive frailty (CF) who live in the community.

**Patients and Methods:** From July to December 2023, we conducted a cross-sectional study in a Beijing community to recruit older adults with CF using convenience sampling. We conducted the survey using the General Information Questionnaire, the Montreal Cognitive Assessment, the Clinical Dementia Rating, the Fried Frailty Phenotype, the Geriatric Depression Scale-15, the Generalized Anxiety Disorder-7, the Athens Insomnia Scale, the Barthel index, the Tinetti Performance Oriented Mobility Assessment, and the Lubben social network scale. The participants were separated into two categories: RCF and PRCF, based on frailty and cognitive assessment. After screening variables with a random forest algorithm, we applied association rule analysis to examine the factors influencing CF and the strength of their interactions.

**Results:** The survey was completed by 529 older adults with CF who lived in the community. Among them, 145 participants (27.4%) were classified as PRCF and 384 (72.6%) as RCF. 24 association rules, 12 for each subtype, were developed using the Apriori algorithm and clinical practice experience. These rules identified polypharmacy, multimorbidity, low educational attainment, and high fall risk as significant factors. Furthermore, the association pattern for PRCF is more complex.

**Conclusion:** The influencing factors associative patterns of the two categories of CF differ. In order to better manage elderly individuals with CF in the community, improve the cognitive health of the elderly, and encourage healthy aging, medical professionals should upgrade the community evaluation system for CF.

**Keywords:** cognitive frailty, older adults, association rule analysis, apriori algorithm

## Introduction

Population aging has become a major public health concern. By 2030, the proportion of the global population aged 60 and above is projected to reach 16.6%.<sup>1</sup> Although promoting physical activity and enhancing social participation among older adults can improve their quality of life and facilitate active aging, the prevalence of geriatric syndromes and chronic illnesses rises sharply with age.<sup>2,3</sup> These conditions not only compromise older adults' health and quality of life, but also impose substantial burdens on healthcare systems and the economy.<sup>4,5</sup> Therefore, early identification of geriatric syndromes can reduce adverse health outcomes among older adults, alleviate healthcare burdens, and improve quality of life. Cognitive frailty (CF) is a common issue among geriatric syndromes, defined as the coexistence of physical frailty and cognitive impairment in the absence of dementia.<sup>6</sup> Physical frailty and cognitive impairment can influence each other, forming a vicious cycle.<sup>7</sup> The overall prevalence of CF worldwide is 9%, and it is showing an upward trend year by year.<sup>8</sup> According to studies, up to 26.16% of older adults in Chinese communities suffer from CF, significantly higher than the global average.<sup>9</sup> As a transitional stage preceding dementia, CF is also associated with various adverse outcomes

such as falls, disability, and hospitalization.<sup>10</sup> Therefore, early identification of this condition can delay the progression of cognitive impairment and reduce the risk of adverse health outcomes.<sup>11</sup>

It is worth noting that CF can be divided into two subtypes: reversible cognitive frailty (RCF) and potential reversible cognitive frailty (PRCF). The two subtypes of CF differ in their underlying mechanisms, clinical manifestations, and adverse health outcomes, making their differentiation clinically significant. RCF is defined as either pre-frailty or frailty, both co-occurring with subjective cognitive decline (SCD). SCD refers to self-perceived decline in memory or other cognitive functions relative to one's own baseline, despite normal performance on cognitive testing.<sup>12</sup> PRCF is defined as either pre-frailty or frailty, both co-occurring with mild cognitive impairment (MCI). Specifically, MCI is characterized by an individual performing poorly on one or more cognitive measures, which indicates deficits in one or more cognitive domains.<sup>13</sup> Regarding adverse outcomes, the risk disparity between the two subtypes was also confirmed. In a cohort of 3,200 community-dwelling older adults in China, 41.0% had RCF and were at significantly higher risk of falls ( $OR=1.302, 95\% CI:1.053\sim1.593$ ). PRCF elderly individuals accounted for 12.5%, with an even higher risk of falls ( $OR=1.442, 95\% CI:1.179\sim1.922$ ).<sup>14</sup> However, most current studies focus solely on the overall incidence and adverse outcomes of CF, lacking in-depth exploration of the distinctive patterns of association between risk factors for the two subtypes.<sup>10,15</sup> The influencing factors and intervention methods differ between the two subtypes. Early accurate assessment and targeted interventions can slow, halt, or even reverse cognitive decline.<sup>16</sup>

The two subtypes of CF result from the interaction of multiple factors, but traditional statistical models often rely on assumptions such as linear relationships, limiting their ability to integrate this type of data. Random forests are an ideal choice for variable selection due to their ability to handle non-linear relationships and their variable importance assessment mechanism. Association rule analysis reveals potential associations between variables by mining frequent item sets in data. It is currently being applied in areas such as the management of elderly diabetic patients, venous thrombosis, and falls.<sup>17,18</sup>

Therefore, this study aims to identify key factors associated with two subtypes of CF. Through data analysis utilizing random forest and association rule analysis methods, we investigate the interactive relationships among demographic characteristics, lifestyle factors, and relevant indicators in community-dwelling older adults with CF. This research provides a reference for identifying intervention targets for precise differentiation between the two subtypes.

## Methods

### Study Design

This cross-sectional study was conducted in a community in Beijing from July 2023 to December 2023.

### Study Population

Convenience sampling can be used to rapidly obtain a sample of community-dwelling CF older adults.

Inclusion criteria: (1) Meets the definition of cognitive frailty:<sup>16</sup> CF screening was conducted using the Fried frailty phenotype, the Montreal Cognitive Assessment (MoCA), and the Clinical Dementia Rating (CDR) scale. Simultaneously meet the following three criteria: ① Fried frailty phenotype score  $\geq 1$  point, ② MoCA score  $< 26$  points (individuals with less than 12 years of education receive an additional 1 point), ③  $CDR \leq 0.5$  points. (2) Aged 65 and above. (3) The ability to cooperate in completing the survey. (4) Giving informed consent and volunteering to participate.

Exclusion criteria: (1) Clinically diagnosed with dementia or mental illness; (2) Severe organ dysfunction and in the final stage of the disease; (3) Hemiplegia or limb impairment.

### Survey Tool

The selection of independent variables is based on the biopsychosocial model and draws upon relevant research on cognitive decline, geriatric syndromes, and other related topics. It encompasses dimensions such as demographic characteristics, health status, psychological factors, and social support.

### General Information Questionnaire

A general information questionnaire was developed based on previous research and a literature review. It collected demographic data including age, sex, body mass index, educational attainment, healthcare payment method, living arrangement, marital status, multimorbidity, medication history, and smoking and alcohol use.

### Fried Frailty Phenotype (FFP)

The Fried Frailty Phenotype, proposed by Fried<sup>19</sup> in 2001, comprises five components: unintentional weight loss, reduced grip strength, self-reported exhaustion, slow gait speed, and low physical activity levels. Each criterion met is assigned 1 point, yielding a total score range of 0~5. Scores are interpreted as 0 = robust, 1~2 = pre-frailty, and 3~5 = frailty.

### Montreal Cognitive Assessment (MoCA)

The Montreal Cognitive Assessment (MoCA), developed by Nasreddine in 2005, comprises eight items: visuospatial/executive function, naming, memory, attention, language, abstraction, delayed recall, and orientation, with a total score ranging from 0 to 30. For participants with  $\leq 12$  years of education, 1 point is added to the total score. For this study, a total scores  $\geq 26$  indicate normal cognitive function. The Cronbach's alpha coefficient for this scale is 0.88.<sup>20</sup>

### Clinical Dementia Rating (CDR)

The Clinical Dementia Rating (CDR), developed by Hughes<sup>21</sup> in 1982, the assessment comprises six domains: memory, orientation, judgment and problem-solving, work and social functioning, family life and hobbies, and independent living skills. Scores range from 0 to 3, where 0 denotes normal cognition, 0.5 indicates possible dementia, and scores  $\geq 1$  signify dementia. In this study, participants with a CDR score of 0 were classified as RCF, and those with higher scores as PRCF.

### Geriatric Depression Scale-15 (GDS-15)

The Geriatric Depression Scale-15 (GDS-15), developed by Sheikh in 1986, this 15-item scale assigns 1 point per item, with reverse scoring applied to specific entries. Total scores range from 0 to 15, where 0~4 denotes normal status, 5~8 suggests mild depressive symptoms, and scores  $\geq 9$  indicate moderate-to-severe depression. The Cronbach's alpha coefficient for this scale is 0.793.<sup>22</sup> For this study, a GDS cutoff score of  $\geq 8$  was defined as representing geriatric depressive state.

### Generalized Anxiety Disorder-7 (GAD-7)

The Generalized Anxiety Disorder-7 (GAD-7), developed by Spizer in 2006, the scale comprises 7 items with a total score range of 0~21 points: 0~4 indicates normal status, 5~9 suggests mild anxiety, 10~14 represents moderate anxiety, and scores  $\geq 15$  denote severe anxiety. The Cronbach's alpha coefficient for this scale is 0.898.<sup>23</sup>

### Athens Insomnia Scale (AIS-8)

Developed by Soldatos in 2000, this scale comprises 8 items with each item scored on a 0~3 scale, yielding a total score range of 0~24. Scores below 4 indicate no sleep disturbance, 4~6 suggest possible insomnia, and scores above 6 signify insomnia. The Cronbach's alpha coefficient for this scale is 0.881.<sup>24</sup>

### Barthel Index (BI)

Developed by Mahoney and Barthel in the United States in 1965, this scale comprises 10 items, each scored at 0, 5, 10, or 15 points, with a total score ranging from 0 to 100. Higher scores reflect greater independence: scores  $\leq 20$  = total dependence, 25~45 = severe dependence, 50~70 = moderate dependence, 75~95 = mild dependence, and 100 points denote complete independence. The Cronbach's alpha coefficient for this scale is 0.902.<sup>25</sup>

### Tinetti Performance Oriented Mobility Assessment (POMA)

The Tinetti Performance Oriented Mobility Assessment (POMA), developed by Tinetti in 1986, the scale comprises two components: balance and gait assessments, totaling 16 items. Scores range from 0 to 28, with lower values indicating greater fall risk. Scores above 24 denote no risk, 19~24 represent fall risk present, and below 19 indicate high fall risk. The Cronbach's alpha coefficient for this scale is 0.887.<sup>26</sup>

## Lubben Social Network Scale- Revised (LSNS-R)

The Lubben social network scale- Revised (LSNS-R), developed by Lubben in 1988, the scale comprises two dimensions: family and friends, each containing 6 items. Scores range from 0 to 5 per item, with a total possible score of 0 to 60. Lower total scores indicate greater social isolation risk, with scores  $\leq 19$  denoting social isolation risk present. The Cronbach's alpha coefficient for this scale is 0.7.<sup>27</sup>

## Sample Size Estimation

The primary objective of this study is to analyze the association patterns and influencing factors of two subtypes of CF among community-dwelling older adults. The sample size was calculated as 10 times the number of study variables.<sup>28</sup> With 16 variables included and a 10% allowance for invalid responses, the estimated sample size required is 178 participants. This study actually included 529 participants, which reduces sampling error and enhances the statistical power of the tests.

## Determining RCF and PRCF

Individuals with CF exhibit heterogeneity in the degree of cognitive dysfunction and clinical manifestations. RCF refers to subjective cognitive decline preceding mild cognitive impairment, where daily functioning in older adults remains largely unaffected and overall functional capacity is well preserved.<sup>12,16</sup> PRCF refers to older adults who have exhibited mild clinical cognitive decline, meeting the criteria for mild cognitive impairment (MCI) and remaining in a potentially reversible stage.<sup>13,16</sup> The International Academy on Nutrition and Aging (IANA) and the International Association of Gerontology and Geriatrics (IAGG) consensus proposes a CDR score of 0.5 as the criterion for MCI.<sup>29</sup> When CDR=0 and a positive response is given to one of the items, it indicates the presence of SCD.<sup>30</sup> Based on the aforementioned consensus and relevant research, this study employs the CDR score to classify CF: CDR=0 is defined as RCF, and CDR=0.5 is defined as PRCF.<sup>31,32</sup>

## Statistical Methods

Data preprocessing for this study comprised two steps: data cleaning and data coding. First, data cleaning was conducted. Any questionnaire containing three or more unanswered questions, obvious contradictions, or any instance of formulaic responses was deemed invalid and excluded from subsequent analysis. Subsequently, data coding was performed. For categorical variables in general information, values were assigned directly based on their categorical attributes. For continuous variables in general information, age and BMI were categorized according to commonly used standards in geriatric medicine and standards for the Chinese population. For continuous variables from each scale test, classification was based on their standardized scoring rules, followed by value assignment coding to meet the requirements for subsequent statistical analysis. See [Table 1](#) for details.

Data analysis was conducted using R software (version 4.3.1). Count data were expressed as frequencies and percentages. Intergroup comparisons were conducted using Pearson's chi-square test or Fisher's exact test (adjusted for cell frequency). In R, a random forest classification model was constructed using the randomforest package. A random seed of 10 was set to ensure reproducibility. The number of decision trees (ntree) was set to 500, while the number of candidate variables per node (mtry) used the default value. Variable importance calculation was enabled (importance=TRUE) to identify significant variables.

The selected significant variables were subsequently analyzed using the Apriori algorithm to examine association rules for CF subtypes. Association rules were expressed as  $X \rightarrow Y$ , characterized by three metrics: support, confidence, and lift. Support represents the co-occurrence probability of both X and Y; higher values suggest stronger associations. Confidence indicates the conditional probability of Y given X, with greater values denoting more reliable rules. Lift quantifies whether X enhances the occurrence of Y: values  $> 1$  demonstrate positive correlation,  $= 1$  indicate independence, and  $< 1$  reflect negative correlation. In alignment with parameter configurations from comparable studies, this research established the maximum antecedent number as 5, minimum support at 0.04, and minimum confidence threshold of 0.6, while selecting association rules with lift values exceeding 1.<sup>17,18</sup>

**Table 1** Variable Assignment

Variable	Assignment Method
Gender	Female = 0, Male = 1
Age	65~75 years old = 1, 75~85 years old = 2, > 85 years old = 3
Education Level	Primary school and below = 1, Secondary education level = 2, Tertiary education level = 3
Marital Status	Married = 1, Divorced/Widowed = 2
Residence Type	Reside with spouse = 1, Reside with relatives = 2, Reside with non - relatives = 3, Live alone = 4
Medical Payment Method	Rural medical insurance = 1, Urban medical insurance = 2, Cadre medical insurance = 3
Whether There is multimorbidity	Yes = 1, No = 2
Polypharmacy (taking ≥5 medications)	Yes = 1, No = 2
Whether There is Smoking and Drinking History	Yes = 1, No = 2
BMI	<18.5=1, 18.5~23.9=2, 24.0~27.9=3, ≥28.0=4
GDS-15	< 8 points = 1, ≥8 points = 2
GAD-7	0~4 points = 1, 5~9 points = 2, 10~14 points = 3
AIS-8	< 4 points = 1, 4~6 points = 2, > 6 points = 3
BI	100 points = 1, 75~95 points = 2, 50~70 points = 3, ≤45 points = 4
POMA	> 24 points = 1, 19~24 points = 2, < 19 points = 3
LSNS-R	> 19 points = 1, ≤19 points = 2

**Notes:** Secondary education includes junior, senior, and vocational high schools; tertiary education refers to junior college, undergraduate, or higher.

Association rules are presented as unordered categorical data. Based on their sample distribution characteristics, Fisher's exact test is applied to their antecedent and consequent items. Multiple comparisons between groups are adjusted using Bonferroni correction, with a significance level of  $\alpha=0.05$ . An adjusted P value < 0.05 indicates statistical significance. Finally, this study performed univariate frequency statistics and visualization analysis on the antecedents of rules corresponding to the two subtypes. This clarified the distribution characteristics of common factors and subtype-specific factors, presented in bar charts.

## Results

### General Information of Community-Dwelling Older Adults with Cognitive Frailty

Of 5,253 community-dwelling older adults screened in Beijing, China, 529 met the criteria for CF and were included. Among the 529 older adults with CF, 384 cases (72.58%) belonged to RCF and 145 cases (27.42%) belonged to PRCF. Participants were classified into two subtypes, and the general data of the two groups of older adults are shown in Table 2.

**Table 2** General Information of Community-Dwelling Older Adults with CF

Variable	Classification	RCF (n=384) n (%)	PRCF (n=145) n (%)	Total	$\chi^2$	P
Gender	Female	226 (42.72%)	95 (17.96%)	321 (60.68%)	1.689	0.193
	Male	158 (29.87%)	50 (9.45%)	208 (39.32%)		
Age	65~75 years old	103 (19.47%)	8(1.51%)	111 (20.98%)	33.220	<0.001
	75~85 years old	190 (35.92%)	79 (14.93%)	269 (50.85%)		
	> 85 years old	91 (17.20%)	58 (10.96%)	149 (28.17%)		
Education Level	Primary school and below	72 (13.61%)	59 (11.15%)	131 (24.76%)	29.230	<0.001
	Secondary education level	163 (30.81%)	53 (10.02%)	216 (40.83%)		
	Tertiary education level	149 (28.17%)	33 (6.24%)	182 (34.40%)		
Marital Status	Married	280 (52.93%)	73 (13.80%)	353 (66.73%)	23.149	<0.001
	Divorced/Widowed	104 (19.66%)	72 (15.61%)	176 (33.28%)		

(Continued)

**Table 2** (Continued).

Variable	Classification	RCF (n=384) n (%)	PRCF (n=145) n (%)	Total	$\chi^2$	P
Residence Type	Reside with spouse	213 (40.26%)	40 (7.56%)	253 (47.83%)	41.987	<0.001
	Reside with relatives	91 (17.20%)	72 (13.61%)	163 (30.81%)		
	Reside with non - relatives	24 (4.54%)	14 (2.65%)	38 (7.18%)		
	Live alone	56 (10.59%)	19 (3.59%)	75 (14.18%)		
Medical Payment Method	Rural medical insurance	28 (5.29%)	43 (8.13%)	71 (13.42%)	45.655	<0.001
	Urban medical insurance	243 (45.94%)	73 (13.80%)	316 (59.74%)		
	Cadre medical insurance	113 (21.36%)	29 (5.48%)	142 (26.84%)		
Whether There is multimorbidity	Yes	265 (50.09%)	99 (18.71%)	364 (68.81%)	0.003	0.954
	No	119 (22.50%)	46 (8.70%)	165 (31.19%)		
Polypharmacy (taking $\geq 5$ medications)	Yes	203 (38.37%)	82 (15.50%)	285 (53.88%)	0.437	0.508
	No	181 (34.22%)	63 (11.91%)	244 (46.12%)		
Whether There is Smoking and Drinking History	Yes	16 (3.02%)	9 (1.70%)	25 (4.73%)	0.572	0.449
	No	368 (69.57%)	136 (25.71%)	504 (95.27%)		
BMI	Underweight	15 (2.84%)	6 (1.13%)	21 (3.97%)	0.143	0.986
	Normal weight	197 (37.24%)	72 (13.61%)	269 (50.85%)		
	Overweight	124 (23.44%)	49 (9.26%)	173 (32.70%)		
	Obese	48 (9.07%)	18 (3.40%)	66 (12.48%)		
GDS-15	No depression	382 (72.21%)	139 (26.28%)	521 (98.49%)	8.205*	0.006
	Geriatric depressive state	2 (0.38%)	6 (1.13%)	8 (1.51%)		
GAD-7	No anxiety	305 (57.66%)	108 (20.42%)	413 (78.07%)	4.486	0.106
	Mild anxiety	66 (12.48%)	35 (6.62%)	101 (19.09%)		
	Moderate anxiety	13 (2.46%)	2(0.38%)	14 (2.84%)		
AIS-8	No sleep disturbance	205 (38.75%)	75 (14.18%)	280 (52.93%)	0.046	0.977
	Possible insomnia	142 (26.84%)	50 (9.45%)	192 (36.29%)		
	Insomnia	142 (26.84%)	50 (9.45%)	192 (36.29%)		
BI	Complete independence	220 (41.59%)	38 (7.18%)	258 (48.77%)	19.845	<0.001
	Mild independence	132 (24.95%)	71 (13.42%)	203 (38.37%)		
	Moderate dependence	26 (4.91%)	32 (6.05%)	58 (10.96%)		
	Severe and complete dependence	6 (1.14%)	4 (0.76%)	10 (1.9%)		
POMA	No fall risk	157 (29.68%)	16 (3.02%)	173 (32.70%)	46.880	<0.001
	Fall risk present	88 (16.64%)	37 (6.99%)	125 (23.63%)		
	High fall risk	139 (26.28%)	92 (17.39%)	231 (43.67%)		
LSNS-R	No social isolation risk	325 (61.44%)	123 (23.25%)	448 (84.69%)	0.003	0.986
	Social isolation risk present	59 (11.15%)	22 (4.16%)	81 (15.31%)		

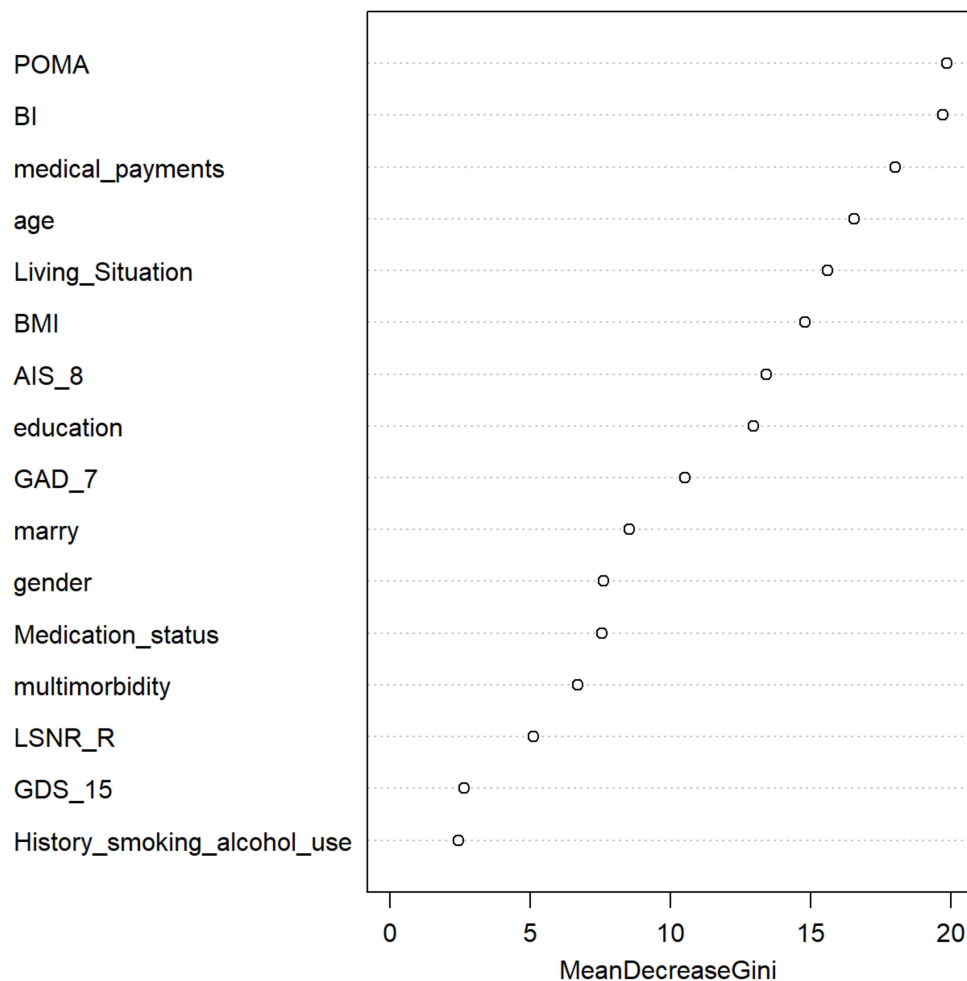
**Note:** \*indicates the use of the Fisher's exact test.

## Screening of Influencing Factors for Community-Dwelling Older Adults with CF

We used the two CF subtypes as dependent variables and entered 16 predictors into a random forest model implemented in R (version 4.3.1). The mean decrease in Gini index serves as a measure of dataset purity, with higher values indicating greater variable importance for the model. [Figure 1](#) presents the importance ranking of influencing factors among community-dwelling older adults with CF. Based on clinical expertise and expert consensus, we selected the 10 most important variables plus 12 additional factors (including multimorbidity and polypharmacy) for association rule analysis.

## Association Analysis results of Community-Dwelling Older Adults with CF

Using the Apriori algorithm, association rule analysis was performed on 12 variables, with RCF and PRCF as the consequents respectively. Rules with confidence  $>60\%$  and lift  $>1$  were screened, resulting in 24 association rules based on relevant professional knowledge and clinical practice experience, with 12 rules for each subtype. Association rules indicate that the antecedents of RCF are relatively simple, while those of PRCF are more complex; multimorbidity and polypharmacy are common risk factors for both RCF and PRCF. Differences exist in education level distribution between



**Figure 1** Importance ranking of influencing factors for community-dwelling older adults with cognitive frailty.

the two subtypes in older adults. Rules 13 and 19–24 indicate that older adults with PRCF predominantly received primary education or below, while those with RCF (Rules 6, 7, 9, 10, 12) mostly attained secondary education. Additionally, most PRCF rules (except Rules 13 and 22) included high fall risk, whereas only one RCF rule encompassed high fall risk. See [Table 3](#) and [Figure 2](#) for details.

## Discussion

### Current Status of Community-Dwelling Older Adults with CF

The proportion of older adults with RCF in this study was higher than those with PRCF, which differs slightly from the findings of Zhao.<sup>33</sup> The analysis suggests that differences in educational attainment among study participants and regional economic development levels may account for these variations. Higher educational levels are associated with greater self-care capacity among older adults while improved economic conditions indicate greater access to care resources for this demographic.<sup>34</sup>

The primary distinction between the RCF and PRCF subtypes lies in the mechanisms underlying cognitive impairment and its reversibility. The former manifests as diminished subjective cognitive abilities and markedly reduced functional connectivity within the cerebellum. By enhancing connectivity through functional compensation between the brain and cerebellum, overall cognitive function can be maintained. Thus, RCF exhibits reversible characteristics, presenting a critical window for cognitive intervention.<sup>16,35</sup> The latter manifests as mild cognitive impairment, potentially linked to structural neuronal damage. At this stage, neuronal cell loss may exceed the brain's physiological compensatory

**Table 3** Association Rules of Two Subtypes of Community-Dwelling Older Adults with Cognitive Frailty

Rule	Antecedent	Consequent	Support Degree	Confidence Degree	Lift Degree	P
1	Reside with spouse; Polypharmacy	RCF	21.73	85.18	1.17	<0.001
2	Overweight; Complete independence		14.74	85.71	1.18	<0.001
3	Married; Possible insomnia		19.47	83.06	1.14	<0.001
4	Married; Reside with spouse; Multimorbidity		28.16	85.63	1.17	<0.001
5	75 - 85 years old; Complete independence		21.73	80.41	1.11	<0.001
6	Secondary education level; No anxiety; Multimorbidity		18.33	81.51	1.12	<0.001
7	Secondary education level; No fall risk		13.23	95.89	1.32	<0.001
8	65 - 75 years old; Multimorbidity		13.79	91.25	1.25	<0.001
9	Secondary education level; Reside with spouse; Multimorbidity		13.23	85.36	1.17	<0.001
10	Secondary education level; Married; Reside with spouse; Multimorbidity; Polypharmacy		10.58	83.58	1.15	<0.001
11	Reside with spouse; High fall risk; Multimorbidity		10.58	84.58	1.15	<0.001
12	Secondary education level; Urban medical insurance; Overweight; No anxiety		10.20	83.07	1.14	<0.001
13	Primary school and below education level; Rural medical insurance	PRCF	7.93	60.86	2.22	<0.001
14	Reside with relatives; High fall risk; Multimorbidity		7.37	60.00	2.18	<0.001
15	Reside with relatives; High fall risk; Polypharmacy		6.42	62.96	2.29	<0.001
16	Reside with relatives; High fall risk; Multimorbidity; Polypharmacy		6.42	62.96	2.29	<0.001
17	≥85 years old; Divorced/Widowed; High fall risk		5.10	67.50	2.46	<0.001
18	Rural medical insurance; High fall risk		4.91	70.27	2.56	<0.001
19	Primary school and below education level; Rural medical insurance; High fall risk		4.72	69.44	2.53	<0.001
20	Reside with relatives; Mild dependence; High fall risk		4.72	62.50	2.28	<0.001
21	Primary school and below education level; High fall risk; Polypharmacy		4.34	60.52	2.20	<0.001
22	Primary school and below education level; Rural medical insurance; Multimorbidity; Polypharmacy		4.34	63.88	2.33	<0.001
23	Primary school and below education level; High fall risk; Multimorbidity; Polypharmacy		4.34	60.52	2.20	<0.001
24	Primary school and below education level; Divorced/Widowed; High fall risk		4.15	61.11	2.22	<0.001

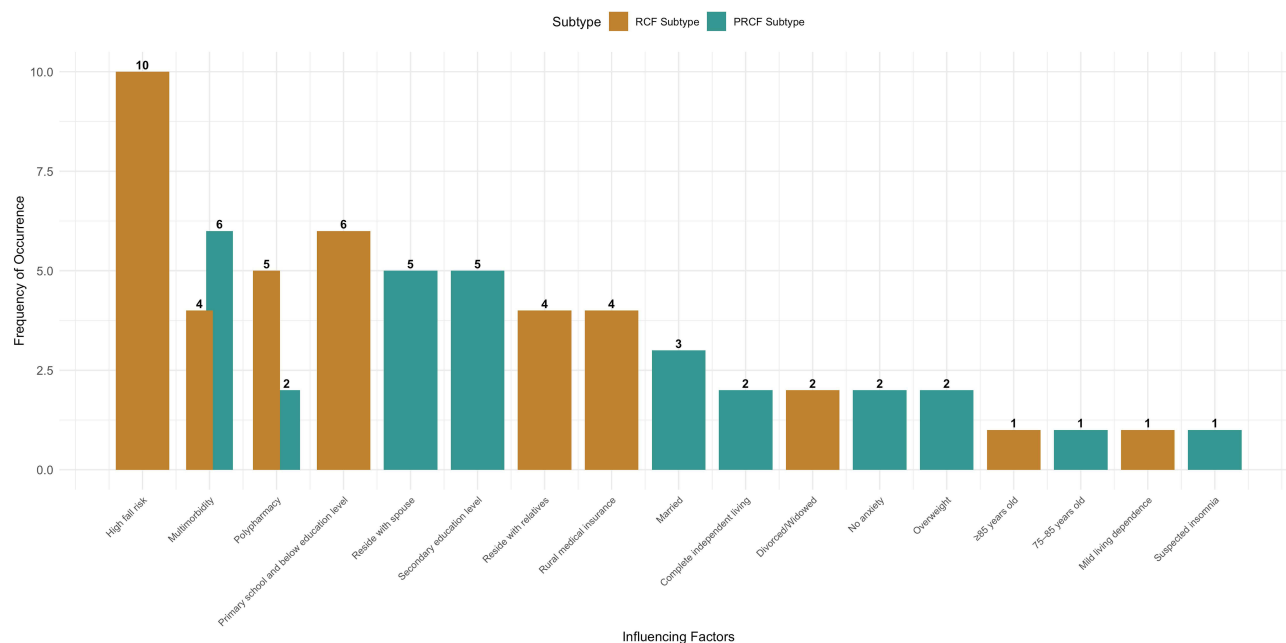
**Abbreviations:** RCF, reversible cognitive frailty; PRCF, potential reversible cognitive frailty.

capacity, potentially leading to irreversible cognitive impairment.<sup>36</sup> Therefore, enhancing early identification of RCF and PRCF and implementing timely interventions are crucial for slowing the progression of cognitive decline in older adults and optimizing long-term cognitive outcomes.

## Association Rule Analysis of Community-Dwelling CF Older Adults

Association rule algorithms aim to uncover frequent co-occurrence patterns within datasets but cannot establish causal relationships. This study found that educational attainment, high fall risk, multimorbidity, and polypharmacy are associated with both subtypes.

Among these, educational attainment is positively correlated with cognitive function. Older adults with higher education levels possess greater cognitive reserve, which stimulates neural network plasticity mechanisms and enhances information processing capabilities, thereby delaying cognitive decline.<sup>37</sup> High fall risk is a significant indicator of cognitive decline, likely because it often signifies deficits in cognitive functions such as attention, processing speed, and executive function, suggesting cognitive frail or even impairment in the elderly.<sup>38</sup> A US cohort study examining the association between multimorbidity and cognitive decline in older adults reported that multimorbidity accelerates the rate



**Figure 2** Frequency Analysis of Influencing Factors for RCF and PRCF.

of cognitive decline.<sup>39</sup> Possible causes include vascular lesions and the release of inflammatory factors due to underlying conditions such as diabetes and hypertension, which elevate systemic inflammation levels. Patients with multimorbidity conditions often require multiple medications. A meta-analysis examining polypharmacy and cognitive impairment in older adults found that polypharmacy increases the risk of cognitive decline, with the risk escalating as the number of medications increases.<sup>40</sup> Due to age-related declines in glomerular filtration and hepatic clearance,<sup>41</sup> which slow down pharmacokinetics in the body, thereby increasing the risk of adverse drug reactions and the prevalence of cognitive impairment. Concurrently, higher medication counts elevate the risk of drug interactions. Compared to monotherapy, polypharmacy can accumulate multiple side effects and amplify neurotoxicity, leading to drug-related cognitive impairment. Additionally, certain medications such as anticholinergics can cause cognitive decline by antagonizing central acetylcholine receptors and disrupting neural transmission.<sup>42</sup> Finally, the diminished self-management abilities of older adults with cognitive impairment also increase the likelihood of inappropriate medication use, creating a vicious cycle.

In RCF association rules, most antecedents are relatively simple, comprising two factors: a single risk factor and a single protective factor. This suggests that a risk factor can offset the protective effect of a protective factor, increasing the risk of cognitive impairment. Therefore, patients with RCF require assessment of specific risk factors and targeted interventions. In contrast, the antecedents in PRCF association rules are more complex, typically involving combinations of multiple risk factors with interactions among them. Consequently, it is essential to establish a multidimensional, comprehensive intervention system to achieve holistic care.

## Management of Community-Dwelling CF Older Adults Improve Community-Based Assessment of CF

«Expert consensus on neuropsychological assessment for mild cognitive impairment (2025 edition)» proposes that comprehensive and accurate evaluation of cognitive function, coupled with targeted interventions, constitutes an effective measure for delaying cognitive decline.<sup>43</sup> This study revealed distinct patterns of risk factor associations between the two subtypes. Early identification of CF subtypes in older adults is essential to focus on risk factors and provide timely interventions. Community health centers can establish cognitive screening teams comprising physicians and nurses to assess cognitive decline using scales such as Fried, MoCA, and CDR. These teams should create dedicated cognitive profiles and conduct regular follow-ups.

### Enhance the Management of Polypharmacy in Older Adults

This study found that multimorbidity conditions and polypharmacy are significant risk factors for cognitive impairment, consistent with previous research findings.<sup>40,44</sup> Therefore, healthcare professionals should regularly organize physical examinations for community older adults, provide periodic health education, monitor their underlying conditions, actively manage these conditions, promptly detect changes in their health status, and minimize the impact on their cognitive function.

Furthermore, when prescribing medications, healthcare providers should tailor treatment plans to the specific circumstances of elderly patients, refer to the Beers criteria, and comprehensively evaluate the efficacy and adverse effects of various drugs to optimize medication regimens. Special attention should be given to elderly patients taking multiple medications. Provide medication education to explain the risks of polypharmacy, remind patients to take medications regularly and in prescribed doses, monitor for adverse reactions, and seek medical attention promptly.

### Expand the Formats and Content of Health Education to Promote Healthy Lifestyles

The findings of this study indicate that older adults with lower educational attainment experience a more rapid decline in cognitive function, consistent with the results of previous research.<sup>45</sup> Older adults with higher levels of education possess greater knowledge reserves, indicating higher activation levels in their brain's neural networks, which in turn delays or mitigates the effects of cognitive decline.<sup>46</sup> At the same time, older adults with higher levels of education possess greater knowledge about disease-related matters, enabling them to proactively identify risk factors and make adjustments to enhance their self-management capabilities.<sup>47</sup> Therefore, community healthcare providers should consider the educational background of older adults and adopt personalized health education approaches. They should flexibly choose methods such as on-site education, home visits, and mobile notifications to enhance their disease knowledge and strengthen their self-management awareness. Additionally, health education content should be diversified, encompassing not only disease knowledge but also cognitive function intervention methods, balanced diets, and appropriate exercise. This will guide older adults in establishing healthy lifestyles and improving their quality of life.

### Develop a Multidimensional Intervention System

The risk factors and mechanisms underlying the two subtypes of CF differ, necessitating distinct intervention strategies. For RCF older adults, interventions should target primary risk factors to prevent progression to PRCF or cognitive impairment. In contrast, PRCF older adults require attention to a range of risk factors and their interactions, necessitating multidimensional, comprehensive intervention measures.<sup>48</sup> The management of CF older adults relies on multidisciplinary collaborative care (involving teams from geriatrics, nutrition, rehabilitation, and nursing) and follow-up monitoring by community health service centers. Research indicates that multicomponent interventions—incorporating cognitive training, physical exercise, nutritional support, and health education—significantly improved cognitive function in community-dwelling older adults and delayed the progression of CF.<sup>49</sup> With the deep integration of artificial intelligence technology in the medical field, cognitive training games developed using AI technology can dynamically adjust difficulty levels based on users' actual conditions. This enhances user adherence and positively impacts their cognitive function.<sup>50</sup> Additionally, leveraging “Internet Plus” technologies can empower patients through features such as mobile notifications and wristband vibration alerts. This approach reduces the implementation costs of intervention measures, enhances patient adherence, and ultimately improves cognitive function.<sup>51</sup> Cognitive function undergoes dynamic changes, which requires close monitoring. By leveraging smart wearable devices to collect physiological data such as blood pressure, sleep cycles, physical activity, and emotional states from older adults, combined with standardized cognitive assessment scale results, a CF risk prediction model is established to identify risk factors and develop personalized intervention measures.<sup>52,53</sup> It is worth noting that the application of artificial intelligence and internet technologies in CF interventions may be hindered by factors such as insufficient digital literacy among older adults and limited access channels. This underscores the need for communities to tailor the implementation of such technological tools to the actual circumstances of older adults and to provide complementary support measures, including digital skills training.

## Limitations

First, this study employed self-report instruments for data collection, which are susceptible to subjectivity among participants. This may lead to discrepancies between reported outcomes and actual results, introducing bias. Second, the Apriori algorithm was selected for association rule analysis. This algorithm can only identify co-occurrence patterns among variables and cannot reveal underlying causal relationships. Finally, the analysis did not account for missing data, potentially introducing selection bias that may compromise the robustness of the findings.

## Conclusion

This study employed the Apriori algorithm to perform association rule analysis on data from community-dwelling older adults with cognitive frailty. It revealed distinct patterns in risk factor associations between RCF and PRCF, indicating differing intervention windows and approaches. Based on these findings, communities can focus on addressing cognitive frailty in the elderly and implement risk stratification, providing a theoretical basis for personalized cognitive interventions. This study addresses the need for cognitive health in an aging society, laying preliminary groundwork for reducing the public health burden associated with cognitive impairment-related diseases.

## Data Sharing Statement

Current research data can be obtained from the corresponding author (Huo Xiaopeng, huoxp001@126.com) upon reasonable request.

## Ethics Approval and Consent to Participate

The study design and procedures strictly adhered to the ethical principles outlined in the Declaration of Helsinki (2013 revision). This study was approved by the Ethics Committee of Peking Union Medical College Hospital, with the ethics review approval number ZS-2943.

## Consent for Publication

All subjects understood and signed the informed consent form.

## Acknowledgments

Thank you to all subjects who participated in this study.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

## Funding

This study was supported by the National High Level Hospital Clinical Research Funding (2022-PUMCH-B-130).

## Disclosure

The authors declare no conflicts of interest in this work.

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