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# Associations of life's crucial 9 with mortality among older adults with frailty: a prospective cohort study from the NHANES 2007 to 2018

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## Abstract

**Background** Frailty among the elderly represents a considerable public health issue linked to increased vulnerability and adverse outcomes. The Life's Crucial 9 (LC9) score, which includes mental health assessments alongside traditional cardiovascular health metrics, may offer a more comprehensive prediction of mortality risk in frail elderly populations.

**Methods** This prospective cohort study leveraged data from the National Health and Nutrition Examination Survey (NHANES) from 2007 to 2018. Participants aged ≥ 60 years were included, and frailty was assessed as Frailty index ≥ 0.21. The LC9 score combined eight physical health metrics with a mental health component focused on depression. Mortality follow-up information was acquired until December 2019. The study employed cox proportional hazards regression to assess the relationship between LC9 scores and mortality and additionally applied restricted cubic spline models to investigate dose–response associations.

**Results** The analysis encompassed a total of 2,690 participants. Each 10-point increase in LC9 score was associated with a 13% decrease in mortality risk (HR: 0.87; 95% CI: 0.80–0.95; $p = 0.002$) after full adjustment. Participants in the highest tertile of LC9 scores demonstrated a 23–28% reduction in mortality risk compared to the lowest tertile. An L-shaped relationship was observed, with higher LC9 scores associated with lower mortality risk.

**Conclusion** The LC9 score represents an important advancement in assessing mortality risk among frail older adults. This study highlights the need for holistic approaches in aging health assessments and suggests that integrating mental health within cardiovascular metrics may enhance the accuracy of risk predictions.

**Keywords** Frailty, Mortality, Life's Crucial 9, Mental Health, NHANES

## Introduction

Frailty, a geriatric syndrome, is defined by a reduction in physiological reserves and heightened susceptibility to stressors, which can result in negative health outcomes, including disability, institutionalization, and increased mortality [1]. With the aging global population, frailty has become a significant public health issue, imposing considerable burdens on healthcare systems and impacting the life quality of elderly individuals [2, 3]. Identifying modifiable risk factors and crafting preventative measures to avert or defer the emergence of frailty are crucial for improving health outcomes in this demographic [4].

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Studies have shown that frailty and Cardiovascular Health (CVH) are interrelated, as poor cardiovascular health can facilitate the escalation of frailty [5, 6]. Previous CVH metrics, namely Life's Simple 7 (LS7) and Life's Essential 8 (LE8), have evaluated CVH and frailty risk in elderly individuals [7, 8]. However, the two metrics do not account for mental health factors, which are increasingly recognized as critical for comprehensive risk assessment, especially in older adults with frailty [9]. Depression, for example, has emerged as a key factor affecting both CVH and frailty, suggesting that mental health should be integrated with CVH metrics to predict mortality risks in aging populations better [10, 11]. Yet, limited research has explored how a combined CVH and mental health metric might better predict the death risk of frail elderly individuals.

In response to the need for broader risk assessments in older adults, the LC9 score combines the LE8 with mental health components, particularly depression, to better predict mortality in this vulnerable population [12, 13]. As frailty is recognized as a predictor of poor health outcomes in cardiovascular disease, assessing the predictive value of LC9 for mortality in frail populations could fill a critical knowledge gap [14].

The objective is to explore the link between LC9 scores and mortality among frail older adults utilizing data from the National Health and Nutrition Examination Survey (NHANES). We aim to facilitate the creation of more effective, integrated health assessments that can be used in clinical and public health settings to identify high-risk individuals and tailor preventive strategies.

## Methods

### Study population

NHANES is a significant program carried out by the National Center for Health Statistics (NCHS) to evaluate the health and nutrition of the U.S. population. In the present study, a total of 11,910 individuals (age ≥ 60 years) from NHANES 2007–2018 were involved. After excluding participants with frailty index < 0.21, people diagnosed with frailty were included. We further remove individuals without follow-up data ($N = 12$), missing data about LC9 scores ($N = 1{,}353$), and missing data on covariates ($N = 295$). Finally, the present analysis included 2,690 participants altogether. Figure 1 depicts a flowchart for participants. The study protocol was approved by the NCHS Ethics Review Board, with each participant providing written informed consent.

### Assessment of frailty

Frailty was evaluated through a deficit accumulation model. The frailty score was derived by summing the

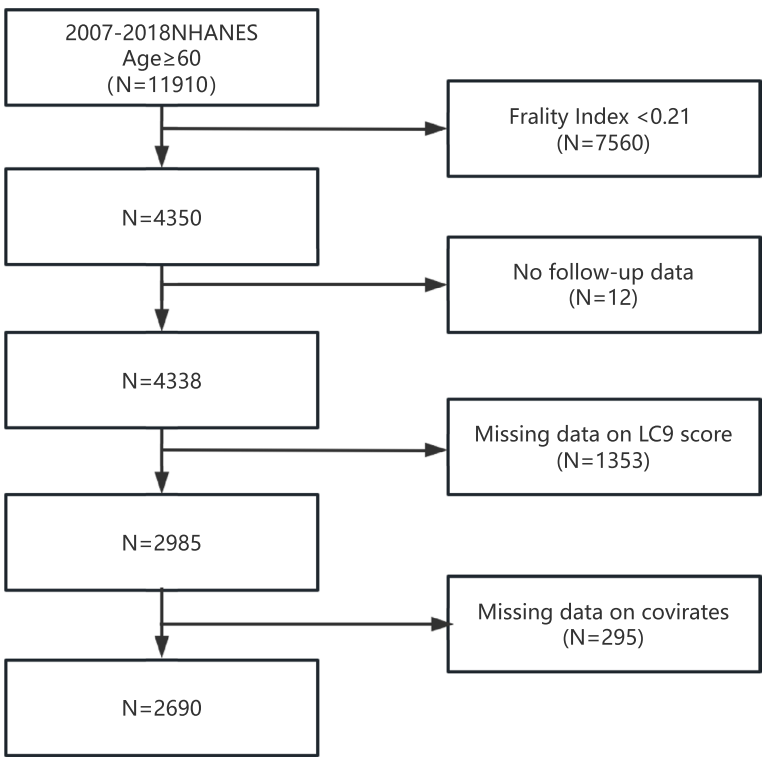


**Fig. 1** Flowchart of participant selection

individual deficit items and dividing by the total number of items completed, yielding a continuous score between 0 and 1, where a score of 0 denotes the absence of deficits, and a score of 1 represents the maximum accumulation of deficits. The frailty index encompassed 49 specific criteria across seven domains: cognitive function, dependence, depressive symptoms, comorbidities, healthcare utilization, physical anthropometric measurements, and laboratory findings (Table S1). For analytical purposes, the continuous frailty score was dichotomized using a threshold value of 0.21, with scores exceeding this cutoff considered indicative of frailty, consistent with established literature [15].

### Assessment of LC9

The LC9 score components were derived exclusively from baseline data collected during participants' initial enrollment in NHANES 2007–2018 [12]. Self-reported metrics (nicotine exposure, physical activity, sleep duration) were obtained through structured interviews. Blood pressure, body mass index (BMI), and handgrip strength were measured by trained staff using standardized protocols. Fasting blood samples were analyzed for glucose, glycated hemoglobin (HbA1c), and lipid profiles (non-high-density lipoprotein cholesterol) at certified laboratories (Table S2). Diet was assessed using the Healthy Eating Index 2015, calculated from 24-h dietary recall data processed according to U.S. Department of Agriculture standards. Depression, a critical component of mental health, was evaluated through the Patient Health Questionnaire-9 (PHQ-9). Each of the nine health indicators was rated on a 0–100 scale, indicating the person's health condition. The composite LC9 score is calculated as the unweighted average of the nine component scores. Consequently, the LC9 score ranges from 0 (worst health) to 100 (optimal health), with higher scores indicating better health status.

### Ascertainment of mortality

The follow-up period spanned from each participant's baseline enrollment date to the study endpoint. Mortality follow-up information was acquired from the NHANES Public-use Mortality File until December 13, 2019.

### Covariates

Data on demographics were gathered through questionnaire-based interviews, encompassing variables such as age, gender, marital status, race, education level, and the family of poverty ratio (PIR). We defined hypertension as the average systolic blood pressure $\geq$140 mmHg or the diastolic $\geq$90 mmHg, the utilization of antihypertensive drugs and a prior diagnosis. Diabetes was established through fasting glucose levels ($\geq$ 7.0 mmol/L), HbA1c ($\geq$ 6.5%), the use of diabetes medications or insulin, or a recorded medical diagnosis by a professional. Cardiovascular disease (CVD) is defined as a history of stroke, congestive heart failure, heart attack, angina, or coronary artery disease. Cancer diagnoses were confirmed based on reports from a physician or other healthcare professionals. All data are available at www.cdc.gov/nchs/nhanes/.

### Statistical analysis

All statistical analyses adhered to the NHANES guidelines for analysis and reporting, considering the complexities of the survey design. Continuous variables are presented as mean ± standard error (SE), whereas categorical ones are depicted by proportions. We employed weighted chi-square analysis and weighted one-way analysis to identify disparities in descriptive statistics. Subsequently, we utilized multivariate Cox proportional hazards regression to assess hazard ratios (HRs) with 95% confidence intervals (CIs), examining the relationship between the LC9 score and mortality. Participants were censored in the survival analysis if they survived until the study endpoint or were lost to follow-up. Censored cases were retained in the analysis until their last confirmed alive date, with their survival time contributing to the risk pool without biasing hazard estimates. Age and sex were modified in Model 1. Model 2 was additionally modified for race, PIR, education level, and marital status. Model 3 was further modified for the history of CVD, diabetes mellitus (DM), hypertension, and cancer. For trend analysis across LC9 tertiles, we assigned integer values to each tertile and tested the linear association using the Wald statistic [16]. We calculated the concordance index with 95% confidence intervals using bootstrapping to assess the predictive performance [17]. The potential linear association was analyzed through adjusted restricted cubic spline regression. We performed stratified analyses and interaction tests to examine potential modifying factors on the link between LC9 scores and mortality. Statistical significance for all analyses was set at a two-tailed *P*-value threshold of less than 0.05. The statistical analyses were performed utilizing R Studio (Version 4.2.2).

## Results

### Characteristics of included participants

A total of 2,690 individuals were enrolled in the cohort, and the average age was 71.25 ± 0.21 years old, and 1,436 (58.51%) were female. After a mean follow-up duration of 61.60 months, a total of 935 deaths were recorded. Table 1 displays the basic features of participants with frailty. The alive and deceased groups were statistically significant with age, sex, race, education level, marital status, PIR, and the history of CVD (Table 1). Table 2

**Table 1** Baseline characteristics of participants according to survival status through December 31, 2019

| Variable | Total | Alive | Deceased | *P* value |
|---|---|---|---|---|
| Number(*N*) | 2690 | 1755 | 935 | < 0.001 |
| Age (year) | 71.25 ± 0.21 | 69.80 ± 0.25 | 74.21 ± 0.28 | |
| Sex, *n* (%) | | | | 0.009 |
| Female | 1436(58.51) | 1010(61.22) | 426(52.98) | |
| Male | 1254(41.49) | 745(38.78) | 509(47.02) | |
| Race, *n* (%) | | | | < 0.001 |
| Non-Hispanic Black | 594(10.02) | 424(10.90) | 170(8.21) | |
| Non-Hispanic White | 1387(76.57) | 771(73.26) | 616(83.30) | |
| Mexican American | 323(4.67) | 257(5.40) | 66(3.18) | |
| Others | 386(8.74) | 303(10.43) | 83(5.31) | |
| Education level, *n* (%) | | | | < 0.001 |
| Less than high school | 1393(45.20) | 941(46.13) | 452(43.31) | |
| College or above | 1074(46.90) | 726(49.16) | 348(42.28) | |
| High school | 223(7.90) | 88(4.71) | 135(14.41) | |
| Marital, *n* (%) | | | | 0.010 |
| Married | 1296(52.89) | 869(54.75) | 427(49.10) | |
| Separated | 1258(42.68) | 788(40.24) | 470(47.65) | |
| Unmarried | 136(4.43) | 98(5.01) | 38(3.25) | |
| BMI (kg/m2) | 31.57 ± 0.25 | 32.15 ± 0.28 | 30.37 ± 0.35 | |
| Family of poverty ratio | | | | 0.019 |
| < 1.3 | 1037(26.87) | 686(26.23) | 351(28.17) | |
| 1.3–3.5 | 1173(46.18) | 741(44.35) | 432(49.92) | |
| > 3.5 | 480(26.95) | 328(29.42) | 152(21.91) | |
| CVD, *n* (%) | | | | < 0.001 |
| Yes | 1281(47.67) | 760(44.05) | 521(55.04) | |
| No | 1409(52.33) | 995(55.95) | 414(44.96) | |
| DM, *n* (%) | | | | 0.160 |
| Yes | 1408(48.56) | 910(47.39) | 498(50.94) | |
| No | 1282(51.44) | 845(52.61) | 437(49.06) | |
| Hypertension, *n* (%) | | | | 0.256 |
| Yes | 2277(83.90) | 1481(83.20) | 796(85.32) | |
| No | 413(16.10) | 274(16.80) | 139(14.68) | |
| Cancer, *n* (%) | | | | 0.203 |
| Yes | 752(33.25) | 443(32.14) | 309(35.53) | |
| No | 1938(66.75) | 1312(67.86) | 626(64.47) | |

Mean ± standard error (SE) for continuous variables, Percentage (%) for categorical variables

presents participants categorized into tertiles based on LC9 scores: Tertiles 1(< 51.67), Tertiles 2 (51.67–62.78), and Tertiles 3 (≥ 62.78). Individuals with higher LC9 scores were generally older, married, identified as Non-Hispanic White, better educated, and had higher family income. They were also less likely to have DM and hypertension while were more likely to have a history of cancer (Table 2).

### Relationship between LC9 and mortality

As shown in Table 3, in the baseline model (Model 1), each 10-point increase in LC9 was related to a 14% reduction in death risk (HR: 0.86; 95% CI: 0.80–0.92; $p < 0.001$). This association remained strong in Model 2. In Model 3, a dose–response relationship was observed, where each 10-point increase in the LC9 score corresponded to a 13% reduction in mortality risk (HR: 0.87), equivalent to a 1.3% risk reduction per 1-point increment (HR: 0.987).

When examining LC9 score tertiles, significant differences in mortality risk were observed across all models. Participants in the second tertile had approximately 22–23% lower mortality risk compared to those in the lowest tertile in three models (Model 1 HR: 0.77, 95% CI: 0.64–0.94; Model 2 HR: 0.77, 95% CI: 0.64–0.93; Model 3 HR: 0.78, 95% CI: 0.64–0.94). Furthermore, participants in the highest tertile demonstrated a 23–28% reduction in mortality risk compared to the lowest tertile (Model 1 HR: 0.72, 95% CI: 0.60–0.87; Model 2 HR: 0.75, 95% CI: 0.62–0.91; Model 3 HR: 0.77, 95% CI: 0.62–0.95). The fully adjusted model demonstrated moderate discriminative ability, with a concordance index of 0.73 (95% CI: 0.71–0.74). The *p*-values for trend across all models indicate a significant dose–response relationship, with higher LC9 scores consistently associated with progressively lower mortality risk (Model 1 $p < 0.001$; Model 2 $p < 0.005$; Model 3 $p = 0.016$).

We also investigated the possible non-linear association between LC9 scores and mortality among frail elderly individuals (Fig. 2). After adjusting for covariates, we observed an L-shaped association between LC9 and mortality ($p > 0.05$ for nonlinearity).

### Sensitivity analysis

To address the potential overlap between frailty and depressive symptoms, we conducted a sensitivity analysis using a revised FI that excluded all depression-related items (Table S3). To assess the robustness of the relationship between LC9 scores and mortality in frail older people, we conducted subgroup analyses. No significant interactions were identified when data were stratified by age, sex, race, CVD, DM, hypertension and cancer (Fig. 3).

## Discussion

Our findings demonstrate that the LC9 score, as a composite metric integrating both CVH and mental health, is significantly associated with reduced mortality risk among frail older adults. Each 10-point increase in LC9 score corresponded to a 13% decrease in mortality risk. This underscores the value of multidimensional health

**Table 2** Characteristics of the participants by tertiles of life's crucial 9 scores

| Variable | Total | T1 | T2 | T3 | *P* value |
|---|---|---|---|---|---|
| Participants, (*N*) | 2690 | 920 | 904 | 866 | < 0.001 |
| Age (year) | 71.25 ± 0.21 | 69.54 ± 0.35 | 72.23 ± 0.31 | 71.97 ± 0.29 | |
| Sex, *n* (%) | | | | | 0.209 |
| Female | 1436(58.51) | 539(61.97) | 471(57.28) | 426(56.36) | |
| Male | 1254(41.49) | 381(38.03) | 433(42.72) | 440(43.64) | |
| Race, *n* (%) | | | | | < 0.001 |
| Non-Hispanic Black | 594(10.02) | 264(13.89) | 189(9.88) | 141(6.47) | |
| Non-Hispanic White | 1387(76.57) | 410(72.26) | 474(76.60) | 503(80.63) | |
| Mexican American | 323(4.67) | 118(5.11) | 122(5.37) | 83(3.59) | |
| Others | 386(8.74) | 128(8.74) | 119(8.15) | 139(9.31) | |
| Education level, *n* (%) | | | | | < 0.001 |
| Less than high school | 1393(45.20) | 528(51.12) | 504(50.11) | 361(34.97) | |
| High school | 223(7.90) | 68(7.69) | 78(8.76) | 77(7.30) | |
| College or above | 1074(46.90) | 324(41.19) | 322(41.13) | 428(57.73) | |
| Marital, *n* (%) | | | | | 0.026 |
| Married | 1296(52.89) | 394(48.97) | 427(50.04) | 475(59.29) | |
| Separated | 1258(42.68) | 472(46.66) | 437(45.41) | 349(36.34) | |
| Unmarried | 136(4.43) | 54(4.37) | 40(4.54) | 42(4.37) | |
| Family of poverty ratio | | | | | < 0.001 |
| < 1.3 | 1037(26.87) | 446(35.04) | 327(25.56) | 264(20.33) | |
| 1.3–3.5 | 1173(46.18) | 365(44.08) | 423(51.39) | 385(43.30) | |
| > 3.5 | 480(26.95) | 109(20.88) | 154(23.05) | 217(36.37) | |
| CVD, *n* (%) | | | | | 0.820 |
| Yes | 1281(47.67) | 448(48.10) | 419(46.59) | 414(48.26) | |
| No | 1409(52.33) | 472(51.90) | 485(53.41) | 452(51.74) | |
| DM, *n* (%) | | | | | < 0.001 |
| Yes | 1408(48.56) | 610(63.30) | 481(50.61) | 317(32.62) | |
| No | 1282(51.44) | 310(36.70) | 423(49.39) | 549(67.38) | |
| Hypertension, *n* (%) | | | | | < 0.001 |
| Yes | 2277(83.90) | 827(88.71) | 760(84.21) | 690(79.03) | |
| No | 413(16.10) | 93(11.29) | 144(15.79) | 176(20.97) | |
| Cancer, *n* (%) | | | | | < 0.001 |
| Yes | 752(33.25) | 212(24.88) | 262(34.77) | 278(39.80) | |
| No | 1938(66.75) | 708(75.12) | 642(65.23) | 588(60.20) | |
| Depression, *n* (%) | | | | | < 0.001 |
| Yes | 543(19.77) | 295(32.66) | 165(18.72) | 83(8.49) | |
| No | 2147(80.23) | 625(67.34) | 739(81.28) | 783(91.51) | |

Mean ± standard error (SE) for continuous variables, Percentage (%) for categorical variables

assessments in capturing the complex interplay of physiological and psychological vulnerabilities inherent to frailty.

In our cohort of frail older adults, the observed mortality rate aligns with prior studies. For instance, studies utilizing Clinical Frailty Scale have reported that 5-year mortality rates were 43% in elderly populations with acute coronary syndrome [18]. Another survey by Noor K et al. found that frail patients with heart failure exhibited a mortality risk of approximately 40% to 50% over 5 years [19]. This consistency highlights the critical need for interventions targeting modifiable LC9 components to reduce mortality in this vulnerable group.

Prior studies have shown that individual LC9 components independently reduce frailty progression and mortality. A meta-analysis by Rashidi Pour Fard et al. showed diets high in vegetables, fruits and whole grains were associated with lower odds of frailty [20]. A study involving five European countries found that adherence to the Mediterranean diet can influence the gut microbiome in

**Table 3** Association between life's crucial 9 scores with mortality among older adults with frailty

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | **HR (95%CI)** | ***P* value** | **HR (95%CI)** | ***P* value** | **HR (95%CI)** | ***P* value** |
| Per 1 point increase | 0.985(0.978,0.992) | < 0.001 | 0.986(0.978,0.994) | < 0.001 | 0.987(0.978,0.995) | 0.002 |
| Per 10 points increase | 0.86(0.80,0.92) | < 0.001 | 0.87(0.80,0.94) | < 0.001 | 0.87(0.80,0.95) | 0.002 |
| LC9 score | | | | | | |
| T1(< 51.67) | Reference | | Reference | | Reference | |
| T2(51.67–62.78) | 0.77(0.64,0.94) | 0.008 | 0.77(0.64,0.93) | 0.006 | 0.78(0.64,0.94) | 0.009 |
| T3(≥ 62.78) | 0.72(0.60,0.87) | 0.002 | 0.75(0.62,0.91) | 0.004 | 0.77(0.62,0.95) | 0.014 |
| *P* for trend | < 0.001 | | < 0.005 | | 0.016 | |

Model 1: adjusted for age, sex

Model 2: adjusted for age, sex, races, education level, marital status, the family of poverty ratio

Model 3: adjusted for age, sex, races, education level, marital status, the family of poverty ratio, cancer, CVD, hypertension, and DM

*HR* hazard ratio, *CI* confidence interval

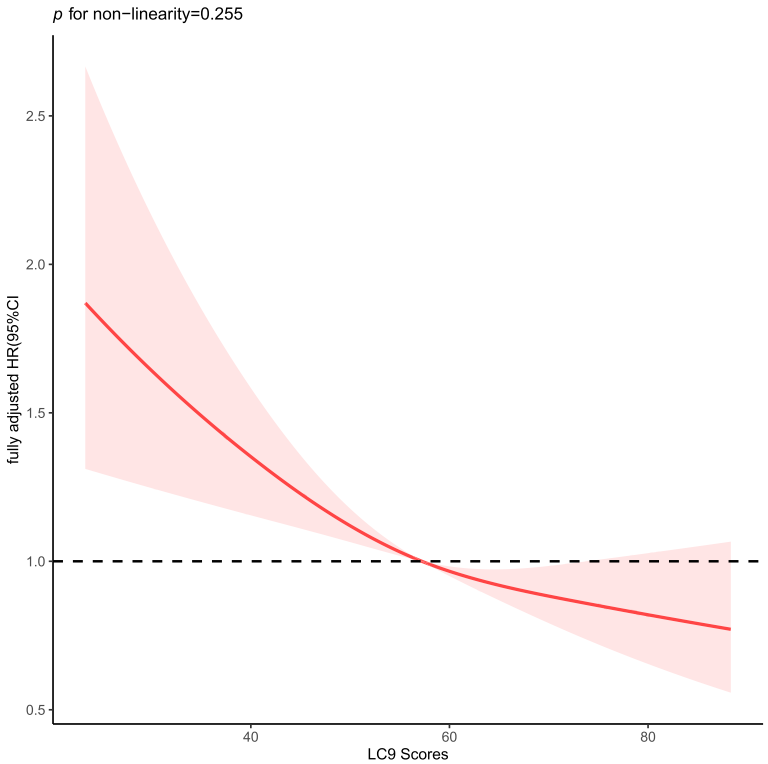


**Fig. 2** Restricted cubic spline analysis between Life's Crucial 9 with mortality among older adults with frailty. The red solid line and gray areas in the figure panels represent HRs and 95% CIs, respectively. HRs were adjusted for age, sex, race, PIR, education level, marital status, CVD, DM, hypertension, and cancer

older individuals, thereby diminishing the risk of frailty [21]. Additionally, a study conducted by Sun et al. found that both a pro-inflammatory diet and poor sleep quality are significant risk factors for frailty and suggested that an anti-inflammatory diet may help to mitigate the negative effects of poor sleep quality on frailty [22]. In the cohort of adults aged 45 to 76 with diabetes, those who were allocated to a program of calorie restriction and regular physical exercise exhibited a reduction in CVD incidents, with a more pronounced effect in participants exhibiting lower degrees of frailty [23]. Additionally, tight glycemic control and effective blood pressure control can mitigate cardiovascular events and frailty in older adults [24, 25]. Our study demonstrates that higher LC9 scores,

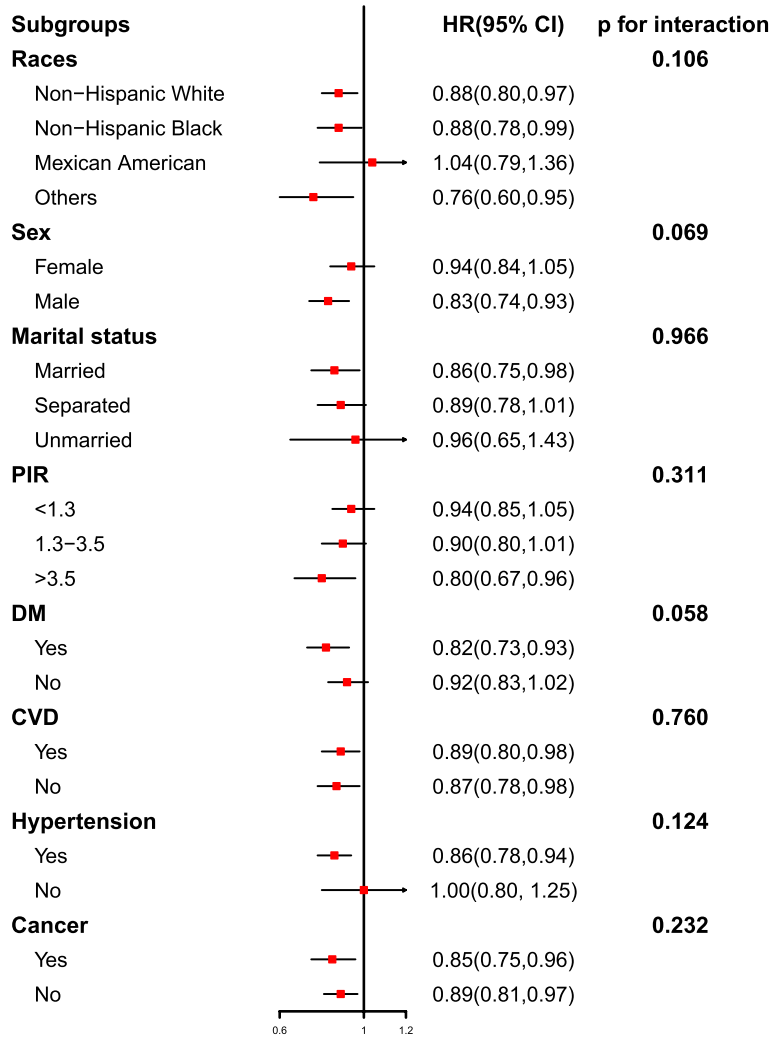


**Fig. 3** The relation of life's crucial 9 (Per 10 points increase) with mortality among older adults with frailty in various subgroups

which synthesize these modifiable factors into a single measurement, are robustly associated with reduced mortality risk among frail older adults. This association is driven by the synergistic interplay of all nine LC9 components, providing clinicians with a practical tool to prioritize interventions across diverse health domains.

Existing literature consistently demonstrates that poor CVH is linked to frailty and higher death rates among the elderly. For instance, studies have shown that traditional metrics, such as LS7, are inversely related to mortality and the onset of frailty in aging populations [7]. More recent work with LE8 has similarly confirmed that CVH benefits extend to reduced risks of various age-related health outcomes, including frailty and CVD [8, 26, 27]. The LC9 score represents a novel advancement in frailty research by explicitly incorporating mental health—a dimension increasingly recognized as critical for holistic risk stratification in aging populations [9].

The interplay between frailty and depression is another critical consideration, as they exacerbate one another, leading to a vicious cycle that hastens the deterioration of health [13]. Frailty often leads to physical limitations, social isolation, and increased dependency, factors that may contribute to depression [28]. Conversely, depression exacerbates frailty by promoting behaviors that lead to muscle loss, mobility limitations, and decreased resilience to stressors [29]. In a meta-analysis, individuals without depression served as the control group, with those experiencing depression more prone to frailty [13]. This cyclical interaction suggests that the combined mental and physical health approach offered by LC9 may be particularly suited to identifying those at higher mortality risk among older, frail adults.

Mechanistically, several pathways may explain the correlation between LC9 scores and reduced mortality rates among frail elderly individuals. Frailty is linked

to chronic inflammation and oxidative stress, accelerating cellular aging and leading to tissue degeneration [30]. Specific LC9 elements, notably a balanced diet and consistent exercise have demonstrated reductions in inflammatory mediators such as TNF-alpha and IL-6 [31, 32]. Poorly managed blood glucose and lipid levels contribute to metabolic disturbances, which aggravate frailty and increase mortality [20]. By managing glucose and lipid levels, LC9 supports metabolic stability, thereby reducing stress on the endocrine and cardiovascular systems, slowing frailty progression, and preventing chronic diseases that can severely impact frail individuals [33]. Depression, as a component of LC9, has been shown to trigger inflammatory responses, activate oxidative stress, and contribute to mitochondrial dysfunction, which together elevate frailty risks [34]. Furthermore, depression disrupts the hypothalamic–pituitary–adrenal axis, resulting in persistent stress reactions that can exacerbate CVD and frailty, highlighting why LC9's inclusion of mental health is beneficial in predicting outcomes among frail adults [35].

Despite its strengths, it is essential to recognize its limitations. Primarily, the study's observational approach limits our capacity to determine causal links between LC9 and the risk of mortality. Even after controlling for various demographic and clinical factors, unmeasured confounders like social support, cognitive health, and subtle lifestyle elements could affect our results [9]. Additionally, our reliance on data from the NHANES, which predominantly reflects the U.S. population, might limit the generalizability to other international populations with differing socio-economic or cultural characteristics.

## Conclusion

In conclusion, the LC9 score provides a clinically actionable framework for mortality risk stratification in frail older adults. By uniting cardiovascular and mental health, it advances personalized interventions tailored to the complex needs of this vulnerable population.

### Abbreviations

| | |
|---|---|
| NHANES | National Health and Nutrition Examination Survey |
| LC9 | Life's Crucial 9 |
| CVH | Cardiovascular Health |
| LS7 | Life's Simple 7 |
| LE8 | Life's Essential 8 |
| NCHS | National Center for Health Statistics |
| PHQ-9 | Patient Health Questionnaire-9 |
| PIR | The family of poverty ratio |
| CVD | Cardiovascular disease |
| DM | Diabetes mellitus |
| BMI | Body mass index |
| SE | Standard error |
| HRs | Hazard ratios |
| CIs | Confidence intervals |

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-025-05996-5.

Supplementary Material 1.

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### Clinical trial number

Not applicable.

### Authors' contributions

Conceptualization, S.Y.; data curation, S.Y. and K.C.; formal analysis, S.Y. and P.Z.; methodology, J.L.; software, J.S.; supervision, H.W.; writing-original draft, K.C. and J.L.; writing—review and editing, J.Y.; visualization, S.Y.; All authors have read and agreed to the published version of the manuscript.

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### Data availability

The survey data are publicly available on the internet for data users and researchers throughout the world ( www.cdc.gov/nchs/nhanes/ ).

## Declarations

### Ethics approval and consent to participate

The portions of this study involving human participants, human materials, or human data were conducted in accordance with the Declaration of Helsinki and were approved by the National Center for Health Statistics (NCHS) Ethics Review Board. The patients/participants provided their written informed consent to participate in this study.

### Consent for publication

Not applicable.

### Competing interest

The authors declare no competing interests.

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