Research Paper

Application of A System Dynamics Model in Forecasting the Effect of Self-care Ability on the Quality of Life of Mildly Disabled Elderly in Nursing Homes

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ABSTRACT

Background: The large number of mildly disabled elderly people in China has resulted in the occupation of a large amount of public social resources. They have also imposed a serious social burden on the society. This study predicts that changes in the level coefficients of physical functioning, motor participation, and external environment are associated with quality of life (QoL) among the elderly with mild disabilities in nursing homes.

Methods: A simulation model was created using the system dynamics method. Meanwhile, a 50-day simulation was used to predict the subsequent changes in the level of QoL of the elderly. This study was completed in the nursing homes of Chengdu, China, using random sampling and 85 elderly subjects participated to obtain the primary data. The data were analyzed using the Vensim software.

Results: The results showed that the level of physical functioning (pain value of 0.241, autonomy of 0.163, and chronic disease of 0.192), the level of motor participation (education value of 0.186, and rehabilitation partner of 0.21), and the level of external environment (medical care value of 0.26, and rehabilitation environment value of 0.184) lead to subsequent changes in the level of QoL of mildly disabled elderly in nursing homes in 30 days.

Conclusion: Considering the results of this simulation study, changes in the level of physical functioning, exercise participation, and external environment could forecast the QoL of mildly disabled elderly in the nursing homes of Chania, China. It is necessary to make the required changes in the nursing homes to promote the QoL of these groups.

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Highlights

- The number of nursing homes and nursing beds in China has vastly grown.

- Decline in the ability of daily life of mildly disabled elderly will intensify the occupation of public resources and severely affect the general capacity of society. Hence, improving the self-care ability of this group of people is of great importance.

- According to the results of this system dynamics study, the 50-day simulation predicted that a significant increase in body function, exercise participation, and level of external environment in the elderly with mild disability will improve their quality of life (QoL) in 30 days.

Plain Language Summary

Several factors affect the quality of life (QoL) of the elderly. This study examined the predictors of changes in the QoL of elderly people with mild disabilities in Chinese nursing homes. The findings showed that changes in body function, level of participation in exercise, and alterations in the external environment predict the QoL of the elderly and can make significant changes in their QoL in 30 days.

Introduction

The centralized care approach in China's nursing homes has shown extensive growth, with the number of institutions increasing from 308 000 to 1.16 million and the number of nursing beds from 1.533 million to 6.272 million from 2006 to 2020 (Xu et al., 2023). Research has shown that habitual caregiving promotes dependency and loss of self-care capacity, and decreases physical functioning in older persons. In addition, behaviors of proactive caregivers are detrimental to older adults' ability to care for themselves and positively correlate with their dependence due to caregiver overcare. The decline in the daily living skills of the elderly with mild disability aggravates the occupation of public resources and severely affects the general capacity of society. Accordingly, improving the self-care ability of the mildly disabled elderly is critical. It is also an effective way to improve the quality of life (QoL) of the elderly (Dusseljee et al., 2011). The ability of the elderly to take care of themselves is affected by their internal factors and regional and environmental factors. In addition, the elderly of different genders also have commonalities as well as differences in their ability to care for themselves (Harisalo & McInerney, 2008). Systems science provides a comprehensive perspective for understanding health problems. It has been widely used to solve complex problems in medical rehabilitation. They all have their specific advantages in medical rehabilitation. Public health has many complex systems. Complex systems are composed of heterogeneous elements that interact with each other, have emergent properties that cannot be explained by understanding the individual elements of the system, persist over time, and adapt to changing conditions. Public health is beginning to use the results of systems science studies to shape practice and policy (Luke & Stamatakis, 2012). The elderly often suffer from chronic diseases and their QoL is affected by complex physiological, psychological, and environmental factors. Hence, analyzing the influencing factors and the dynamic changes has an essential value in predicting the QoL of elderly patients (Jifeng et al., 2008). The system dynamics model can predict the impact of chronic diseases and disabilities on the QoL of the elderly in different conditions. Accordingly, this study predicts that changes in the level coefficients of physical functioning, motor participation, and external environment are associated with QoL among elderly people with mild disabilities in nursing homes.

Materials and Methods

Research methodology

System dynamics, founded in 1956 by Professor Forrest at the Massachusetts Institute of Technology, is a cross-cutting discipline that integrates the social and natural sciences (Ciccarello et al., 2022). The most systematic idea of the discipline is that all systems must have a structure, and the system's structure determines the system's function, which guides the study of the QoL of mildly disabled elderly in nursing homes. Compared with other research methods, system dynamics has a high

accuracy of simulation calculation. In this study, a set of scenarios were generated through system dynamics modeling and tested through simulation (Bastan et al., 2017), which significantly improved the reliability of this study in predicting the QoL of mildly disabled elderly.

Setting and sample

A random sampling method was used to select six nursing homes in the urban areas of Chengdu, China, with 300 or more beds, as the source sites for the survey sample in 2023.

The inclusion criteria were as follows: Stable patients aged ≥65 years, clearly conscious and able to answer questions alone and elderly with mild disability. To determine the disability level of the subjects this study used the activity of daily living scale, a modified version of the Barthel index of the Taiwan Province of China. This index measures the level of dependency and mobility in the activities of daily living, i.e. feeding, bathing, grooming, dressing, bowel control, bladder control, toileting, chair transfer, ambulation, and stair climbing. Each item in this scale is assigned a score of 0, 5, or 10. In this study, the score for mildly disabled elderly is 61–99, moderately disabled elderly 46–60, totally disabled elderly 21–45, and severely disabled elderly 0–20 (Gibson et al., 2022).

Participation in the study was voluntary and the subjects provided their informed consent. The patients on long-term psychotropic medications or co-occurring cognitive impairment and dementia and subjects with severe mental illness and speech or hearing impairments that prevented them from communicating were excluded from the sample. The sample size was determined according to the scope and content of the study (Hennink & Kaiser, 2022) using the Equation 1:

1. $$N=\frac{\mu^2_{\alpha/2}\pi(1-\pi)}{\delta^2}$$

In this study, $\alpha=0.05$, $\mu\alpha/^2=1.96$, and π is the incidence of disablement. According to the incidence of disablement among the Chinese elderly and previous studies is 60.5%. Meanwhile, 10% of the allowable error is considered in this study, i.e. $\delta=0.1\pi$. The calculated sample size is about 77. Also, 10% of invalid questionnaires were considered, and the final sample size was estimated at around 85.

Construction of a system dynamics model of QoL for mild disabled elderly in nursing homes

Cause-effect diagram, flow diagram, and equations

To gain insight into the relationship between self-care ability and the QoL of mildly disabled older adults in nursing homes and to explore the related influencing factors, this study uses a system dynamics model for modeling and simulation (Sun et al., 2022). By modeling the interaction between self-care ability, body functioning level, exercise participation level, and external environment level of mild disabled older adults in nursing homes, the effects of different conditional factors are predicted (Nanthamongkolchai et al., 2022). This study will examine how self-care abilities (body function, motor participation, external environment) changes affect the QoL of older adults with mild disabilities in nursing homes.

Causal loop diagram construction

By a causal loop diagram of system dynamics for the mild disabled elderly in nursing homes using the Vensim PLE software (Zhang & Tang, 2022), we can understand the causal relationships and loops between variables and the relationship between the inputs and outputs of each variable through special functions in the program; hence, we can understand the model structure. In system dynamics, causal diagrams are a model-building tool that can help to systematically analyze and describe the causal relationships between different variables. The complex interactions between variables in a system can be better understood using causal diagrams, and the basic patterns of event development can be revealed. In a typical cause-effect diagram, variables are represented as nodes, and the causal relationships are represented as arrows (Arif & MacNeil, 2023). The arrows indicate the effect of one variable on another, allowing for more explicit identification of the main influences and determining how to intervene in the system. The three modules of body functioning level (coordination, autonomy, chronic disease, emotional function, muscular endurance, health condition, urinary function, muscle strength), exercise participation level (education level, bed, and chair movement, free time, body mass index, sports rehabilitation, going outside, joint flexibility), and external environment levels (rehabilitation environment, service attitude, safety facilities, health care, health education, working system, and social welfare) were integrated and optimized to eventually form a general diagram of the causal cycle for the mildly disabled elderly in nursing homes (Figure 1).

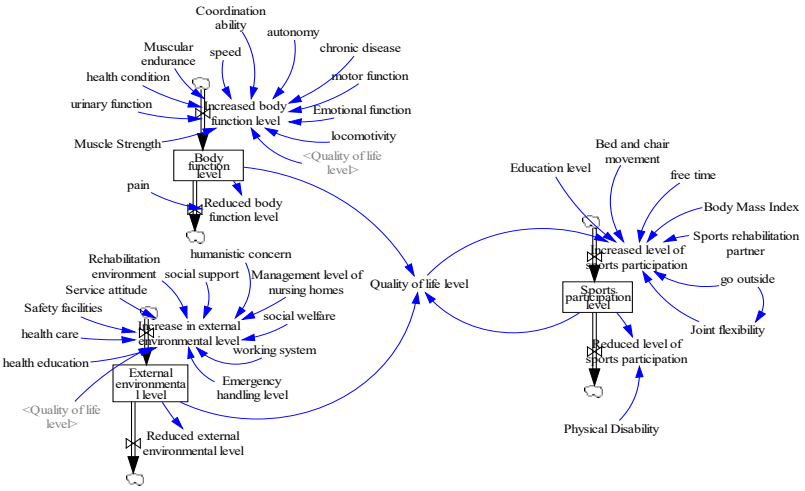

Figure 1. General diagram of the cause-effect cycle for elderly people with mild disabilities in nursing homes

After the causal diagram is built, the stock flow diagram needs to be built (Pasaribu, 2021). A stock-flow diagram is a standard model-building tool in system dynamics that provides a way to represent the interactions between the variables in a system. In a stock-flow diagram, each system variable can be considered a stock, and the relationships between them are represented as flows. These flows represent transfers or interactions between variables and enable a better understanding of the system's behavior and evolutionary processes.

In the system dynamics modeling process, equations between the variables need to be established to calculate the values of each variable (Kim et al., 2014). The main computational model equations are shown below:

• Inventory equation (Equation 2):

2. $Stock(t)=\int_{t0}^{t}[Inflow(s)-Outflow(s)]ds+Stock(t_0)$

• Flow equation (Equation 3):

3. $d(Stock)/dt=Inflow(t)-Outflow(t)$

• Auxiliary variable equation (Equation 4):

4. $aux(t)=f[lv(t),aux\times(t),exo(t),const]$

Regarding the variables, Stock(t) represents the quantity of stock at time t, Inflow(s) represents the inflow, Outflow(s) represents the outflow, $Stock(t_0)$ shows the quantity of stock at the initial time, aux(t) demonstrates the auxiliary variables at time t, aux(t) are the variables

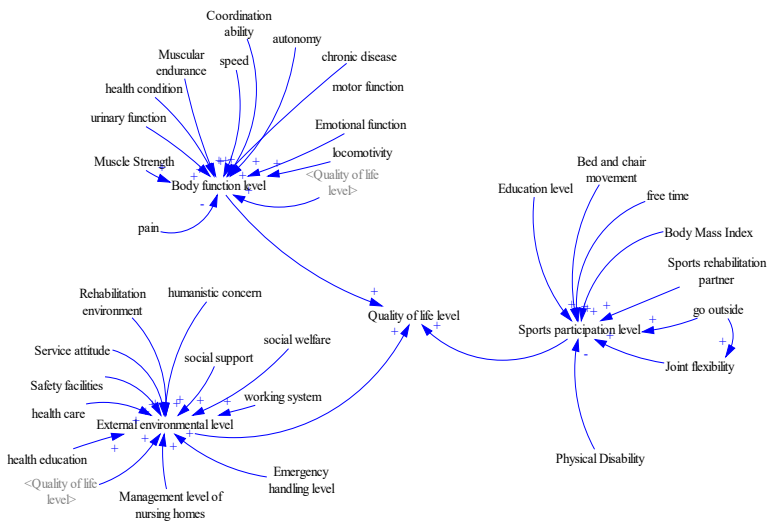

Figure 2. QoL system dynamics stock flow of mild disabled elderly in nursing homes

Table 1. Modeling equation of quality-of-life impact weights for mild disabled elderly in nursing homes

No.	Variables Name	Formulas	Number	Variables Name	Formulas
01	Final time	50	24	Urinary function	0.144
02	Initial time	0	25	Quality of life level	(External link level+level of body function+campaign participation levels)/3
03	Save per	Time step	26	Pain	0.241
04	Time step	1	27	Social support	0.173
05	Human care	0.13	28	Social welfare	0.158
06	Health education	0.16	29	Mobile capability	0.163
07	Health status	0.18	30	Leisure time	0.185
08	Articular flexibility	Outdoor activities (0.153*)	31	Critical incident handling level	0.128
09	Nursing home management level	0.14	32	Muscle strength	0.135
10	Health care coverage	0.26	33	Muscular endurance	0.138
11	Coordination ability	0.156	34	Physical disability	0.132
12	Education level	0.186	35	Self-motivation	0.163
13	Outbound activities	0.153	36	Body function level	INTEG (increased level of body function-decreased level of body function (0.2*)
14	External environmental level	Increased level of external environment - Reduced level of external environment (0.2*)	37	Decreased level of body function	Body function level (0.6*)+pain
15	Reduced external environment level	External environment level (0.163*)	38	Increased level of body function	ln (1+(health status+coordination ability+emotional function+chronic diseases+urinary function+quality of life level+mobility capabilities+muscle strength+muscular endurance+self-motivation+sports functions+speed))+(health status+coordination ability+emotional function+chronic diseases+urinary function+quality of life levels+mobility capabilities+muscle strength+muscular endurance+self-motivation+sports functions+speed)/10 (0.3*)
16	Increase in external environment level	(Human care+health education+nursing home management level+medical coverage+security facilities+work system+rehabilitation environment+service attitude+quality of life level+social support+social welfare+level of emergency handling)/10	39	Body mass index	0.17
17	Security facilities	0.13	40	Sports functions	0.159
18	Work system	0.173	41	Campaign participation level	INTEG (Increased sports participation levels decreased level of sports participation) (0.2*)

No.	Variables Name	Formulas	Number	Variables Name	Formulas
19	Bed and chair mobility	0.147	42	Decreased exercise participation levels	Campaign participation level (0.2*)+physical disability
20	Rehabilitation environment	0.184	43	Increased exercise participation levels	(Articular flexibility+education level+outbound activities+bed and chair moving+quality of life level+leisure time+body mass index+sports rehabilitation companion)/8
21	Emotional function	0.14	44	Sports rehabilitation companion	0.21
22	Chronic diseases	0.192	45	Speed	0.16
23	Service attitude	0.183			

*Percentage of influencing factors.

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other than the auxiliary variables to be sought, exo(t) is the exogenous variable, and const is the endogenous variable.

The primary role of stock flow diagrams is to help identify and analyze the relationships between different system variables and reveal their complexity (Sun Y et al., 2022). This graphical representation allows for a better understanding of the behavioral patterns of the system, thus guiding effective policy and decision-making. In addition, stock flow diagrams can be used to predict future system trends and assess the impact of different decisions on the system. The stock-flow of system dynamics of the QoL for mild disabled elderly in nursing homes is provided in Figure 2.

Data analysis

The influences of different variables on the QoL of the mildly disabled elderly were weighted to establish the model equations and the equations of the variables in the model were given values (Table 1).

3. Results

The model's validity should be checked before simulating the impact of the model on the QoL of the mildly disabled elderly in nursing homes. At first, the model structure and equations can be checked for accuracy with the "Check Model" function in the Vensim software; if the Model is "OK", it passes the test (Arif et al., 2023). The validation result is shown in Figure 3.

Simulation analysis of system dynamics for mildly disabled elderly in nursing homes

The trends of changes in QoL by body function were simulated in elderly people with mild disabilities in nursing homes. The initial value of QoL in the model was 0.25, and after simulating the body function in the nursing home, there was a significant increasing change in the body function in the first 30 days of the simulation time and reached 0.82, and then a stable trend was observed (Figure 4).

The level of exercise participation of the mildly disabled elderly in the nursing home was simulated and predicted. The level of mobility and exercise participation significantly increased, starting from the initial value of 0.20, and then there was a brief decline as the body had a recovery period after exercise participation, after the fourth day of the simulation there was a steady increase, which is also consistent with the physiological characteristics of exercise. After 40 days of simulation, a steady trend was observed (Figure 5).

The level of external environmental factors was also simulated and predicted. The trend of the predicted external environmental factors on QoL showed a steady and continuous increase from a starting value of 0.2 to a plateau after 30 days (Figure 6).

By simulating the body function, exercise participation level, and external environment for 50 days, the final proposed evaluation graph of the QoL of the mild disabled elderly in nursing homes was synthesized, and the QoL level showed a linear increase with the increase of simulation time (Figure 7).

The results show that through the 50-day simulation prediction, the dynamic changes of the factors at the level of physical functioning (pain value=0.241, autonomy=0.163, and chronic diseases=0.192), at the level of motor participation (value of education=0.186, rehabilitation partner=0.21) and the level of the external environment (medical care=0.26 and rehabilitation environment=0.184) leads to subsequent changes in the QoL

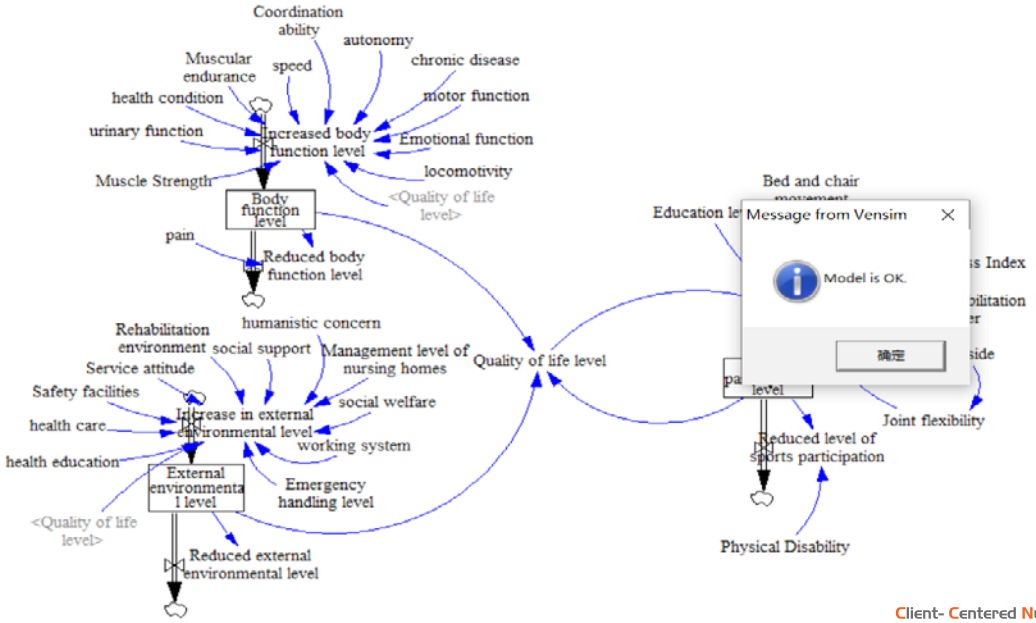

Figure 3. Model validation of factors influencing QoL of mild disabled elderly in nursing homes

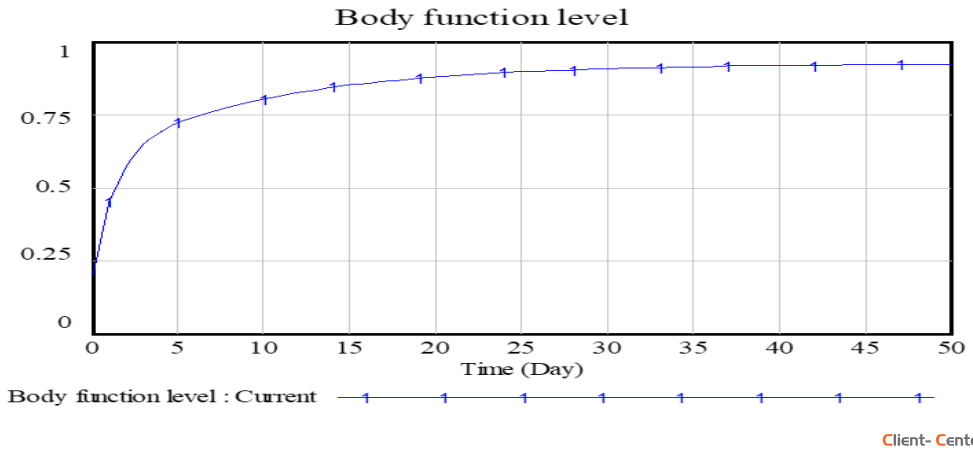

Figure 4. Trends of body function on QoL in elderly people with mild disabilities in nursing homes after simulation

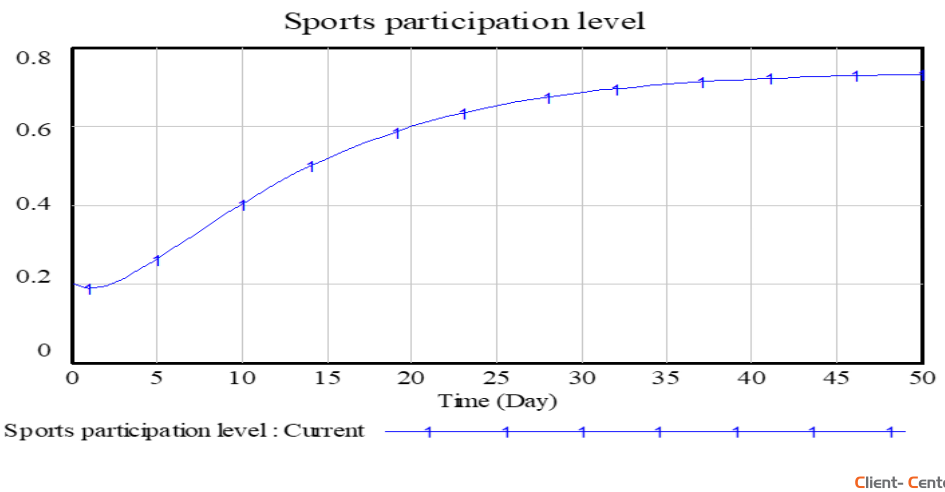

Figure 5. Trends of exercise participation levels of mildly disabled elderly people in nursing homes after simulation

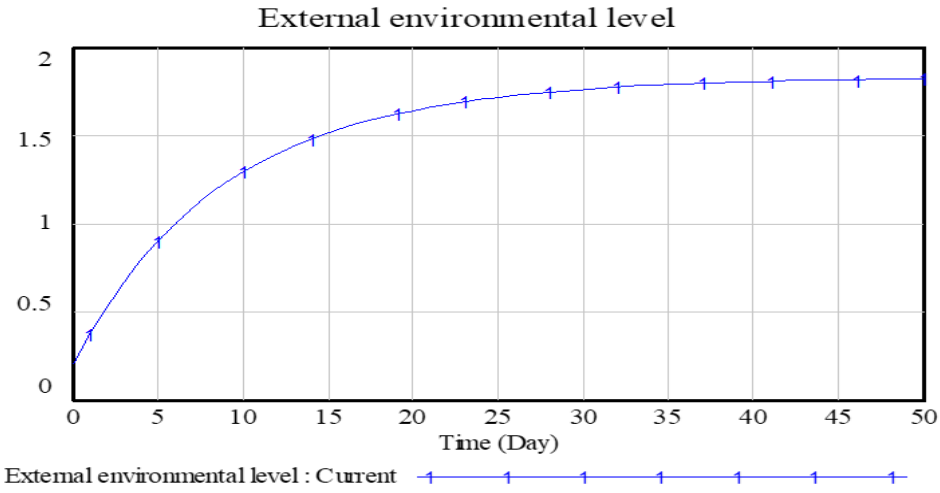

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Figure 6. Trends in external environmental factors on QoL of mildly disabled elderly people in nursing homes after simulation

of the mildly disabled elderly in nursing homes, and the values of these indicators are significantly higher than the corresponding indicators, which shows an increase in the indicators. The QoL of the elderly increases after passing the 50-day simulation prediction.

Discussion

The study showed that the level of physical functioning (pain value, autonomy, and chronic disease), the level of motor participation (education value and rehabilitation partner), and the level of the external environment (medical care value and rehabilitation environment value) are the most critical factors contributing to the level of QoL of the mildly disabled elderly living in the nursing homes, as it was predicted by a 50-day simulation through which the indicators reflected the top factors influencing the QoL of the elderly.

The problem of pain in the mildly disabled elderly is particularly prominent, as a study by the Pain Society of the Chinese Medical Association showed that there are at least 100 million patients with pain in China and about 80% of elderly patients have experienced pain in one part of the body. Chronic pain causes both physical and mental torture in the mildly disabled elderly, reducing their level of daily activity and causing negative emotions, such as anxiety, depression, and fear. Subsequently, we can focus on thinking about the pain mitigation aspects of the mildly disabled elderly in the future implementation of rehabilitation programs.

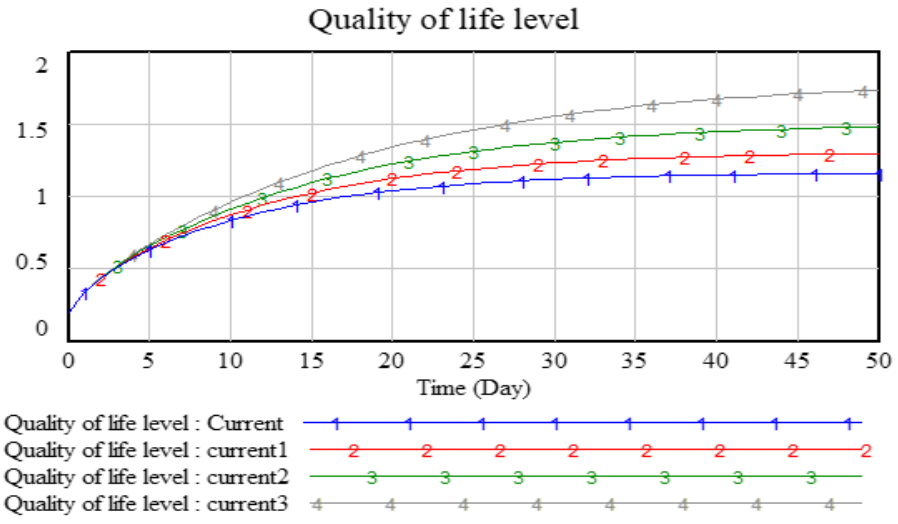

Figure 7. Evaluation chart of the QoL of mild disabled elderly in nursing homes

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According to the results, improving the activity and motor participation levels of mild disabled older adults in nursing homes can effectively improve their quality of life. Chronic diseases reduce the level of self-care ability of the residents, which in turn affects their quality of life. The study showed that a higher number and type of chronic diseases indicate a lower level of self-care ability of the mild disabled elderly, cardiovascular and cerebrovascular diseases (stroke, coronary heart disease, and chronic heart failure) are the leading chronic diseases that affect the QoL of the elderly (Pearlman & Uhlmann, 1988; Chen & Chen, 2017). The poor self-care ability of mildly disabled elderly leads to different degrees of dependence on the care of others, which creates a severe psychological burden and causes anxiety, depression, guilt, and other emotions that weaken the self-care ability.

Nursing staff in nursing homes should consider the development of the self-care ability of the elderly with mild disabilities, actively communicate with them, and provide timely help to stimulate the self-care motivation of these elderly (Song, 2023).

Improving the rehabilitation environment in the nursing home also has a significant effect on improving the QoL of the elderly with mild disabilities, and this study also precisely showed that improving the level of the external environment can effectively improve the QoL of the elderly with mild disabilities.

Conclusion

The results of this study show that dynamic changes in the level of body functioning (pain, autonomy, and chronic diseases), level of exercise participation (education and joint flexibility), and level of the external environment (medical coverage and rehabilitation environment) lead to positive changes in the QoL of mild disabled older adults in nursing homes. To improve the QoL of the elderly with mild disability, it is suggested that the managers of the nursing homes strengthen the physical functioning of the elderly, increase their participation in exercise, and modify the external environment. Further studies are recommended using nursing homes of multiple types (for-profit, social welfare) with larger samples.

In this research, the variables of the system dynamics model were assigned based on the objective ranking of the weight of the variables of the research subjects, which may have reduced the access to the model due to the wide range of choices of the research subjects, which raises the possibility of differences in the weight of the variables.

Ethical Considerations

Compliance with ethical guidelines

This study did not intervene in the samples and made data predictions through primary data. All subjects gave informed consent to participate in this study.

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Authors' contributions

Conceptualization and methodology: Maoqiang Xu and Asha Hasnimy Mohd Hashim; Questionnaire count: Zhiwei Chen; Writing the original draft: Maoqiang Xu; Review and editing: Asha Hasnimy Mohd Hashim; Final approval: All authors.

Conflict of interest

The authors declared no conflict of interest.

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