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ORIGINAL RESEARCH

Evaluating the Risk of Social Isolation in Older People: AHP-Fuzzy Comprehensive Evaluation

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Background: Social isolation is a serious and pervasive health issue among older people, and it is difficult to identify and assess effectively. Based on a thorough and scientific evaluation index system, AHP-Fuzzy comprehensive evaluation could be a valuable technique.

Objective: It is crucial to establish interventions that focus on risk factors for the prevention of social isolation in order to give a strong scientific foundation for enhancing older people's health habits. This can be achieved by using a fuzzy comprehensive evaluation method to assess the risk of social isolation in older people.

Methods: A hundred community members over 60 from Nanjing were selected as the evaluation subjects in China. After the element layer was split into three categories of "social risk, economic risk, and cultural risk" using the analytic hierarchy process approach, a total of 22 assessment indicators were picked to develop a risk evaluation index system.

Results: The risk level of social isolation belonging to the "low risk, relatively low risk, medium risk, relatively high risk, high risk" of membership degree are respectively "0.3392, 0.2632, 0.2257, 0.1069, 0.0650". Fuzzy comprehensive evaluation analysis showed that social relations (0.4934), monthly income (0.4654), health status (0.5960) were significant factors of social isolation risk in older people. The results showed that factors related to social risk had the most significant impact on social isolation.

Conclusion: It is scientific and feasible to construct the risk evaluation index model of social isolation risk for the elderly by using AHP-Fuzzy comprehensive evaluation method. In preventing social isolation of older people in the future, we should pay attention to the impact of social and cultural factors on them, and provide practical intervention programs and references from the government, community, family.

Keywords: AHP, fuzzy comprehensive evaluation method, social isolation, older people

Introduction

Social isolation could be defined as an objective measure that reflects an individual's lack of contact or ties with others such as family, friends, acquaintances, and neighbors,[1] there is also perceived social isolation, the feeling of not belonging to the society.[2] Due to the complicated contexts of a rapidly aging population, fast social transformation, and speedy urbanization, the phenomenon of intergenerational separation has become a common social trend in China, leading to a high prevalence of socially isolated "left behind" people, especially among the older population.[3] At the same time, as older individuals get older, the physical health status gradually declines, and the severity and variety of chronic diseases continue to rise. Older people are more likely to experience social isolation due to physical functional limitations that make it difficult for them to participate in social activities, a lack of access to reliable transportation, the burden of greater physical and psychological pain, and the loss of formal social roles and meaningful interpersonal connections.[4]

Numerous studies have shown the significant relationship between older people's social networks and health-related quality of life.[5] Individuals who are socially isolated have been proven to have a higher chance of acquiring heart disease,

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stroke, depression, dementia, and early mortality.[6,7] Social isolation has a major negative impact on older people's health behaviors, sleep, energy levels, and social connections. This could lead to a higher illness burden and a higher risk of early death.[8] In addition to its negative impact on quality of life, previous studies have linked social isolation to an increased risk of cognitive decline and Alzheimer's disease.[9] The World Health Organization (WHO) declared that the social isolation of older persons has become a public health issue.[10] Individuals and the larger community are both negatively impacted by social isolation, which has a significant negative economic impact on individuals, families, and society.

Although social isolation is a significant and prevalent health problem among community-dwelling older adults, leading to numerous detrimental health conditions,[11] there are lots of influencing factors that lead to social isolation in older people. Due to the lack of regular evaluation, social isolation frequently goes unnoticed.[12] When elderly adults are discovered to be socially isolated, it is likely that this has a profound effect on them, leading to feelings of loneliness, sadness, and suicidal thoughts. Especially since the outbreak of novel coronavirus pneumonia (COVID-19), China firmly adheres to the community closed management mode in order to guarantee resident safety. Older people living in the community are momentarily cut off from friends and society friends and society. At the same time, their ability to use smart technological products is insufficient, and these circumstances will result in older people only having access to single source of health information, readily developing psychological traits like herd anxiety or stubbornness and conceit. During the epidemic prevention and control period, older people's physical health and primary livelihood are facing greater threats, which will increase the possibility of social isolation among older people.

In conclusion, the steady decline of the social network of older people will always pose a practical issue, regardless of whether it is the result of changes in the objective environment or older people's subjective preferences. In November 2019, the Chinese government published the "An Interpretation of The Medium-and Long-term Plan for Responding Proactively to Population Aging", which asserts that actively addressing population aging is a key national policy. "Active" means that preventing disease is more crucial than treating the disease that has already occurred. Early identification of older people who have an accumulated risk of social isolation may present possibilities for early strategic intervention to avert negative behavioral and health outcomes.[13] Currently, most researchers have concentrated on the outcomes of the results of influencing factors derived from cross-sectional surveys, such as retirement,[14] being 75 years and over,[15] having limited financial resources,[14] having a high level of residential mobility,[16] and having limited access to services, amenities and public transportation.[17] Only a few conventional methods were used to demonstrate obvious results, these studies were unable to systematically analyze the combined effect mechanism of multiple related factors of social isolation in older people. According to the literature we have reviewed, the identification and evaluation of social isolation risks for older people have been neglected, and there is few standardized evaluation tool or quality index system to evaluate the risk of social isolation in older people.

In this work, we integrated the analytical hierarchy process (AHP) and fuzzy comprehensive evaluation (FCE) to provide a predicting approach towards the risk of social isolation in older people. In comparison to previous studies, risk factors of relevant economic and cultural aspects were included in order to consider the influence of multiple factors comprehensively,[18] which could provide better quality research evidence and a reference for developing interventions for social isolation in older people, ultimately achieving the effect of reducing adverse health outcomes among older people.

Research Question and Research Hypotheses

The occurrence of social isolation in older people is a serious but under-recognized public health problem, and effective identification of risk factors for social isolation in older people plays a key role in helping them connect with society. So, what are the risk factors that contribute to social isolation in older adults? Is there variation in the degree to which these factors influence social isolation? Thus, we proposed our first hypothesis.

Hypothesis 1: We hypothesize that the risk factors of social isolation in older people may include the aspects of social interactions, economic position, and cultural literacy, and the degree to which different risk factors influence social isolation is varied.

Since the occurrence of social isolation in older people is occult and uncertain. The risk factors of social isolation among older people are not identified clearly, and there is no effective and unified prediction method at present.

Therefore, which methods could be used to effectively assess the risk of social isolation in older people, and overcome the subjectivity of the results to obtain accurate and objective assessments results? We proposed the second hypothesis.

Hypothesis 2: We hypothesize that we could accurately predict and assess the social isolation risk of older people through the combination of AHP and FCE method.

Research Objectives

The purpose of the present study is twofold: (i) to gain an in-depth understanding of the various aspects risk factors of social isolation in older people and examine the impact mechanisms of these risk factors; to (ii) construct a risk evaluation index system of social isolation in older people and offer guidance on various risk levels for enhancing older people's health habits. Our research will offer a solid scientific foundation for lowering social isolation and enhancing older people's life satisfaction and well-being.

Methods

Study Design

In this study, the AHP-fuzzy comprehensive evaluation method was used in the research method. In Phase 1, we constructed "the evaluation index system of risk of social isolation in older people" based on the two rounds of Delphi expert correspondence and AHP method, and the weights of each index were determined; In Phase 2, a questionnaire survey was utilized to collected pertinent data by asking the older people to answer paper or electronic questionnaire issued by community workers to help this study, and determined the evaluation index membership degree. Based on the results of two phases, the FCE method was used to assess and predict the social isolation risk of older people.

Data Sources

Phase 1

"The evaluation index system of risk of social isolation in older people" was constructed based on the opinions obtained from the first round of expert correspondence method. In the second round of Delphi, 20 experts were asked to score the importance of each index to determine the weight of the indicator. The selection criteria of experts included: ①Working in the field of elderly management, elderly care, elderly service, elderly education; ②Having a bachelor degree or above; ③Having an intermediate title or above; ④Working in their professional field for 10 years or above; ⑤Being willing to accept the correspondence based on the principle of informed consent and having enthusiasm for this study. The experts were inquired by correspondence through face-to-face or telephone interviews, regular mail and working email, and requested the experts to reply within two weeks. There were 2 experts from provincial authorities, 8 experts from universities, 2 experts from well-known elderly care institutions and 1 expert from hospital. The active coefficient of experts of two rounds were 100%, the authority ratio were 0.901 and 0.903, the Kendall 'W coefficient of experts were 0.306 and 0.392 ($P<0.001$). It showed that the experts in this research institute have certain authority in this field, and the results of the correspondence were representative.

Phase 2

Through the index system constructed in this study, a questionnaire survey was conducted among 100 older people over 60 living in the Pukou District of Nanjing, Jiangsu Province of China, the index membership of "The evaluation index system of risk of social isolation in older people" was determined. Among them, there were 47 elderly males and 53 elderly females, with an average age of 76.5±5.6. These 100 older people had a low level of education, 27 were illiterate and semi-illiterate, 22 were in primary schools, accounting for nearly half (49%), 11% of them had more than 3 kinds of chronic diseases, most of them suffered from 1–2 chronic diseases (83%). The questionnaire recovery rate was 100%. All the data questionnaires are valid, ensuring the validity of the research results.

Inclusion criteria included: ①age ≥ 60 years old; ②ability to conduct verbal communication or written conversation; ③participants or guardians agreed and signed the informed consent form for this study; ④no substantial cognitive

impairments or serious physical illnesses; ⑤older people or their caregivers, such as nursing staff and nurses, have the ability to accept the questions on the questionnaire from the assessors and answer the relevant questions correctly;

Exclusion criteria included: ①those who fill in the form incorrectly or incompletely; ②those who are unable to continue the investigation due to sudden emergency during the research process; ③significant speech and communication impairments, mental disorders, cognitive impairment, and dementia; ④refusing to take part in this survey.

Quality Control

The process of expert consultation and questionnaire research was conducted rigorously under the guidance of research groups and the research department. In the preparation of "the evaluation index system of risk of social isolation in older people", our study team was familiar with recent literature, and the expert coordination committee will make modifications, hold discussions, and make decisions to guarantee the accuracy of the index system. As for data collection, data were collected through face-to-face interviews in respondents' homes or the community center, conducted by trained interviewers using standardized questionnaires. After the respondents completed the filling, the questionnaires were double-checked carefully to ensure the information's authenticity, completion, integrity, and accuracy.

Statistical Analysis

We input all the collected data to Microsoft Office Excel © 2013 with two researchers checking, and we used SPSS 22.0 version to analyze the data. Mean and standard deviation (SD) were used to describe the normally distributed continuous variables. By frequency and percentage, the general characteristics of the respondents were examined. The adoption rate of open opinions was described and classified and summarized; The overall quality of scenario simulation teaching was evaluated by the fuzzy comprehensive evaluation method. The adoption rate of open opinions was described, classified, and summarized.

The Combination of the AHP and FCE Method

The risk of social isolation is an ill-defined notion that can be influenced by numerous hazy linked variables. While the evaluation outcomes are typically based on subjective assessment, this shows that precise and quantitative research is frequently challenging and ambiguous.[22] A multi-level fuzzy comprehensive evaluation is an advanced method in which AHP and FCE are integrated. After specifying the weights of each indicator, this method is based on the hierarchical analysis method, converts the qualitative evaluation into a quantitative evaluation by using the fuzzy mathematics notion of maximum membership degree and the transformation principle.

Additionally, this approach is simple and intuitive, the model is simple to build and solve, and some calculations may be performed using Excel or programming tools. Consequently, the thorough AHP-fuzzy evaluation is quite doable and further ensures the objectivity and logic of the evaluation outcomes. Based on the evaluation index system of risk of social isolation in older people, elements were grouped according to their degree of membership and association by using the analytical hierarchy approach, improving the weights and creating a disjoint multi-level structure model. The comprehensive value was subsequently determined using the fuzzy comprehensive multi-level assessment approach. Figure 1 illustrated the fundamental procedure.

Since each influencing risk factor could more accurately describe the relative importance among factors, we adopted a fuzzy comprehensive evaluation method in this study to evaluate the influencing risk factors of social isolation in older people. This allowed us to quantitatively describe these uncertain factors and present the qualitative results and subjective feelings, and to some extent avoid the evaluation results being influenced by the state and mood of older people. At the same time, this study could provide a valid methodological reference for evaluating of social isolation risk for older people.

The Evaluation Index System of Risk of Social Isolation in Older People

This section was constructed using the findings from the study team's earlier literature review. Using the expert correspondence method, the experts were asked to compare the significance of each indicator based on the Saaty1–9 evaluation scale (Table 1). "The evaluation index system of risk of social isolation in older people" was then created based on the opinions and evaluation scores of 20 representative experts. These factors could be further divided into different states according to their specific characteristics. According to this principle, the AHP method was used to identify the social isolation risk

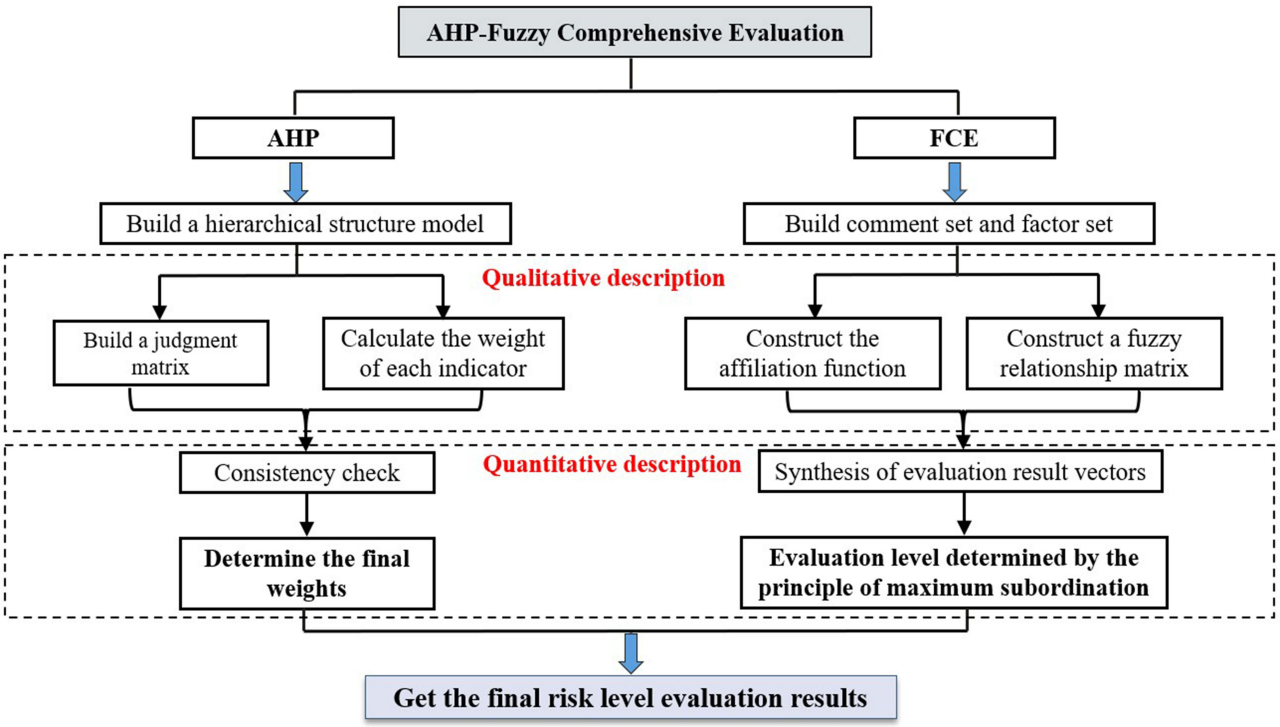

Figure 1 Evaluation method flow chart.

systematically. As evaluation layers, several levels of social isolation risk for older individuals were employed, including low risk, relatively low risk, medium risk, relatively high risk, and high risk. The index layer was divided into a factor layer and state layer, which each contained 7 second-level items and 22 third-level items. The index layer covers social risk, economic risk, and cultural risk. The evaluation index system of risk of social isolation in older people was shown in Figure 2. The risk of social isolation in older people was thoroughly assessed using the AHP method in conjunction with the fuzzy mathematics assessment approach based on the determination of the index system.

Calculation of Evaluation Indicator Weights

Construction of Judgment Matrix

The indicator weights were determined using the AHP approach, and the indicator factors were compared two-by-two for each tier. Assuming A and B are both finite sets on the argument's domain, with A= (a_1, a_2, …, a_m), B= (b_1, b_2, …, b_n), R is used to express the fuzzy relation A × B.

$$R = A \times B = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix}$$

Table 1 Quantitative Values of Judgment Scale

Judgment Scale a_{ij}	Definition
a_{ij}=1	The two types of factors are of equal importance
a_{ij}=3	Compared with the two types of factors, the score rate of factor i is 10% higher than factor j (i is more important than j)
a_{ij}=5	Compared with the two types of factors, factor i has a 20% higher score rate than factor j (i is obviously more important than j)
a_{ij}=7	The score rate of factor i is 30% higher than factor j compared to the two types of factors (i is significantly more important than j)
a_{ij}=9	Compared with the two types of factors, factor i has a 40% higher score rate than factor j (i is extremely important than j)
2, 4, 6, 8	In the middle of the above two adjacent judgment scales
Reciprocal	If the ratio of importance of factor i to factor j is a_{ij}, then the ratio of importance of factor j to factor i is $a_{ij} = 1/a_{ij}$

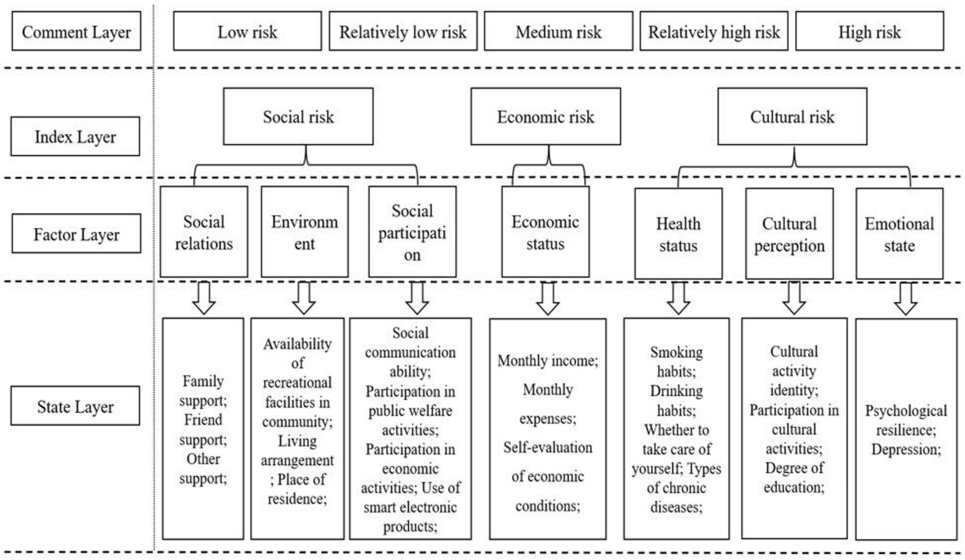

Figure 2 Multilevel index system for social isolation risk assessment in older people.

Where r_{mn} represents the degree to which the mth element a_m of set A is subordinate to the nth element b_n of set B.[19]

Calculation of Weights

Using the square root approach, the calculation steps for the single hierarchical ranking result in a vector of weights corresponding to the components of each level of the judgment matrix for the preceding level.

Calculated the product of the elements in each row of the judgment matrix A:

$$m_t = \prod_{j=1} a_{ij}, i = 1, 2 \cdots n$$

Calculated the product of each row element of the judgment matrix A:

$$v_i = \sqrt[n]{\prod_j a_{ij}}$$

To obtain the weight W of the importance of each index relative to the index of the previous index, the normalization of the feature vector $w^* = \left(w_1^*, w_2^*, \cdots, w_n^*\right)^T$ was as follows:

$$w_i = \frac{w_i^*}{\sum_{i=1}^n w_i^*} \ (i = 1, 2, \cdots, n)$$

Consistency Check

After the feature vector had been created, a consistency test was employed to regulate the method's outcome. It examined the comparison matrix's logic and the weights' reasonableness. The following equation represents the departures from consistency, and the CI was a measure of inconsistency.[20]

The CI value was obtained by calculating the maximum eigenvalue

The maximum eigenvalue of the judgment matrix:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(Aw)_i}{w_i}$$

The calculation of consistency test indicators was as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

When the order of the judgment matrix "n" was greater than 2, the indicator was corrected by the average random consistency indicator RI of the judgment matrix (Table 2).

Second, calculated the consistency check results.

$$CR = CI/RI$$

If CR was less than or equal to 0.1, the judgment matrix satisfied the consistency criteria; Otherwise, it had to be adjusted until consistency is achieved.

Determine the Factor Set and the Comment Set

Identified the evaluation index set after analyzing the evaluation index system of the risk of social isolation in older people. The target layer was set to A = (evaluation of social isolation risk in older people), including 3 first-level indicators: A = {B1, B2, B3}; There were 7 secondary indicators: B1 = {C1, C2, C3}; B2 = {C4, C5, C6}; B3 = {C7, C8, C9, C10}; B4 = {C11, C12, C13}; B5 = {C14, C15, C16, C17}; B6 = {C18, C19, C20}; B7 = {C21, C22}, and the comment set was V = {V1, V2, V3, V4, V5}, in which Vi (i = 1, 2, 3, 4, 5) means "low risk, relatively low risk, medium risk, relatively high risk, high risk", respectively.

Determining the Matrix of Fuzzy Relationships

Determining the matrix of fuzzy relationships$R = (R_1, R_2, \cdots, R_n)^T$,

$$R_i = \left(w^i{}_1, w^i{}_2, \cdots, w^i{}_k\right) \begin{bmatrix} s^i{}_{11} & s^i{}_{12} & \cdots & s^i{}_{1m} \\ s^i{}_{21} & s^i{}_{22} & \cdots & s^i{}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ s^i{}_{k1} & s^i{}_{k2} & \cdots & s^i{}_{km} \end{bmatrix} = (r_{i1}, r_{i2}, \cdots, r_{im})$$

$(w^i{}_1, w^i{}_2, \cdots, w^i{}_k)$ is a vector of weights for the tertiary indicators to which the ith secondary indicator belongs.

The Caculation of Final Weights

The weight of each indication on the target was calculated layer by layer using the resulting model that was produced. The judgment matrix's CI and CR values were less than 0.1, showing that it makes sense and the weights assigned to each evaluation element in "the evaluation index system of risk of social isolation in older people" have passed the consistency test (Table 3).

The Calculation of Evaluation Level Membership Degree

By analyzing the level corresponding to each indication, the evaluation member degree values were determined. In this study, 100 older participants completed questionnaires, and the findings were used to create an assessment index membership degree of social isolation in older people (Table 4).

The Calculation of Membership Degree Matrix

In order to assess the social isolation risk strata in older people, the score results from the formula "X = m/n" were utilized to create a single-factor membership degree matrix, with the following values:

$$D_1 = \begin{bmatrix} u_{11} \\ u_{12} \\ u_{13} \end{bmatrix} = \begin{bmatrix} s^1{}_{11} & s^1{}_{12} & s^1{}_{13} & s^1{}_{14} & s^1{}_{15} \\ s^1{}_{21} & s^1{}_{22} & s^1{}_{23} & s^1{}_{24} & s^1{}_{25} \\ s^1{}_{31} & s^1{}_{32} & s^1{}_{33} & s^1{}_{34} & s^1{}_{35} \end{bmatrix} = \begin{bmatrix} 0.47 & 0.25 & 0.17 & 0.07 & 0.04 \\ 0.29 & 0.36 & 0.21 & 0.07 & 0.07 \\ 0.35 & 0.34 & 0.13 & 0.15 & 0.03 \end{bmatrix}$$

Table 2 Random Consistency Index

Dimension	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 3 Weighting of Each Evaluation Factor of the Evaluation Index System

Comment Layer	Index Layer	Weight	Factor Layer	Weight	State Layer	Weight	Global Weights
Social isolation risks	Social risk (A_1)	0.5842	Social relation (B_1)	0.4934	Family support (C_1)	0.5757	0.1659
					Friend support (C_2)	0.2620	0.0755
					Other support (C_3)	0.1623	0.0468
			Environment (B_2)	0.3108	Availability of recreational facilities in community (C_4)	0.3110	0.0565
					Living arrangement (C_5)	0.4114	0.0747
					Place of residence (C_6)	0.2776	0.0504
			Social participation (B_3)	0.1958	Social communication ability (C_7)	0.3952	0.0452
					Participation in public welfare activities (C_8)	0.2322	0.0266
					Participation in economic activities (C_9)	0.2320	0.0265
					Use of smart electronic products (C_{10})	0.1406	0.0161
	Economic risk (A_2)	0.2318	Economic status (B_4)	1.0000	Monthly income (C_{11})	0.4654	0.1079
					Monthly expenses (C_{12})	0.2777	0.0644
					Self-evaluation of economic conditions (C_{13})	0.2569	0.0595
	Cultural risk (A_3)	0.1840	Health status (B_5)	0.5960	Smoking habits (C_{14})	0.2761	0.0303
					Drinking Habits (C_{15})	0.1953	0.0214
					Whether to take care of yourself (C_{16})	0.3905	0.0428
					Types of chronic diseases (C_{17})	0.1381	0.0151
			Cultural perception (B_6)	0.2185	Cultural activity identity (C_{18})	0.5327	0.0214
					Participation in cultural activities (C_{19})	0.2346	0.0094
					Degree of education (C_{20})	0.2327	0.0094
			Emotional state (B_7)	0.1855	Depression (C_{21})	0.7530	0.0257
					Psychological resilience (C_{22})	0.2470	0.0084

$$D_2 = \begin{bmatrix} u_{21} \\ u_{22} \\ u_{23} \end{bmatrix} = \begin{bmatrix} s^2{}_{11} & s^2{}_{12} & s^2{}_{13} & s^2{}_{14} & s^2{}_{15} \\ s^2{}_{21} & s^2{}_{22} & s^2{}_{23} & s^2{}_{24} & s^2{}_{25} \\ s^2_{31} & s^2_{32} & s^2_{33} & s^2_{34} & s^2_{35} \end{bmatrix} = \begin{bmatrix} 0.52 & 0.20 & 0.23 & 0.02 & 0.03 \\ 0.43 & 0.19 & 0.24 & 0.05 & 0.09 \\ 0.52 & 0.2 & 0.23 & 0.02 & 0.03 \end{bmatrix}$$

$$D_3 = \begin{bmatrix} u_{31} \\ u_{32} \\ u_{33} \\ u_{34} \end{bmatrix} = \begin{bmatrix} s^3{}_{11} & s^3{}_{12} & s^3{}_{13} & s^3{}_{14} & s^3{}_{15} \\ s^3{}_{21} & s^3{}_{22} & s^3{}_{23} & s^3{}_{24} & s^3{}_{25} \\ s^3{}_{31} & s^3{}_{32} & s^3{}_{33} & s^3{}_{34} & s^3{}_{35} \\ s^3{}_{41} & s^3{}_{42} & s^3{}_{43} & s^3{}_{44} & s^3{}_{45} \end{bmatrix} = \begin{bmatrix} 0.56 & 0.21 & 0.03 & 0.08 & 0.12 \\ 0.21 & 0.17 & 0.36 & 0.18 & 0.08 \\ 0.16 & 0.37 & 0.19 & 0.23 & 0.05 \\ 0.26 & 0.13 & 0.32 & 0.25 & 0.04 \end{bmatrix}$$

$$D_4 = \begin{bmatrix} u_{41} \\ u_{42} \\ u_{43} \end{bmatrix} = \begin{bmatrix} s^4{}_{11} & s^4{}_{12} & s^4{}_{13} & s^4{}_{14} & s^4{}_{15} \\ s^4{}_{21} & s^4{}_{22} & s^4{}_{23} & s^4{}_{24} & s^4{}_{25} \\ s^4{}_{31} & s^4{}_{32} & s^4{}_{33} & s^4{}_{34} & s^4{}_{35} \end{bmatrix} = \begin{bmatrix} 0.13 & 0.26 & 0.42 & 0.12 & 0.07 \\ 0.18 & 0.32 & 0.26 & 0.19 & 0.05 \\ 0.33 & 0.24 & 0.21 & 0.14 & 0.08 \end{bmatrix}$$

$$D_5 = \begin{bmatrix} u_{51} \\ u_{52} \\ u_{53} \\ u_{54} \end{bmatrix} = \begin{bmatrix} s^5{}_{11} & s^5{}_{12} & s^5{}_{13} & s^5{}_{14} & s^5{}_{15} \\ s^5{}_{21} & s^5{}_{22} & s^5{}_{23} & s^5{}_{24} & s^5{}_{25} \\ s^5{}_{31} & s^5{}_{32} & s^5{}_{33} & s^5{}_{34} & s^5{}_{35} \\ s^5{}_{41} & s^5{}_{42} & s^5{}_{43} & s^5{}_{44} & s^5{}_{45} \end{bmatrix} = \begin{bmatrix} 0.23 & 0.45 & 0.21 & 0.07 & 0.04 \\ 0.45 & 0.23 & 0.13 & 0.08 & 0.11 \\ 0.32 & 0.36 & 0.19 & 0.06 & 0.07 \\ 0.23 & 0.31 & 0.21 & 0.16 & 0.09 \end{bmatrix}$$

$$D_6 = \begin{bmatrix} u_{61} \\ u_{62} \\ u_{63} \end{bmatrix} = \begin{bmatrix} s^6{}_{11} & s^6{}_{12} & s^6{}_{13} & s^6{}_{14} & s^6{}_{15} \\ s^6{}_{21} & s^6{}_{22} & s^6{}_{23} & s^6{}_{24} & s^6{}_{25} \\ s^6{}_{31} & s^6{}_{32} & s^6{}_{33} & s^6{}_{34} & s^6{}_{35} \end{bmatrix} = \begin{bmatrix} 0.43 & 0.17 & 0.16 & 0.18 & 0.06 \\ 0.43 & 0.17 & 0.16 & 0.18 & 0.06 \\ 0.11 & 0.21 & 0.21 & 0.24 & 0.23 \end{bmatrix}$$

Table 4 Evaluation Level Membership Degree of Each Indicator

State Layer \ Risk Level	Low Risk	Relatively Low Risk	Medium Risk	Relatively High Risk	High Risk
Family support (C_1)	0.47	0.25	0.17	0.07	0.04
Friend support (C_2)	0.29	0.36	0.21	0.07	0.07
Other support (C_3)	0.35	0.34	0.13	0.15	0.03
Availability of recreational facilities in community (C_4)	0.52	0.20	0.23	0.02	0.03
Living arrangement (C_5)	0.43	0.19	0.24	0.05	0.09
Place of residence (C_6)	0.52	0.2	0.23	0.02	0.03
Social communication ability (C_7)	0.56	0.21	0.03	0.08	0.12
Participation in public welfare activities (C_8)	0.21	0.17	0.36	0.18	0.08
Participation in economic activities (C_9)	0.16	0.37	0.19	0.23	0.05
Use of smart electronic products (C_{10})	0.26	0.13	0.32	0.25	0.04
Monthly income (C_{11})	0.13	0.26	0.42	0.12	0.07
Monthly expenses (C_{12})	0.18	0.32	0.26	0.19	0.05
Self-evaluation of economic conditions (C_{13})	0.33	0.24	0.21	0.14	0.08
Smoking habits (C_{14})	0.23	0.45	0.21	0.07	0.04
Drinking Habits (C_{15})	0.45	0.23	0.13	0.08	0.11
Whether to take care of yourself (C_{16})	0.32	0.36	0.19	0.06	0.07
Types of chronic diseases (C_{17})	0.23	0.31	0.21	0.16	0.09
Cultural activity identity (C_{18})	0.43	0.17	0.16	0.18	0.06
Participation in cultural activities (C_{19})	0.43	0.17	0.16	0.18	0.06
Degree of education (C_{20})	0.11	0.21	0.21	0.24	0.23
Depression (C_{21})	0.15	0.22	0.27	0.17	0.19
Psychological resilience (C_{22})	0.16	0.35	0.36	0.07	0.06

$$D_7 = \begin{bmatrix} u_{71} \\ u_{72} \end{bmatrix} = \begin{bmatrix} s^7{}_{11} & s^7{}_{12} & s^7{}_{13} & s^7{}_{14} & s^7{}_{15} \\ s^7{}_{21} & s^7{}_{22} & s^7{}_{23} & s^7{}_{24} & s^7{}_{25} \end{bmatrix} = \begin{bmatrix} 0.15 & 0.22 & 0.27 & 0.17 & 0.19 \\ 0.16 & 0.35 & 0.36 & 0.07 & 0.06 \end{bmatrix}$$

Results

The Result of Multi-Level Comprehensive Evaluation

The Result of Factor Layer Fuzzy Evaluation

The result vector of fuzzy comprehensive evaluation of Social relation (B_1) was:

$$R_1 = W_1 \times D_1 = (0.5757, 0.2619, 0.1623) \begin{bmatrix} 0.47 & 0.25 & 0.17 & 0.07 & 0.04 \\ 0.29 & 0.36 & 0.21 & 0.07 & 0.07 \\ 0.35 & 0.34 & 0.13 & 0.15 & 0.03 \end{bmatrix}$$

= (0.3975, 0.2995, 0.1654, 0.0949, 0.0428).

Similarly, it could be obtained:

The result vector of fuzzy comprehensive evaluation of Environment (B_2) was:

$$R_2 = W_2 \times D_2 = (0.4975, 0.1975, 0.2325, 0.0275, 0.0450)$$

The result vector of fuzzy comprehensive evaluation of Social participation (B_3) was:

$$R_3 = W_3 \times D_3 = (0.3483, 0.2230, 0.1808, 0.1683, 0.0796)$$

The result vector of fuzzy comprehensive evaluation of Economic status (B_4) was;

$$R_4 = W_4 \times D_4 = (0.2020, 0.2655, 0.3234, 0.1399, 0.0692)$$

The result vector of fuzzy comprehensive evaluation of Health status (B_5) was:

$$R_5 = W_5 \times D_5 = (0.2978, 0.3629, 0.1889, 0.0816, 0.0689)$$

The result vector of fuzzy comprehensive evaluation of Cultural perception (B_6) was:

$$R_6 = W_6 \times D_6 = (0.3305, 0.1824, 0.1755, 0.1986, 0.1128)$$

The result vector of fuzzy comprehensive evaluation of Emotional state (B_7) was:

$$R_7 = W_7 \times D_7 = (0.1525, 0.2525, 0.2925, 0.1450, 0.1575)$$

The Result of Index Layer Fuzzy Evaluation

Based on the combined membership degree R_1, R_2, R_3, the judgement matrix C_1 for the secondary indicator "social risk" was obtained:

$$C_1 = [R_1, R_2, R_3]^T = \begin{bmatrix} 0.3975 & 0.2995 & 0.1654 & 0.0949 & 0.0428 \\ 0.4975 & 0.1975 & 0.2325 & 0.0275 & 0.0450 \\ 0.3483 & 0.2230 & 0.1808 & 0.1683 & 0.0796 \end{bmatrix}$$

$C_1 \times A_1$ obtained $d_1 = [0.4189, 0.2528, 0.1893, 0.0883, 0.0507]$

Based on the combined membership degree R_4, the judgement matrix C_2 for the secondary indicator "economic risk" was obtained:

$$C_2 = [R_4] = [\,0.2020 \quad 0.2655 \quad 0.3234 \quad 0.1399 \quad 0.0692\,]$$

$C_2 \times A_2$ obtained $d_2 = [0.2020, 0.2655, 0.3234, 0.1399, 0.0692]$

Based on the combined membership degree R_5, R_6, R_7, the judgement matrix C_3 for the secondary indicator "cultural risk" was obtained:

$$C_3 = \begin{bmatrix} R_5 \\ R_6 \\ R_7 \end{bmatrix}^T = \begin{bmatrix} 0.2978 & 0.3629 & 0.1889 & 0.0816 & 0.0689 \\ 0.3305 & 0.1824 & 0.1755 & 0.1986 & 0.1128 \\ 0.1525 & 0.2525 & 0.2925 & 0.1450 & 0.1575 \end{bmatrix}$$

$C_3 \times A_3$ obtained $d_3 = [0.2591, 0.2932, 0.2185, 0.1242, 0.1050]$

The Result of Fuzzy Comprehensive Evaluation Model

Based on the combined membership degree d_1, d_2, d_3, the judgment matrix of the first level indicators was obtained:

$$B = [d_1, d_2, d_3]^T = \begin{bmatrix} 0.4189 & 0.2528 & 0.1893 & 0.0883 & 0.0507 \\ 0.2020 & 0.2655 & 0.3234 & 0.1399 & 0.0692 \\ 0.2591 & 0.2932 & 0.2185 & 0.1242 & 0.1050 \end{bmatrix}$$

The combined membership degree W is obtained from $B \times A$:

$$W = [0.3392, 0.2632, 0.2257, 0.1069, 0.0650]$$

The first-level item in this study, "risk of social isolation", yielded a comprehensive evaluation result of $W = [0.3392, 0.2632, 0.2257, 0.1069, 0.0650]$, which means that the degree of "low risk" was at the level of 33.92%, the degree of "relatively low risk" was at the level of 26.32%, the degree of "medium risk" was at the level of 22.57%, the degree of "relatively high risk" is at the level of 10.69%, and the degree of "high risk" is at the level of 6.50%.

According to the principle of maximum membership degree, 0.3392 was the biggest size of membership degree, which corresponds to the risk level V1 (low risk). In this neighborhood, 100 older people were evaluated, and the risk of social isolation was rated as "low risk". The outcome of the examination was the V1. Table 5 displayed the final percentages of each risk category of social isolation for the 100 elderly residents of the neighborhood. The findings implied that, in order to better offer older people with the assistance they require, the risk of social isolation merits attention and should be assessed in a reasonable and timely way.

Table 5 Percentage of Social Isolation Risk in Older People

Risk Level	Low Risk	Relatively Low Risk	Medium Risk	Relatively High Risk	High Risk
Percentage	33.92%	26.32%	22.57%	10.69%	6.50%

Analysis of Evaluation Results

The evaluation indicator system's weighting in the index layer was rated as follows: social risk A_1 (0.5842) > economic risk A_2 (0.2318) > cultural risk A_3 (0.1840). This implies that the first essential components of intervention and prevention of social isolation risk for older people are the social relationships, social networks and social participation of older people. Further risk prevention of economic and cultural risks could only be accomplished if these risks are diminished. All of the hypotheses were supported empirically by the findings. The results of the weighting of the various levels of social risk showed that Social relations B_1 (0.4934) > Environment B_2 (0.3108) > Social participation B_3 (0.1958). In the State layer, family support C_1, living arrangements C_5, and social communication ability C_7 were given the first weight in their attribution strata, at 0.5757, 0.4114, and 0.3952, respectively, which showed that the social support, living arrangement, and social participation ability of older people are essential factors influencing social risk of social isolation in older people. In the weighting of the indicators of economic risk, monthly income C_{11} (0.4654) > monthly expenses C_{12} (0.2777) > self-evaluation of economic conditions C_{13} (0.2569). The economic status of older people plays a decisive role in the high level of economic risk of social isolation. For the weighting results of the cultural risk, health status B_5 (0.5960) > cultural perception B_2 (0.2185) > emotional state B_3 (0.1855). Depression C_{21}, cultural activity identity C_{18}, and whether or not to take care of oneself C_{16} had greater weights in the state layer, respectively, of 0.7530, 0.5327, and 0.3905. It is clear that older adults' capacity for self-care, degrees of depression, and cultural sensitivity play significant roles in determining their risk of social isolation.

Based on the quantitative evaluation results, this study could evaluate the effects of risk factors with various weights and provide targeted recommendations. Different risk levels could be derived from a tiered intervention program for older people, which has greater practical guidance significance for improving the sense of well-being and social acquisition of older people.

Discussion

Taking the community older people of Jiangsu province as an example, based on risk society theory, this study comprehensively evaluated the social isolation in older people from three aspects: social risk, economic risk and cultural risk. The AHP analytic hierarchy process was used to determine the index weight, and the fuzzy comprehensive evaluation model was used for comprehensive and systematic quantitative evaluation.

The complicated approach for evaluating social isolation risk for older people fully considers the impact of society, family, and environment on the many components of social isolation risk. The pertinent risk variables in the social, economic, and cultural elements were covered by "the evaluation index system of social isolation in older people" developed in this study. The comprehensive evaluation result of the previous level could be utilized as input data for the comprehensive evaluation of the next level since the fuzzy comprehensive evaluation can perform the multilayer assessment and the evaluation process is recyclable.[23] Compared with other qualitative methods, it has the advantages of scientificity, applicability and feasibility, which has a specific guiding role in putting forward the intervention plan to prevent social isolation of older people.

Based on the above analysis, it could be seen that the classification of different types of factors is relative, and they may also be interconnected and transformed with each other. In our opinion, it's important to comprehend the crucial and challenging aspects of social participation of older people. Considering the fact that older people now experience a high prevalence of social isolation and low levels of genuine social involvement, the principal causes include that the view of "old people are the burden of society and families" still predominates the mainstream, there are certain restrictions on the social participation of older people, discrimination against older people is increasingly prevalent in laws, regulations, and policies. It is difficult for older people to participate in social activities and to preserve their rights, and they receive

minimal subsistence allowance and medical assistance. This study found that deteriorating social relationships, insufficient social participation, declining health status, and reduced psychological flexibility psychological resilience will lead to a lack of social contact and interaction, resulting in depression and the lack of communication with the outside world, which in turn affects social isolation in older people. The results of the weight vector of evaluating index for evaluating the risk of social isolation in older people stand for the critical degree of the different factors. Therefore, this article puts forward the following suggestions.

First of all, the State should emphasize the role of social forces such as enterprises, non-profit organizations, and government agencies in community services for older people. The community should encourage community staff, community volunteers and medical attendant to participate in the integrated medical and nursing services, expand community medical service centers to provide health consultation, disease diagnosis, treatment, Traditional Chinese Medical health care nursing for older people.[21] Through the joint efforts of the government, community and family, improve the opportunities and capabilities of older people in social participation.

Secondly, the government should further improve the classification of the older people's health status and economic income evaluation mechanism, formulate detailed and reasonable service subsidy standards,[4] and provide appropriate subsidies for the purchase of health and nursing services for low-income older people who live in economically backward areas or rural areas and do have a demand for health and nursing care services and lack financial capacity. When the financial situation of older people is problematic, they gradually reduce their interaction with the outside world and shrink their social network. At the same time, due to their weak financial situation, older people's basic health care needs are not met for issues such as access to medical care, which impacts the physical and psychological aspects of older people. The results of the questionnaire survey in this study also found that the social isolation of older people in rural areas is more serious than that of older people in urban areas. Subsistence allowance could cover part of the living expenses of older people in a poor financial situation, while nursing allowances address the funding needed for long-term nursing services for disabled older people. These subsidy systems should be linked to the financial situation of older people, with the government stepping in to take on the appropriate areas of responsibility to assist older people reduce economic pressure.

Thirdly, our research findings also found that depressive status and psychological resilience of older people mediated the risk of social isolation. These elements could greatly diminish the well-being and satisfaction of older people in their life, and may even raise their risk of suicide. Therefore, we should promptly pay attention to and assess the mental health status of older people. Especially in the special period since the outbreak of the COVID-19 pandemic, anxiety, irritation, and sadness would more likely to occur in older people who are at home and have less contact with the outside world. The government and community workers should establish and improve a comprehensive service system of social and mental health for older people in the community, provide efficient daily living support and psychological counseling services to older people who with poor psychological quality. At the same time, sympathy and care of family members could provide emotional support for older people with reduced social activities, leading to higher levels of mental health. These methods could regularly screen elderly groups at risk of social isolation, and establish comprehensive physical, psychological and social health records of older people.

Last but not least, it is necessary to strengthen the investigation on the social participation and life satisfaction of older people, and explore their diversified service needs. The community could give full play to the active role of volunteers, regularly organize older people to carry out group activities, and guide them to set up mutual aid groups to increase social participation, meet older people's social and emotional needs, and reduce the risk of social isolation. In addition, the community could widen the sources of information channels for older people by organizing activities or offering health science knowledge seminars, actively monitoring the health of older people in conjunction with family doctors, providing psychological and emotional support for them by integrating resources, and improving the level of social network support for older people. These measures could meet the material, social, cultural and psychological needs of older people, and effectively prevent and reduce the possibility of social isolation in older people.

Limitations

There are some limitations on this study. Firstly, due to the limited time of the survey, when we assessed the risk of social isolation and tested the effectiveness of this method, we only selected 100 older people for analysis. Secondly, as this

study had a cross-sectional study design, the possibility of bias cannot be eliminated. Therefore, generalisation of this study's results might be limited. To overcome these limitations, we will conduct a multi-center, long-term follow-up randomized control study in the future.

Conclusion

The primary risk causes of social isolation might be examined and identified through risk identification by considering the integrated environmental circumstances of social isolation in older people as a complicated fuzzy system with uncertainty. A multi-level fuzzy comprehensive evaluation approach for risk evaluation of social isolation, which combines AHP with FCE was presented. In our study, we constructed "the evaluation index system of risk of social isolation in older people", including 3 first-grade indexes, 7 second-grade indexes, and 22 third-grade indexes, to evaluate the social isolation risk in older people with fuzzy comprehensive evaluation methods. To the greatest extent feasible, ambiguity in the evaluation process was eliminated by using the scale and weight models to identify the membership degree and evaluation criteria of each contributing risk factor. Compared to the conventional method, the risk assessment's robustness has significantly increased. Based on the evaluation's findings, we proposed a prediction and intervention strategy for the elderly's risk of social isolation from a social, economic, and cultural standpoint. These approaches could develop the capacity for self-regulation of older people, and improve their autonomy and satisfaction, thereby expanding social networks and enhancing body functions. In the end, this susceptible population could escape the negative effects of social isolation to the greatest extent feasible.

In conclusion, according to the findings of our literature review, the use of a fuzzy comprehensive evaluation in geriatric care is unprecedented. A new, simple and effective method is provided for quantitative analyses of the uncertainty in the development and occurrence processes of social isolation in older people. This technique broadens the application of risk society theory in the field of social isolation risk assessment in older people. This study suggests that the AHP-fuzzy comprehensive evaluation could be widely applied in the field of elder care. In order to better promote a sense of belonging, respect, inclusion, and respect for older people, as well as to ultimately be able to improve older people's health status and well-being, it is necessary to discuss how to choose more practical evaluation indexes, and how to more objectively and accurately define the area of each stability grade in the future.

Data Sharing Statement

The raw/processed data required to reproduce these findings cannot be shared at this time as the data also forms part of an ongoing study.

Ethical Approval

This study complies with the Declaration of Helsinki, which was approved by Nanjing University of Chinese Medicine Ethics Committee. Before data collection, the research team signed the "Contract for Scientific Research Entrustment of Nanjing University of Chinese Medicine" with Jiangsu Provincial Department of Civil Affairs and obtained communities' approval, we confirm that the participants themselves signed informed consent in this study.

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Disclosure

The authors declare that there is no conflict of interests in this work.

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