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Latent classes of frailty and their association with intrinsic capacity in older cancer survivors: A study under the healthy aging paradigm

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Abstract: The aim of this study was to identify frailty profiles using latent class analysis (LCA) and examine their associations with intrinsic capacity (IC) among Chinese elderly cancer survivors. A total of 308 elderly cancer survivors were recruited from a tertiary hospital in Nantong, China between November 2023 and April 2024, and data were collected through questionnaires and clinical assessments. LCA was used to classify frailty subtypes, univariate analysis and multinomial logistic regression (reference: robust group) were used to identify associated factors, and one-way ANOVA was used to compare IC differences across subtypes. Three frailty profiles were identified—frail (31.5%), pre-frail (19.8%), and robust (48.7%)—with significant IC variations. Lower monthly household income (odds ratio (OR) = 16.00, $p = 0.028$), smoking (OR = 8.76, $p = 0.013$), malnutrition (OR = 5.25, $p = 0.044$), activities of daily living (ADL) (OR = 71.31, $p < 0.001$), depression (OR = 15.91, $p = 0.048$), and fatigue (OR = 33.43, $p < 0.001$) were independent risk factors. These findings indicate that Chinese elderly cancer survivors exhibit heterogeneous frailty profiles and that IC decline is positively associated with the severity of frailty. The identified risk factors and subtype characteristics provide a basis for devising tailored interventions to improve health outcomes in this population.

***Keywords*:** elderly cancer survivors, frailty, intrinsic capacity, latent class analysis, root cause analysis

1. Introduction

Currently, "healthy aging" has become a major issue of global public health concern. The data shows that China has the world's largest population of people age 65 and above (*1*). As a disease closely related to age, the incidence of cancer is significantly higher in the elderly population. By 2035, the incidence of newly diagnosed cancer among the elderly population over 65 years of age worldwide is estimated to reach as high as 60% (*2*). As forms and means of clinical treatment have advanced, the survival rate of cancer patients has risen. Therefore, the health and quality of life issues of cancer survivors after treatment have attracted widespread attention.

Frailty, as one of the research hotspots in the field of gerontology in recent years, refers to a clinical syndrome characterized by a decline in an individual's physiological reserves and resistance, rendering the body more susceptible to stressors and at a higher risk for adverse health outcomes (*3*). Cancer survivors, due to the complex impact of cancer itself as well as comprehensive treatments such as surgery and chemotherapy, experience a decline in physiological reserve, increased sensitivity to disease, and are more susceptible to the stimulation of the tumor itself and its treatment, thereby disrupting the body's balance and predisposing them to frailty (*4*). Moreover, the relationship between cancer and frailty may be attributed to their shared physiological mechanisms, such as reduced muscle mass and increased levels of inflammatory and cytokine factors (*5*). Among elderly cancer survivors, the incidence of frailty varies between 6% and 86%, with a median rate of 42% (*6*). In fact, over half of elderly cancer survivors are pre-frail or frail, leading to increased dependency, reduced treatment tolerance, and increased risks of postoperative complications, disease progression, and mortality (*7*). This significantly hampers patients' quality of life and increases readmission rates and medical costs, imposing a heavy burden of care on families and society.

To address the growing burden of frailty and care dependency among older cancer survivors, the World Health Organization (WHO) has proposed an innovative approach — Integrated Care for Older People (ICOPE). Within this framework, optimizing intrinsic capacity (IC)

is central to promoting healthy aging and reducing care dependency (*8*). Multiple studies have confirmed that the onset of frailty is closely associated with a decline in an individual's IC, and enhancing IC represents a core strategy for frailty prevention (*9*). The WHO defines IC as the composite of all an individual's physical and mental capacities, encompassing the domains of locomotion, vitality, cognition, psychology, and sensory function (*10*). This metric comprehensively reflects the overall physiological reserve of the organism, and its trajectory serves as a key predictor of frailty onset. Therefore, in the holistic management of older cancer patients, early identification, continuous monitoring, and proactive intervention in IC decline are essential. These measures not only help predict the risk of frailty but also form the core pathway for intervening in and ameliorating frailty, enhancing functional ability, and ultimately achieving the goal of "healthy aging".

Moreover, researchers universally agree that frailty represents a dynamic state that causes individuals to suffer losses in one or more functional domains (physiological, psychological, or social) and increases the risk of adverse outcomes. It is potentially reversible and preventable in the early stages (*11-13*). This reversibility underscores the need to prioritize frailty prevention and management in cancer care. Indeed, frailty screening is increasingly used for risk stratification in elderly cancer survivors to predict surgical prognosis and chemotherapy toxicity (*14*), making early identification and targeted intervention critical. However, effective intervention relies on accurate assessment, which currently faces a key limitation. While no consensus exists on a universal definition, the most widely used tool is Fried's frailty phenotype, which defines frailty by five criteria: unintentional weight loss, self-reported exhaustion, weakness, slow walking speed, and low physical activity (*15*). However, most existing studies use scale scores as the criterion for frailty assessment, potentially overlooking the individual differences and diversity within the population.

Latent class analysis (LCA) is a probabilistic model-based approach that effectively identifies homogeneous subgroups within heterogeneous populations by clustering individuals based on similar observed characteristics (*16*). Its utility in uncovering the heterogeneity of frailty is well-supported by existing research. For instance, LCA has been used to identify distinct physical frailty subgroups with varying severity among older US nursing home residents (*17*). Similarly, studies of community-dwelling adults have revealed diverse risk profiles, such as "relatively healthy", "malnourished", and "cognitively or mood-impaired" classes (*18*). These findings collectively demonstrate that LCA is a robust method for delineating heterogeneous frailty phenotypes in older populations. Despite this established methodological utility, its application to the specific population of elderly cancer survivors remains limited. In particular, there is a paucity of research examining how the distinct frailty categories identified *via* LCA are associated with IC in this vulnerable group.

To address this gap, the current study uses LCA to classify frailty in elderly cancer survivors, it investigates the differences in influencing factors, and it explores the relationship between different frailty categories and IC. These findings will assist healthcare providers in formulating targeted interventions to alleviate frailty and improve IC in elderly cancer survivors.

2. Patients and Methods

2.1. Study design and participants

Convenience sampling was used to recruit 308 cancer patients from a Grade A tertiary hospital in Nantong, Jiangsu Province between November 2023 to April 2024. Inclusion criteria included being age 60 years or older; having a histological or cytological diagnosis of malignant tumors; being able to ambulate independently with or without assistance; and providing informed consent for voluntary participation. Exclusion criteria consisted of having hearing or speech impairments and communication challenges; cognitive impairment, mental illness; and the inability of patients with other serious illnesses to cooperate with investigation. The formula used for sample size estimation was $n = Z^2 \alpha/2[P(1-P)]/\delta^2$, with a significance level of $\alpha = 0.05$ and a two-tailed $Z\alpha/2$ value of 1.96. The estimated value of the expected incidence was set at 42% (*6*), based on the combined frailty rate of elderly cancer survivors from previous systematic reviews. Given the higher incidence of frailty in elderly hospitalized cancer patients, a δ of $\pm$ 10% was chosen for this study. The sample size was estimated to be 94, with a final sample size of 118 determined after accounting for a 20% non-response rate.

2.2. Research instruments

2.2.1. Demographic and disease characterization questionnaire

A general information survey form, developed collaboratively by the research team based on a review of relevant literature, included demographic information such as sex, age, marital status, level of education, average monthly family income, smoking, drinking alcohol, comorbidities, and disease-related data including cancer site and cancer staging.

2.2.2. Fried phenotype (FP)

The FP was developed by Fried *et al.* (*15*) and is used to assess the frailty status of elderly individuals. There are five diagnostic criteria: *i*) Weight loss: A weight loss of 4.5 kg in the past 12 months, *ii*) Self-reported exhaustion:

Asking the patient if he or she feels that everything he or she does requires effort and if this feeling has occurred for more than 3 days in the past week, *iii*) Low physical activity: A "yes" answer to either of the following questions indicates low physical activity: having limitations in performing certain activities of daily living due to physical reasons; in the past month, being able to complete only part of what one intended to do in daily activities due to physical reasons, *iv*) Slow gait speed: Measuring the time taken for the patient to walk 4.5 meters. If the time taken by a male (height ≤ 173 cm) or female (height ≤ 159 cm) is > 7 seconds or if the time taken by a male (height > 173 cm) or female (height > 159 cm) is > 6 seconds, this indicates slow gait speed, *v*) Weak grip strength: Using a grip strength meter to measure the maximum grip strength of the dominant hand of elderly individuals. Grip strength values are stratified by sex and BMI, and if the individual's grip strength value is lower than the grip strength cutoff value corresponding to his or her BMI, it indicates decreased grip strength. Meeting 1-2 criteria indicates pre-frailty, meeting 3 or more criteria indicates frailty, and not meeting the above criteria indicates non-frailty.

2.2.3. IC

Based on the five key domains of IC proposed by the WHO and its recommended assessment tools, our research team collectively developed an IC assessment instrument and methodology covering the following five domains (*19,20*):

i) Locomotor capacity: This was evaluated using the Short Physical Performance Battery (SPPB) developed by Guralnik *et al.*. This scale includes three tests: a balance test (3 items), a gait speed test, and a chair stand test. For the balance test, items 1 and 2 are scored 0–1 point each, while item 3 is scored 0–2 points; both the gait speed test and chair stand test are scored 0–4 points each. The total score ranges from 0 to 12, with higher scores indicating better locomotor capacity.

ii) Sensory function: Sensory function decline was defined as self-reported visual or hearing impairment that affects daily life.

iii) Vitality: The Short-form Mini Nutritional Assessment (MNA-SF) was used to assess the nutritional status of participants. It includes six items—appetite, body weight, activity, acute illness, neuro-psychological issues, and BMI—with a total score of 14 points. A lower score indicates poorer nutritional status, and a score of < 11 points is considered malnutrition.

iv) Psychological function: The Geriatric Depression Scale (GDS) was used to evaluate the depression status of participants. It consists of 15 items with a total score of 15 points. A higher score indicates more severe depressive symptoms, and a score of ≥ 5 points is considered indicative of depression.

v) Cognitive function: A Chinese version of the Mini-Mental State Examination (MMSE) that was developed by Folstein *et al.* was created by Chinese researcher Xiaoxuan Zhou. It includes 30 items covering orientation, immediate memory, and calculation, with 1 point awarded for each correct answer and 0 points for incorrect answers. The total score ranges from 0 to 30, with higher scores indicating better cognitive function. In this study, each of the five domains of IC was dichotomized: a score of 0 indicated decline in that domain, and 1 indicated normal function. The total IC score ranged from 0 to 5, with a score of ≤ 4 defined as overall IC decline; lower total scores indicated more severe IC impairment.

2.2.4. Cancer Fatigue Scale (CFS)

The CFS was developed by Okuyama *et al.* (*21*) and is used to assess the fatigue status of cancer patients. It includes three dimensions—physical, emotional, and cognitive—with a total of 15 items and a score ranging from 0–60 points. A higher score indicates more severe fatigue, and a score of ≥ 18 points is defined as fatigue.

2.2.5. Instrumental Activities of Daily Living Scale (IADL)

The IADL includes eight items such as cooking, housekeeping, laundry, medication management, transportation use, shopping, financial management, and phone use, with a total score of 16 points (*22*). If a patient needs assistance with one item, he or she is considered to have an IADL disability. A lower score indicates lesser ability to perform activities of daily living.

2.3. Data collection

Somatic measurements were obtained by a trained professional, while the questionnaire survey was administered with standardized instructions that outlined the study's objectives and importance. Participants were required to provide informed consent by signing a consent form prior to participation. In cases where participants had difficulty completing the questionnaire, the researcher assisted in completing the form without using leading language to ensure an unbiased and comprehensive recording of responses. Upon receipt of the questionnaire, a thorough assessment of its completeness was promptly conducted. Any missing items or omissions were promptly identified and participants were requested to provide the necessary information to supplement their responses.

2.4. Data analyses

The software Mplus 8.3 was used to perform a LCA on frailty. The fit indices mainly included: *i*) the Akaike Information Criterion (AIC), the Bayesian Information

Criterion (BIC), and the adjusted Bayesian Information Criterion (aBIC). Smaller values for these three statistical indices indicate better model fit, *ii*) Entropy was used to evaluate the accuracy of the model, with values ranging from 0 to 1. A value closer to 1 indicates a more precise model fit, and *iii*) Significant values ($p < 0.05$) for the Lo-Mendell-Rubin likelihood ratio test (LMRT) and bootstrap likelihood ratio test (BLRT) indicated that the k-class model fit better than the (k-1)-class model.

Data were analyzed using SPSS 26.0, with categorical data expressed as frequencies and percentages and continuous data expressed as the mean ± standard deviation ($\bar{x} \pm s$). Between-group comparisons were performed using χ^2 tests or Fisher's exact probability test and analysis of variance. Multiple logistic regression analysis was used to explore the factors influencing frailty subtypes. Finally, one-way analysis of variance was used to compare differences in IC among different frailty classes. The significance level was set at $\alpha = 0.05$.

2.5. Ethical approval

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Affiliated Hospital of Nantong University (2023-K141-01). All participants in this study provided signed informed consent and willingly took part in this study.

3. Results

The Harman single-factor test was used to assess common method bias (*23*). Findings revealed that the characteristic roots of the seven factors surpassed 1, elucidating 57.35% of the overall variance, with the predominant factor representing 19.69%, falling below the threshold of 40%. Consequently, one can plausibly conclude that there is no pronounced common method bias in this study.

3.1. Participant characteristics

A total of 315 survey questionnaires were distributed in this study, with 308 valid responses returned, resulting in a valid response rate of 97.8%. Among the 308 cancer patients, the average age was 69.38 ± 6.26 years, with 203 males (66.1%) and 104 females (33.9%). In terms of their level of education, 140 participants had a primary school education or below (39.7%), while 168 had at least a junior high school education (47.6%). Additional information can be found in Table 1.

3.2. Classification of the latent profile

LCA was performed using five frailty-related items. Models with varying numbers of classes ranging from 1 to 5 were generated, and the fit of each model is shown in Table 2. As the number of classes increased, values for the AIC decreased, with the 3-class model exhibiting the highest entropy value. However, beyond the 3-class model, values for the AIC, BIC, and aBIC increased with each additional class. The statistical tests for model 4 (BLRT) and model 5 (LMRT and BLRT) did not yield significant results ($p > 0.05$). After conducting a thorough evaluation of the fit indices for each model, model 3 was determined to be the most suitable latent class model.

The data shown in Table 3 demonstrates that the average probability of categorization for elderly cancer survivors ranged from 95.6% to 99.5%, exceeding the threshold of 95%. This suggests that the outcomes derived from the optimal model utilized in this study to analyze potential categories were dependable and exhibited strong discriminatory capability.

3.3. Features and names of each latent profile

The latent class conditional probability plot for the three categories of elderly cancer survivors across five external indices is shown in Figure 1. C1 group exhibits a relatively high probability across all five external indices, indicating that this group of elderly cancer survivors displays significant signs of frailty in multiple aspects. Specifically, they may have experienced notable weight loss, frequently feel extreme exhaustion, engage in low levels of daily physical activity, have a noticeably slower gait, and possess weaker grip strength. The combination of these characteristics led to the classification of the C1 group as the "frail group".

The C2 group exhibit performance on the five external indices that fell between the C1 and C3 groups. Specifically, the C2 group exhibited a moderate to high conditional probability for certain indices, particularly in terms of self-reported exhaustion and slow gait speed, indicating a certain degree of frailty risk in these areas. However, compared to the C1 group, patients in the C2 group performed relatively better on other indices, without displaying the widespread frailty signs seen in the C1 group. Therefore, the C2 group was classified as the "pre-frail group", meaning that while they exhibit some frailty characteristics, they have not reached the level of comprehensive frailty observed in the C1 group.

In contrast to the C1 group, the C3 group exhibited a lower probability across the five external indices, indicating that this group of elderly cancer survivors is generally in better condition without obvious signs of frailty. They likely maintain an appropriate weight, report less fatigue, engage in higher levels of physical activity, have a steady gait, and possess stronger grip strength. Based on these characteristics, the C3 group has been designated as the "robust group". The class membership probability was 31.5% ($n = 97$) for "frail group", 19.8% ($n = 61$) for "pre-frail group", and 48.7% ($n = 150$) for the "robust group".

Table 1. Comparison of frailty in groups with different characteristics

Variables	Robust group *n* (%)	Frail group *n* (%)	Pre-frail group *n* (%)	Statistics	*P*
Sex				14.884*	0.001
Male	19 (18.3)	65 (62.5)	20 (19.2)		
Female	78 (38.2)	85 (41.7)	41 (20.1)		
Age				10.212**	0.111
60–69	51 (38.1)	54 (40.3)	54 (40.3)		
70–79	38 (27.1)	79 (56.4)	23 (16.4)		
80–89	8 (26.7)	14 (46.7)	14 (46.7)		
90~	0	3 (75.0)	3 (75.0)		
Marital status				5.546*	0.062
Single	3 (12.5)	13 (54.2)	8 (33.3)		
Cohabitation	94 (33.1)	137 (48.2)	53 (18.7)		
Level of education				15.464*	< 0.001
Primary school and below	28 (20.0)	77 (55.4)	34 (24.5)		
Junior high school and above	69 (41.1)	73 (43.2)	27 (16.0)		
Monthly family income (RMB)				31.823*	< 0.001
< 3000	3 (11.5)	18 (12.7)	5 (19.2)		
3000–5000	23 (40.3)	75 (62.3)	30 (23.4)		
> 5000	71 (48.5)	57 (75.0)	26 (16.9)		
Living alone				2.931**	0.289
Yes	3 (50.0)	1 (16.7)	2 (33.3)		
No	94 (31.1)	149 (49.3)	59 (19.5)		
Smoking				21.993*	< 0.001
No	32 (20.5)	95 (60.9)	29 (18.6)		
Yes	65 (42.8)	55 (36.2)	32 (21.1)		
Drinking alcohol				13.181*	< 0.001
No	34 (22.2)	88 (57.5)	31 (20.3)		
Yes	63 (40.6)	62 (40.0)	30 (40.6)		
Malnutrition				61.859*	< 0.001
No	92 (41.6)	77 (34.8)	52 (23.5)		
Yes	5 (5.7)	73 (83.9)	9 (10.3)		
Comorbidity				9.563**	0.119
0	56 (35.4)	72 (45.6)	30 (19.0)		
1	34 (32.7)	48 (46.2)	22 (21.2)		
2	7 (17.1)	25 (61.0)	9 (22.0)		
≥ 3	0 (0)	5 (100.0)	0 (0)		
Polypharmacy				5.515	0.063
≥ 5	4 (18.2)	16 (72.7)	2 (9.1)		
< 5	93 (32.5)	134 (46.9)	59 (20.6)		
Cancer site				22.170*	0.005
Upper GI	26 (39.4)	32 (47.8)	8 (12.1)		
Lower GI	15 (33.3)	22 (48.9)	8 (17.8)		
Breast	27 (37.5)	26 (36.1)	19 (26.4)		
Liver	6 (12.2)	36 (73.5)	7 (14.3)		
Other	23 (30.3)	34 (44.7)	19 (25.0)		
Cancer stage				11.744*	0.003
I-II	60 (38.0)	62 (39.2)	36 (22.8)		
III-IV	37 (24.7)	88 (58.7)	25 (16.7)		
ADL				204.662*	< 0.001
normal	94 (60.3)	14 (76.0)	48 (30.8)		
disability	3 (2.0)	136 (74.0)	13 (30.1)		
Fatigue				184.933*	< 0.001
No	86 (58.5)	9 (6.5)	44 (31.7)		
Yes	11 (6.8)	141 (83.4)	17 (10.1)		
Depression				55.790*	< 0.001
No	96 (38.7)	95 (38.3)	57 (23.0)		
Yes	1 (1.7)	55 (91.7)	4 (6.7)		

*χ^2; **Fisher's exact probability method.

3.4. Univariate analysis of frailty latent profiles in elderly cancer survivors

Univariate analysis revealed significant differences among the three groups in terms of sex, level of education, average monthly household income, smoking, drinking alcohol, malnutrition, ADL, cancer site, cancer stage, fatigue, and depression ($p < 0.05$), as shown in Table 1.

A multifactorial analysis was performed to examine

Table 2. Fit indices for each model

Model	AIC	BIC	aBIC	Entropy	*p* (LMRT)	*p* (BLRT)	Categorical probability
1	2082.512	2101.163	2085.305				
2	1637.603	1678.634	1643.747	0.913	0.0000	0.0000	0.506/0.494
3	1635.420	1698.831	1644.914	0.940	0.0025	0.0300	0.314/0.198/0.487
4	1635.864	1721.656	1648.710	0.855	0.0286	0.4286	0.302/0.014/0.208/0.471
5	1643.659	1751.832	1659.856	0.926	0.4142	0.6667	0.266/0.432/0.026/0.208/0.068

Abbreviations: AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; aBIC, Adjusted Bayesian Information Criterion; LMRT, Lo-Men-dell-Rubin likelihood ratio test; BLRT, Bootstrapped likelihood ratio test.

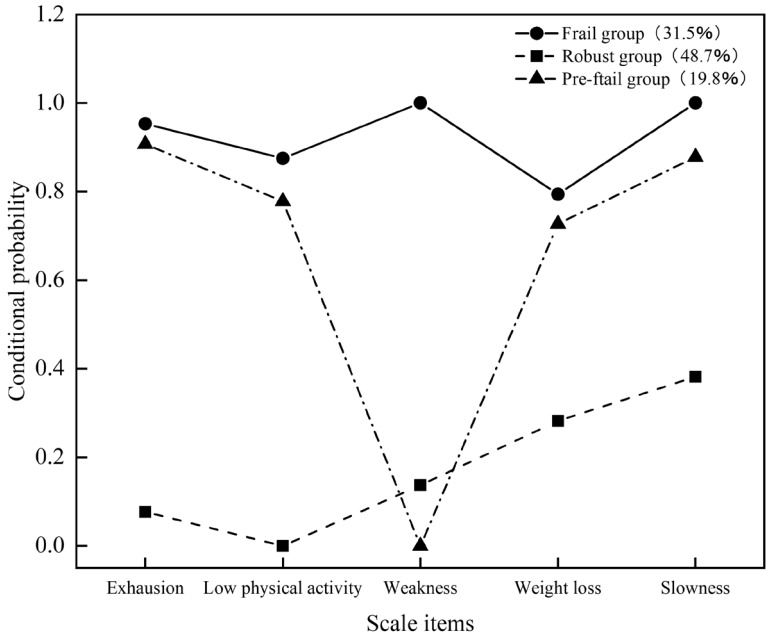

Figure 1. Latent profiles of frailty among elderly cancer survivors.

Table 3. The probability of latent profile analysis

Profile	1	2	3
1	0.995	0.000	0.005
2	0.000	0.956	0.044
3	0.002	0.029	0.968

potential categories of weakness in elderly cancer survivors as shown in Table 4. The statistically significant single-factor variables including sex, level of education, monthly household income, smoking, drinking alcohol, malnutrition, low ADL, cancer site, cancer stage, fatigue, and depression were included as categorical variables, with the last category serving as the reference. Using the three latent classes of frailty as dependent variables and the robust group as the reference group, multivariate logistic regression analysis was performed.

Specifically, an individual with a monthly household income below 3,000 RMB (frail group: odds ratio (OR) = 16.000, 95% confidence interval (CI) [1.343, 190.617]) was more likely to be in the frail group compared to individuals in the robust group. Moreover, an individual with a monthly household income ranging from 3000 to 50,000 RMB (frail group: OR = 4.278, 95% CI [1.221, 14.988]; pre-frail group: OR = 3.392, 95% CI [1.439, 7.997]) was more likely to be in the frail group or pre-frail group. Similarly, an individual who smoked (frail group: OR = 8.757, 95% CI [1.579, 48.553]), was malnourished (frail group: OR = 5.252, 95% CI [1.043, 26.459]), had fatigue (frail group: OR = 33.433, 95% CI [7.662, 145.882]), or had depression (frail group: OR =15.907, 95% CI [1.025, 246.960]) was more likely to be in the frail group. Additionally, an individual with low ADL (frail group: OR = 71.313, 95% CI [13.715, 370.802]); pre-frail group: OR = 5.747, 95% CI [1.246, 26.509]) was more likely to be in the frail group or pre-frail group.

3.5. Comparison of IC among patients with different latent classes of frailty

In this study, the proportion of patients with IC decline was 79.5%. Comparisons of IC across the three latent classes are shown in Table 5.

4. Discussion

Using LCA to categorize frailty in this population, the study reveals distinct classification characteristics of

Table 4. Multiple logistic regression on subtypes of frailty

Variables		"Frail group"				"Pre-frail group"			
		β	OR	95% CI	p	β	OR	95% CI	p
Sex	Male, Ref.: Female	0.584	1.793	0.346–9.289	0.486	0.245	1.278	0.409–3.989	0.673
Monthly household income	< 3,000, Ref.: > 5,000	2.773	16.000	1.343–190.617	0.028	1.581	4.858	0.900–26.224	0.066
	3,000-5,000, Ref.: > 5,000	1.453	4.278	1.221–14.988	0.023	1.222	3.392	1.439–7.997	0.005
Level of education	Primary and below, Ref.: Middle school and above	-0.291	0.748	0.206–2.714	0.659	0.798	2.222	0.988–5.000	0.054
Cancer site	Upper GI, Ref.: Other	-0.364	0.695	0.143–3.369	0.651	-1.116	0.328	0.101–1.061	0.063
	Lower GI, Ref.: Other	0.957	2.604	0.402–16.863	0.315	-0.088	0.916	0.261–3.212	0.891
	Breast cancer, Ref.: Other	1.116	3.053	0.584–15.978	0.186	0.264	1.303	0.484–3.508	0.601
	Lung cancer, Ref.: Other	1.489	4.432	0.529–37.097	0.170	0.508	1.662	0.349–7.910	0.523
Cancer stage	I-II, Ref.: III-IV	0.719	2.052	0.422–9.981	0.373	0.031	1.031	0.325–3.274	0.959
Smoking	Yes, Ref.: No	2.170	8.757	1.579–48.553	0.013	0.556	1.744	0.591–5.141	0.314
Drinking alcohol	Yes, Ref.: No	1.088	2.969	0.612–14.411	0.177	0.556	1.744	0.591–5.141	0.314
Malnutrition	Yes, Ref.: No	1.659	5.252	1.043–26.459	0.044	0.518	1.679	0.388–7.263	0.488
Low ADL	Yes, Ref.: No	4.267	71.313	13.715–370.802	< 0.001	1.749	5.747	1.246–26.509	0.025
Fatigue	Yes, Ref.: No	3.510	33.433	7.662–145.882	< 0.001	0.596	1.815	0.593–5.553	0.296
Depression	Yes, Ref.: No	2.767	15.907	1.025–246.960	0.048	1.754	5.777	0.425–78.516	0.188

frailty scores, delineating three potential subtypes. The "frail group" accounted for 31.5% (97/308), the "pre-frail group" accounted for 19.8% (61/308), and the "robust group" accounted for 48.7% (150/308). Multiple fit indices demonstrated the strong fit of the model, revealing distinctions among potential categories of frailty in elderly cancer survivors and reflecting the diversity of frailty within this population, which is consistent with findings from a previous study (*24*). Based on scale scoring criteria, elderly cancer survivors in the "robust group" exhibited lower scores across all items, indicating that these patients remain in good physical and mental condition despite cancer stress and are less affected by the disease. Conversely, patients in the "frail group" exhibited elevated scores across all measured parameters, making them the key population that requires focused intervention. In addition, individuals in the "pre-frail group" had moderate scores overall, yet they did have a markedly higher score for "exhaustion" and "slowness" in particular, suggesting diminished physical capacity and a heightened perception of fatigue in this population. Hence, healthcare personnel need to recognize the differences in care requirements across patient demographics, they need to more thoroughly evaluate frailty indices in elderly cancer survivors, and they need to incorporate resources and interventions into care strategies to mitigate and delay the onset and progression of frailty.

An analysis of the demographic characteristics of frail elderly cancer survivors can assist healthcare personnel in promptly identifying patients across various categories and offering tailored guidance and interventions. The findings of this study indicate significant variability in average monthly household income and smoking status among elderly cancer survivors categorized as frail ($p < 0.05$). Zhang *et al.* found that non-frail elderly individuals have higher household incomes compared to frail elderly individuals (*25*). The combination of cancer and frailty results in increased medical costs and the need for prolonged care, further compounding the economic strain on patients. This heightened financial burden may hamper patients' compliance with treatment regimens, exacerbate the progression of frailty, and perpetuate a detrimental cycle of deteriorating health. Additionally, a previous smoking habit has been identified as a factor contributing to frailty in elderly individuals with cancer, which is consistent with the study by Shewa *et al.* (*26*). Smoking is a major risk factor for cancer development, and it is associated with 20 to 30% of cancer cases (*27*). Prolonged smoking has been linked to the exacerbation of cancer-related complications (*28*). The harmful substances present in cigarettes have the potential to elevate inflammatory markers, ultimately resulting in a deterioration of overall health and muscle wasting (*29*). Therefore, healthcare personnel should conduct comprehensive health education on smoking cessation, explain the harmful effects of smoking to the body to

Table 5. Comparison of intrinsic capacity scores among different frailty classes in elderly cancer survivors

Group	Number	IC
Frail group	97	3.44 ± 0.61
Pre-frail group	61	3.56 ± 0.67
Robust group	150	4.02 ± 0.87
F*		19.347
p		< 0.05

*F: One-way ANOVA.

patients who have not quit smoking, and provide diverse, comprehensive, and effective smoking cessation support to increase the success rate of smoking cessation and prevent or alleviate the onset and progression of frailty.

In addition, regression analysis indicated that elderly cancer survivors with malnutrition are more likely to be classified in the "frail group", which is consistent with existing evidence (*30,31*). Malnutrition plays a crucial role in the pathophysiology of frailty (*32*). In cancer patients, the tumor itself, adverse effects of treatment, and cachexia reduce appetite and nutrient intake while increasing catabolism (*30,33*), leading to protein insufficiency. This drives muscle loss, reduced physiological reserve, and a heightened risk of frailty (*34*). Additionally, adverse outcomes of malnutrition, such as osteoporosis, sarcopenia, cognitive impairment, and falls, all contribute to the progression of frailty. The European Society for Clinical Nutrition and Metabolism recommends oral nutritional supplements (ONS) as a first-line intervention, combined with exercise (*35*). The Mediterranean diet is recognized as a suitable dietary regimen for addressing frailty in accordance with international guidelines (*36*). This diet can reduce the levels of inflammatory mediators in the body, thereby reducing the likelihood of frailty (*37*). Consequently, early evaluation of the risk of malnutrition in cancer patients is recommended for the future. A thorough assessment, which includes the measurement of body composition and resting energy expenditure, should be performed. For those at risk, adopting the Mediterranean diet or some other anti-inflammatory diet may help to mitigate metabolic stress and inflammation.

Moreover, these findings indicate that elderly cancer survivors with depression have a higher likelihood of being classified in the "frail group", which is consistent with the findings of Gilmore *et al.* (*38*). Notably, depression and frailty share overlapping mechanisms and neurobiological features (*39*). Depressive symptoms correlate with elevated inflammatory markers, such as C-reactive protein (CRP) and interleukin-6 (IL-6), which promote neurohormone-mediated muscle protein catabolism. This leads to sarcopenia, metabolic dysfunction, and impaired resilience, collectively driving frailty (*40*). Additionally, depression induces mitochondrial dysfunction in metabolically vulnerable dopaminergic neurons, reducing ATP synthesis. The resulting decline in dopaminergic tone contributes to apathy, reduced mobility, and accelerated functional decline, thereby exacerbating frailty (*41*). Healthcare personnel should incorporate depression screening in frailty assessments for elderly cancer survivors, promptly identify depressive symptoms, and offer psychological support to alleviate negative emotions, alleviate depression, and mitigate the progression of both frailty and depression.

In addition, findings indicated that elderly cancer survivors experiencing fatigue are more likely to be categorized in the "frail group", which aligns with the study by Tohi *et al.* (*42*). The main reason why is that cancer patients experience a high degree of physical fatigue, which leads to decreased exercise tolerance, feelings of exhaustion, and impaired daily functioning, indirectly resulting in the onset of frailty (*43*). Moreover, the long-term presence of chronic fatigue can cause negative emotions such as anxiety and depression in patients, interfering with treatment compliance and reducing quality of life, thereby exacerbating frailty (*44*). Consequently, healthcare personnel should add to their understanding of cancer-related fatigue, recognizing its multifaceted and enduring nature, and enhance patients' quality of life. Additionally, various forms of peer support activities can facilitate mutual sharing and stress relief among patients, helping them build confidence in overcoming the disease, encouraging more active coping strategies for cancer-related fatigue, and ultimately delaying frailty.

The findings of this study indicate that elderly cancer survivors with lower levels of ADL are more likely to be classified into the "frail group", which is in line with the conclusions reached by Pu *et al.* (*45*). Additionally, Yuan *et al.* highlighted the significance of impairments in daily activities and balance issues in the identification of frailty among the elderly (*46*). The primary reason why is that patients' long-term reduction in independent activities leads to muscle atrophy, and the progressive loss of skeletal muscle mass and function increases the risk of frailty (*45*). Moreover, patients with less ability to perform ADLs often suffer from compromised personal health, dysfunction, or limited mobility, resulting in reduced social activities, disrupted social networks, and decreased social participation, which can easily lead to feelings of loneliness (*47*). A study has found that social isolation and loneliness are closely related to frailty (*48*). Therefore, nurses should develop individualized nursing plans based on the ADLs of elderly cancer survivors, such as encouraging them to continue engaging in daily exercise within their capabilities, exposing them to new things, encouraging them to actively participate in social activities, and encouraging them to build up their social networks, in order to delay the decline of physical function and the progression of frailty.

The results of this study indicated that 79.5% of elderly cancer survivors exhibited IC decline, a

proportion consistent with findings from a previous study (*49*). This indicates that IC impairment in elderly cancer survivors is a pressing issue that cannot be ignored. Additionally, significant differences in IC were observed among the three frailty subtypes ($p < 0.05$), suggesting a close association between IC and frailty severity in elderly cancer survivors, which is in line with the findings of Ntsama *et al.* (*8*). Existing research has confirmed that impairments in all IC domains including sensory function, psychosocial function, locomotor capacity, cognitive function, and vitality are correlated with frailty (*50*). The underlying mechanism may be explained as follows: elderly patients with frailty already have reduced physiological reserves and an elevated risk of physiological function decline. As a persistent stressor, cancer can further diminish their physiological function, thereby exacerbating IC impairment. These findings highlight the need for healthcare personnel to develop targeted interventions to enhance IC, delay the progression of frailty, and ultimately improve patients' health outcomes.

Nevertheless, this study had several limitations. Firstly, this study used convenience sampling, resulting in a lack of representativeness in the sample and causing selection bias. Second, this study is a small-scale, single-center cross-sectional survey with limited sample representativeness. The method of classification used in the study relies on the characteristics of the current sample and the specific assessment tools used, precluding detailed classification for all patients. This may lead to limitations in the method of classification, thereby restricting the general applicability of the study's findings. In future studies, we plan to expand the sample size and adopt widely recognized assessment tools for patient classification. Moreover, we intend to conduct additional research to validate the applicability of these methods of classification in different patient populations. Third, this study examined the correlation between different variables and frailty only in a cross-sectional fashion, failing to track the causal link between variables and frailty over time. Therefore, future research should aim to increase the sample size through systematic sampling, conduct multi-center longitudinal studies to understand the trajectory of changes in frailty among elderly cancer survivors, and provide a basis for precise interventions. Finally, the wide confidence intervals for some strong predictors indicate imprecision in the effect size estimates, which was likely due to the sample size and skewed distribution of these factors. While confirming their importance, future larger-scale studies need to quantify these associations more precisely.

5. Conclusion

Elderly cancer survivors have a high incidence of frailty and exhibit heterogeneity. Here, they were classified into three categories, namely a "frail group", a "pre-frail group", and a "robust group", based on LCA. Through careful classification of frail patients, we can gain a more precise understanding of the frailty characteristics of different patient groups. Potential categorical factors, such as monthly household income, smoking, fatigue, depression, malnutrition, and low ADL, heighten the risk of elderly cancer survivors becoming frail. These findings provide a theoretical basis for healthcare personnel to regularly assess the risk of frailty, identify high-risk groups, and develop patient-centered interventions. Moreover, there were differences in IC among patients in different classes. These findings provide a basis for healthcare personnel to regularly assess the risk of frailty, identify high-risk groups with reduced IC, and thereby alleviate frailty and improve IC levels in those groups.

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