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Factors associated sarcopenia and frailty in hemodialysis patients with chronic kidney disease: a cross-sectional study

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Abstract: The study investigated the relationships between sarcopenia, frailty, and related factors in hemodialysis patients with chronic kidney disease. A prospective cross-sectional study with convenience sampling was conducted between August 2021 and February 2022 at a hospital-affiliated hemodialysis center. Ninety-six hemodialysis patients participated in the study. Quantitative data were collected with structured interviews. Sarcopenia was determined with a rapid screening tool. Frailty was determined with the Rockwood clinical frailty score. Descriptive analysis, Person Correlations, and Linear regression analysis were used to evaluate the associations between frailty, sarcopenia, and health-related factors in hemodialysis patients. The mean age of the participants was 65.4 ± 11.5 years, with an average of 95.0± 77.5 months of hemodialysis. The most common comorbidity was hypertension (72.9%), followed by diabetes mellitus (39.6%) and cardiovascular health problems (35.4%). A significant difference in frailty between sarcopenia patients and a healthy population ($X2 = 9.51$, $p < .001$) was identified. There was a strong negative correlation ($r = -.853$, $p < .001$) between sarcopenia and frailty, while moderate correlations between sarcopenia and frailty in sarcopenia patients ($r = -.66$, $p < .001$) and a healthy population ($r = -.58$, $p < .001$) were observed. Age, body weight before dialysis, and hand grip strength were found to be potential predictors of sarcopenia and frailty. Left calf circumference was significantly associated with sarcopenia ($ß = -.128$, $p = .049$). Age, body weight before dialysis, and hand grip strength are potential predictors of sarcopenia and frailty in hemodialysis patients with chronic kidney disease. Comorbidities, which may be preventable, are common in this population.

Keywords: renal insufficiency; comorbidity; frailty; renal dialysis; sarcopenia

1. Introduction

According to the Annual Report of the National Health Research Institutes and Taiwan Society of Nephrology [1], the prevalence of chronic kidney disease (CKD) and hemodialysis in Taiwan has increased significantly, leading to a rise in health insurance expenditures. This population consists mainly of seniors with multiple chronic diseases. While health management for hemodialysis patients has focused on ensuring their health security, health promotion to prevent comorbidities has received little attention. It is crucial to investigate comorbidities that inordinately affect hemodialysis patients, such as sarcopenia and frailty, be investigated [2].

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Fried et al. [3] have identified a chain of health problems: CKD, sarcopenia, and frailty. In an aging society like Taiwan's, CKD and hemodialysis have received community attention and research to reduce their adverse effects. The literature on sarcopenia has focused on its occurrence, primarily within nutrition [4] and rehabilitation [5]. However, limited research has addressed the relationship between CKD or hemodialysis and sarcopenia. Preventing a chain reaction of health problems, such as sarcopenia and frailty among CKD hemodialysis patients, requires evaluation and implementation of effective interventions. Accordingly, this study investigated the relationships between sarcopenia, frailty, and related factors in hemodialysis patients with chronic kidney disease.

Frailty, sarcopenia, and CKD are critical determinants of adverse clinical outcomes, including falls, hospitalization, and mortality [6]. Frailty refers to the body's reduced capacity to withstand health stressors, which can lead to a loss or decline of bodily functions, culminating in multiple functional deficits or adverse health outcomes [7]. The concept of frailty has derived from biological age and can provide insights into an individual's overall health status. Older individuals are prone to debilitating conditions and have a heightened risk of adverse health outcomes, including falls, extended hospitalization, need for long-term care, and mortality [6]. Frailty is strongly associated with cardiovascular disease [8], depression [9], and quality of life [10], which highlights the importance of assessing frailty in these conditions.

Fried et al. [11] have characterized the behavioral performance patterns of frailty, including unintended weight loss, physical exhaustion, low physical activity, slow walking, and muscle weakness. On the other hand, Rockwood and Mitnitski [12] have characterized the physical multiple impairment pattern of frailty based on sensory, functional, and clinical deficits. These two patterns of frailty interrelate aspects of biology, pathophysiological mechanisms, and clinical features, making it challenging to identify the precise cause of an individual's weak state [7]. Thus, Rodriguez-Manas et al. [13] proposed a multidimensional frailty model based on the frailty mechanism and evaluates an individual's actions, cognition and emotions, nutritional status, physical activity, and psychosocial and economic factors. Although the multidimensional frailty model can define an individual's infirmity state, applying it in practical circumstances is challenging. For example, in the above three patterns of frailty, frailty could include insufficient muscle mass and strength. However, when muscle mass and muscle strength are not correlated, an individual's weakness cannot be interpreted [14].

The concept of sarcopenia originated with Rosenberg [15], who advocated the exploration of aging and the loss of body muscle mass and functional decline in older people. Age-related sarcopenia is mainly associated with adverse individual health outcomes [16]. Several groups working on sarcopenia defined it as low skeletal muscle mass and poor muscle strength or physical performance throughout the body or limbs [17–19]. The more adverse health factors there are, the higher the likelihood of sarcopenia. For example, decreased muscle strength leads to reduced muscle performance, which can cause impaired mobility, poor health, or higher mortality [20]. Therefore, physical inactivity is a significant factor in developing sarcopenia [21], which may be improved by improved nutritional intake [22].

Sarcopenia is a significant factor in frail patients with CKD. Their pathophysiological changes are associated with age, physical activity, malnutrition, acidosis, metabolic problems, and chronic inflammation [7]. CKD accelerates the body's protein catabolism, and sarcopenia can impact body functions when insufficient protein intake [23]. Also, low serum vitamin D and parathyroid hormone concentrations can accentuate sarcopenia in hemodialysis patients [24]. While sarcopenia is preventable and reversible, timely intervention is crucial to improve muscle mass and strength [22].

2. Materials and Methods

Study Design and Samples: This prospective cross-sectional study used convenience sampling to recruit participants between August 2021 and February 2022 from a regional hospital affiliated with a hemodialysis center in Southern Taiwan. The hospital had 375 beds, of which 21 were allocated for hemodialysis patients, and operated three daily shifts to service about 117 CKD patients requiring

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hemodialysis. The inclusion criteria for participants were i) diagnosis of end-stage renal disease; ii) clear consciousness; iii) ability to communicate; and iv) willingness to participate in the study by signing a consent form. Individuals with cognitive impairment, severely weakened states, or critically ill were excluded. The sample size was calculated using G* Power (version 3.1.9.7). A power of 0.8, an alpha of 0.05, and an effect size of 0.3 were used to calculate the sample size. The expected minimum sample size was 71.

Instruments: The study explored the relationship between participants' characteristics, habits, and health information. The participant characteristics included age, sex, education level, marital status, number of children, living status, number of hospitalizations, falls in the past year, duration of hemodialysis, frequency of hemodialysis per week, and body weight and height. Health information and personal habits were comorbidities, medications, smoking, chewing betel nuts, alcohol consumption, and self-perceived sleep quality. Personal habits were identified through a literature review.

Studies have provided evidence for the relationship between muscle mass and strength and the occurrence of sarcopenia [25]. In this study, participants' muscle mass and strength were assessed through i) non-dialysis side hand grip strength, measured twice with a one-minute interval using an electronic grip (TTM-YD, Tokyo, Japan). Maximum grip strength values of less than 28 kg for males and less than 18 kg for females were considered indicative of sarcopenia by criteria of the Asian Workshop on Sarcopenia in Older People [18]. Ii) calf circumference, measured at the fullest part of the calf while the participant was sitting on a chair with both feet on the ground. Calf circumference of less than 34 cm for males and less than 33 cm for females was considered indicative of sarcopenia by the criteria proposed by Shiota et al. [26]; iii) body mass index (BMI), calculated as body weight (in kg) divided by height (in m2).

The SARC-F, a rapid screening tool designed to measure muscle strength through daily activities [27], assessed sarcopenia. Each subscale was scored from 0 to 2, with a higher score indicating worse physical function. A total SARC-F score greater than 4 predicted sarcopenia or poor health outcomes. The sensitivity of the SARC-F scale for identifying sarcopenia was 42.9%, and the specificity was 70.8%. The SARC-F has demonstrated internal consistency and validity in detecting sarcopenia [28].

CFS, developed by Rockwood et al. [29], was used to evaluate the frailty of hemodialysis patients. CFS consists of nine levels, ranging from very healthy to terminally ill, and it is accompanied by pictures and text descriptions for rapid and accurate assessment. The CFS was scored from 9 to 1, with a higher score indicating better physical health. The scale is sensitive and specific for identifying the degree of frailty, with reported sensitivity and specificity values of 94.1% and 85.2%, respectively [30,31]. The CFS has also been correlated with mortality, comorbidity, length of hospitalization, falls, cognition, and physical functioning and has demonstrated a high predictive value for health outcomes in hospitalized patients [20].

Data collection and analysis: Basic health information and the consent form were obtained before the commencement of hemodialysis, and further information was collected during the process with no delay in the participants' hemodialysis. Data were obtained through face-to-face structured interviews, considering the participants' hemodialysis needs from August 2021 to February 2022.

The data were analyzed with SPSS version 28 for Windows (IBM Corp., Armonk, NY, USA). A statistically significant P value was considered <.05. Descriptive statistics, including means, standard deviations, frequency distributions, and proportions, were used to summarize variables. Pearson's correlation coefficient was calculated to determine the associations between variables, such as demographics between sarcopenia and healthy population, sarcopenia, and frailty. Linear and logistic regression analyses were used to investigate potential predictors of sarcopenia.

Ethical considerations: The National Science and Technology Council supported this study for Taiwanese undergraduate students' research program (110-2813-C-255-016-B). The institutional review board (202101081B0) approved the study, and informed consent was obtained from all participants. This study was conducted in accordance with the principles of the Declaration of Helsinki.

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3. Results

Participant characteristics and health information. Ninety-six hemodialysis patients participated in this study. This sample represented 82% of the population in the dialysis center. Reasons for non-participation included concerns about privacy, interference with the hemodialysis process, patient exhaustion, impaired awareness, dementia, and nonverbal condition (with tracheostomy). Table 1 provides participants' health information.

Table 1. Demographic Characteristics (n=96).

	Mean (SD)/n (%)		Mean (SD)/n (%)
Age	65.38 (SD11.52)	**Month of dialysis**	95.02(SD77.54)
Gender		**No. of dialysis per week**	
Men	52 (54.2%)	2 times	3(3.1%)
Women	44 (45.8%)	3 times	93(96.9%)
Educational level		**No. of hospitalized**	
Illiterate	12 (12.5%)	Never	60 (62.5%)
Primary school	27 (28.1%)	Once	29 (30.2%)
Middle/high school	40 (41.6%)	Two times	4 (4.2%)
College and above	17(17.7%)	Three times and above	3 (3.1%)
Marital status			
Married	66 (68.8%)		
Single/divorced/ Widowed	30 (31.2%)		
No. of children		**Hand grip strength**	13.88 (SD8.61)
No	21 (21.9%)	Left calf circumference	32.90(SD4.58)
1–2	37(38.5%)	Right calf circumference	33.57(SD5.25)
3–4	34(35.4%)	Waist circumference	91.46 (SD13.77)
≥5	4(4.2%)		
Body height	160.83 (SD8.51)	**BMI**	24.85(SD5.15)
Body weight			
Before dialysis	64.69 (SD17.27)		
After dialysis	62.25(SD16.82)		
No. of Chronic disease		**No. of cigarettes per day**	
1	11 (11.5%)	0–3	89 (92.7%)
2	31 (32.3%)	5–10	5 (5.2%)
3	32 (33.3%)	16 and above	2 (2%)
4	19 (19.8%)	**Betel nut per day**	
5	2 (2.1%)	Never	95 (99%)
6	1 (1%)	Yes	1 (1%)
Sleep Quality		**Alcohol consumption**	

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Very dissatisfied	5(5.2%)	Never	73(76%)
Dissatisfied	18(18.8%)	Quitted	22(23%)
Neutral	35(36.5%)	Still drink	1(1%)
Satisfied	21(21.9%)		
Very satisfied	17(17.7%)		
Comorbidities			
Hypertension	70 (72.9%)	Hematology	5 (5.2%)
Diabetes Mellitus	38 (39.6%)	Skin	1 (1%)
Cardiovascular system	34 (35.4%)	Gastrointestinal system	2 (2.1%)
Respiratory system	5 (5.2%)	Endocrine System	2 (2.1%)
Cancer	9 (9.4%)	Urinary system	30 (31.3%)
Stroke	5 (5.2%)		

SD: standard deviation; BMI: body mass index; n: count.

Differences in demographic characteristics between patients with sarcopenia and healthy population. Table 2 presents the differences in demographic characteristics between sarcopenia patients and the healthy population. Age (t= −5.41, p <.001)), illiteracy (t= 9.50, p=.02), married (t= 6.07, p=.01), no children (t= 8.33, p=.04), body height (X2 =2.45, p=.02), body weight before (X2 =2.75, p=.01) and after (X2 =2.59, p=.01) dialysis, hand grip (X2 =5.82, p<.001), and left (X2 =4.02., p<.001) and right (X2 =3.52, p=.001) calf circumference were significantly different between sarcopenic patients and the healthy population. There is also a significant difference between sarcopenic patients and the healthy population in frailty (X2 =9.51, p <.001).

Table 2. The Difference in Demographic Characteristics Between Sarcopenia and A Healthy Population.

Variables		SARC_F Healthy (Total scores = 0–4) n (%)	SARC_F Sarcopenia (Total scores > 4) n (%)	*t* / *X*²	*p*
Age (years)	M (SD)	61.33 (10.77)	73.09 (8.71)	−5.410***	<0.001
Gender					
Men		38 (60.3)	14 (42.4)	2.793	0.095
Women		25 (39.7)	19 (57.6)		
Educational level					
Illiterate		7 (11.1)	5 (15.2)	9.502*	0.023
Primary school		12 (19.0)	15 (45.5)		
Middle/high school		32 (50.8)	8 (24.2)		
College and above		12 (19.0)	5 (15.2)		
Marital status					
Married		38 (60.3)	28 (84.8)	6.066*	0.014
Single/divorced/ Widowed		25 (39.7)	5 (15.2)		
No. of children					
No		19 (30.2)	2 (6.1)	8.326*	0.040
1–2 kids		20 (31.7)	17 (51.5)		
3–4 kids		21 (33.3)	13 (39.4)		

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≥5 kids		3 (4.8)	1 (3.0)		
Numbers of Chronic disease	M (SD)	2.62 (1.05)	2.91 (1.01)	−1.298	0.197
Months of dialysis	M (SD)	95.86 (80.59)	93.42 (72.55)	0.145	0.885
Times of dialysis per week					
2 times		2 (3.2)	1 (3.0)	0.001	0.969
3 times		61 (96.8)	32 (97.0)		
Hospitalized					
Never		40 (63.5)	20 (60.6)	0.077	0.781
Yes		23 (36.5)	13 (39.4)		
Times of hospitalized	M (SD)	0.41 (0.61)	0.61 (0.90)	−1.108	0.273
Fall					
Never		50 (79.4)	22 (66.7)	1.862	0.172
Yes		13 (20.6)	11 (33.3)		
Times of fall	M (SD)	0.35 (0.81)	0.61 (1.09)	−1.311	0.193
Times of surgery					
1 time		10 (15.9)	2 (6.1)	3.902	0.142
2 times		10 (15.9)	10 (30.3)		
> 2 times		43 (68.3)	21 (63.6)		
Number of cigarettes per day	M (SD)	9.86 (6.26)	10.00	−0.021	0.984
Betel nut per day					
Never		50 (79.4)	29 (87.9)	3.831	0.147
Quitted		13 (20.6)	3 (9.1)		
Yes		0 (0.0)	1 (3.0)		
Alcohol consumption					
Never		46 (73.0)	27 (81.8)	3.453	0.178
Quitted		17 (27.0)	5 (15.2)		
Still drink		0 (0.0)	1 (3.0)		
Sleep Quality					
Very dissatisfied		2 (3.2)	3 (9.1)	5.776	0.216
Dissatisfied		9 (14.3)	9 (27.3)		
Neutral		23 (36.5)	12 (36.4)		
Satisfied		17 (27.0)	4 (12.1)		
Very satisfied		12 (19.0)	5 (15.2)		
Body height (cm)	M (SD)	162.33 (8.63)	157.97 (7.61)	2.449*	0.016
Body weight (kg)					
Before dialysis	M (SD)	67.47 (19.89)	59.39 (8.67)	2.762**	0.007
After dialysis	M (SD)	64.80 (19.41)	57.39 (8.53)	2.591*	0.011
BMI (kg/m^2)	M (SD)	25.35 (5.76)	23.88 (3.62)	1.332	0.186
Hand grip strength (kg)	M (SD)	16.79 (8.50)	8.33 (5.65)	5.823***	<0.001
Left calf circumference (cm)	M (SD)	34.13 (4.64)	29.58 (6.32)	4.018***	<0.001

Right calf circumference (cm)	M (SD)	34.59 (5.65)	29.50 (8.45)	3.516**	0.001
Waist circumference (cm)	M (SD)	92.51 (15.20)	89.47 (10.47)	1.027	0.307
Hematocrit (%)	M (SD)	32.31 (4.29)	33.12 (4.18)	−0.886	0.378
Albumin (g/dL)	M (SD)	4.07 (0.29)	4.73 (5.07)	−0.744	0.462
Cholesterol (mg/dL)	M (SD)	153.52 (33.15)	157.48 (38.93)	−0.523	0.602
Triglycerides (mg/dL)	M (SD)	137.03 (89.71)	135.79 (68.81)	0.070	0.945
Blood Urea Nitrogen (mg/dL)	M (SD)	74.93 (17.13)	68.67 (22.61)	1.520	0.132
Creatinine (mg/dL)	M (SD)	11.73 (13.22)	8.65 (1.81)	1.328	0.187
The clinical frailty scale (scores)	M (SD)	6.86 (0.47)	5.09 (1.01)	9.509***	<0.001

t: *t* test; X^2: chi-square test; * $p<0.05$; ** $p<0.01$; *** $p<0.001$; M (SD): mean (standard deviation); BMI: body mass index.

Correlation between sarcopenia and frailty. A higher frailty score and a lower sarcopenia score indicate a person with good health status. We found a strong negative correlation (r= −.853, p<.001) between sarcopenia and frailty, indicating that sarcopenia and frailty have a strong mutual influence. A moderate correlation between sarcopenia and frailty in sarcopenia patients (r= −.66, p<.001) and healthy populations also was found (r= −.58, p<.001) (Table 3).

Table 3. Correlation Analysis Between Sarcopenia and Frailty.

Sarcopenia	Frailty	
	r	*p*
SARC-F	**−0.853*** **	**<0.001**
Muscle strength	−0.582***	<0.001
Walking	−0.693***	<0.001
Lifting chairs	−0.620***	<0.001
Climbing stairs	−0.668 ***	<0.001
Falling	−0.229*	0.025
SARC-F = 0–4	**−0.578*** **	**<0.001**
Muscle strength	−0.233	0.066
Walking	−0.296*	0.019
Lifting chairs	−0.133	0.300
Climbing stairs	−0.343**	0.006
Falling	−0.197	0.122
SARC-F > 4	**−0.664*** **	**<0.001**
Muscle strength	−0.246	0.168
Walking	−0.483**	0.004

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Lifting chairs	−0.454**	0.008
Climbing stairs	−0.303	0.087
Falling	−0.060	0.740

r: Pearson Product Moment Correlation Coefficient; * *p*<0.05; ** *p*<0.01; *** *p*<0.001; SARC-F> 4: sarcopenia; SARC-F=0–4: healthy population.

Logistic regression analysis of the risk of sarcopenia. Age and hand grip strength predict the risk of sarcopenia. The findings in Table 4 indicate that an increase of one year in age significantly increases the risk of sarcopenia (OR 1.163, 95% CI=1.049, 1.288; p=.04). Each kilogram of hand grip strength affects the probability of having sarcopenia by 89.7% (OR 0.897, 95% CI=.807, .998; p=.046).

Table 4. Logistic Regression Analysis of the Risk of Sarcopenia (n 96).

Variables	SARC-F		
	OR	95% CI	*p*
Age (years)	1.163**	(1.049, 1.288)	0.004
Educational level [a]			
Primary school	3.067	(0.531, 17.728)	0.211
Middle/high school	2.008	(0.257, 15.663)	0.506
College and above	2.797	(0.229, 34.230)	0.421
Marital status (Single/divorced/ Widowed) [b]	0.141	(0.014, 1.382)	0.093
No. of children [c]			
1–2 kids	0.621	(0.036, 10.625)	0.742
3–4 kids	0.297	(0.013, 6.806)	0.447
≥ 5 kids	0.084	(0.001, 10.485)	0.315
Body height (cm)	0.953	(0.867, 1.048)	0.323
Body weight before dialysis (kg)	1.085	(0.996, 1.182)	0.063
Hand grip strength (kg)	0.897*	(0.807, 0.998)	0.046
Left calf circumference (cm)	0.905	(0.681, 1.204)	0.494
Right calf circumference (cm)	0.921	(0.721, 1.175)	0.507

The effect value of the overall model: Cox & Snell=0.420, Nagelkerke=0.580; [a]: 3 variables of educational level compared with "Illiterate", respectively; [b]: Marital status (Single/divorced/ Widowed) compared with "Married"; [c]: 3 variables of numbers of children compared with "no kids", respectively; * *p*<0.05; ** *p*<0.01.

Predictors of sarcopenia and frailty in hemodialysis patients. Differences between sarcopenia and frailty in hemodialysis patients reached statistical significance in age, body weight before hemodialysis, and left calf circumference. Increased age resulted in an increased chance of the hemodialysis patients developing sarcopenia (ß=.096, p < .001) and a decreased possibility of developing frailty (ß=.049, p < .001). Increased body weight before dialysis indicated a high risk of sarcopenia in the SARC-F measure (ß=.083, p < .001) and a low risk of frailty in CFS (ß= −.032, p < .001). Furthermore, every kilogram in hand grip strength reduced the SARC-F score (ß= −.075, p = .012) and increased the CFS score (ß=.047, p < .001). This result identified hand grip strength as a potential predictor of sarcopenia and frailty. However, increased left calf circumference resulted in a lower SARC-F score (sarcopenia) (ß= −.128, p = .049) but an insignificant change in CFS score (frailty) (ß= .027, p = .332). These findings suggest that age, body weight before dialysis, hand grip strength, and calf circumference are essential factors in sarcopenia and frailty of hemodialysis patients (Table 5).

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Table 5. Linear Regression Analysis of the Risk of Sarcopenia and Frailty.

	SARC-F			CFS		
Variables	**β**	**95% CI**	***p***	**β**	**95% CI**	***p***
Age (years)	0.096***	(0.047, 0.144)	<0.001	−0.049***	(−0.070, −0.028)	<0.001
Educational level [a]						
Primary school	0.321	(−0.965, 1.606)	0.621	0.054	(−0.505, 0.613)	0.849
Middle/high school	−0.433	(−1.823, 0.957)	0.537	0.000	(−0.605, 0.605)	0.999
College and above	−0.730	(−2.337, 0.876)	0.368	−0.204	(−0.903, 0.494)	0.562
Marital status (Single/divorced/ Widowed) [b]	−0.937	(−2.202, 0.329)	0.145	0.204	(−0.346, 0.754)	0.463
No. of children [c]						
1–2 kids	−1.332	(−2.866, 0.201)	0.088	0.260	(−0.407, 0.927)	0.440
3–4 kids	−1.811*	(−3.468, −0.155)	0.032	0.127	(−0.593, 0.848)	0.726
≥ 5 kids	−1.903	(−4.298, 0.492)	0.118	0.492	(−0.550, 1.534)	0.350
Body height (cm)	−0.033	(−0.094, 0.027)	0.278	0.010	(−0.016, 0.037)	0.448
Body weight before dialysis (kg)	0.083***	(0.045, 0.121)	<0.001	−0.032*	(−0.049, −0.016)	<0.001
Hand grip strength (kg)	−0.075*	(−0.133, −0.017)	0.012	0.047*	(0.021, 0.072)	<0.001
Left calf circumference (cm)	−0.128*	(−0.256, 0.000)	0.049	0.027	(−0.028, 0.083)	0.332
Right calf circumference (cm)	−0.063	(−0.157, 0.032)	0.190	0.025	(−0.016, 0.066)	0.232
Adjusted R-squared=0.440				Adjusted R-squared=0.474		

a: 3 variables of educational level compared with "Illiterate", respectively; b: Marital status (Single/divorced/ Widowed) compared with "Married"; c: 3 variables of numbers of children compared with "no kids", respectively; * *p*<0.05; ** *p*<0.01; *** *p*<0.001.

4. Discussion

About one-third of hemodialysis patients were found to have sarcopenia and were a mean age of ten years older than the healthy population. Differences in hand grip strength and calf circumferences were statistically significant between those with vs. without sarcopenia. These results

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are consistent with the results of previous research on the relationship between aging and muscle loss [32] and an increased risk of sarcopenia, as highlighted in previous studies by Ferrucci and Fabbri [7] and Rosenberg [15]. In addition, the occurrence of sarcopenia may be tracked back to the pathophysiology of chronic diseases. However, limited literature exists on the relationship between demographics, future studies should investigate these factors to understand the risk factors for sarcopenia better.

As determined from current research, sarcopenia is strongly associated with frailty, whether with or without sarcopenia. The results revealed that age is essential in developing sarcopenia and frailty, with senior individuals experiencing more significant physical weakness [33]. However, participants were predominantly senior citizens. Therefore, it is unclear whether their sarcopenia and frailty are caused by age or their underlying CKD. Moreover, hand grip strength and left calf circumference can be predictors of sarcopenia, which can infer frailty among hemodialysis subjects. Knowing if the independent variable is sarcopenia or frailty would be valuable in managing the influences of these two conditions. Age, muscle mass, muscle strength, and several chronic diseases can be seen as a loop reaction between sarcopenia and frailty, which should be explored further.

This study revealed that hand grip strength could identify sarcopenia and frailty, and several studies support it. Escriche-Escuder et al. [25] found a positive correlation between muscle mass in the lower limbs and muscle strength and a negative correlation with the risk of falling [34]. Ito et al. [35] documented that skeletal muscle mass is associated with bone mineral density in CKD dialysis patients' spinal cord and femoral head. While muscle mass is essential, Marini et al. [28] emphasized that muscle strength, determined by walking, lifting chairs, climbing stairs, and falling (SARC-F), may provide more helpful information than muscle mass alone. These studies demonstrate that pathophysiological changes in CKD hemodialysis patients can decrease muscle mass and strength, significantly diminishing health and quality of life.

This study found no correlation between the length of hemodialysis and the incidence of sarcopenia, consistent with a recent study by Shu et al. [36]. However, an older study by Takamoto et al. [37] reported that longer hemodialysis duration was associated with a higher incidence of sarcopenia. The discrepancy between these findings may be attributed to differences in the hemodialysis duration among participants. Nevertheless, our study highlights the importance of maintaining the quality of hemodialysis to prevent sarcopenia and improve the overall health of hemodialysis patients.

Most hemodialysis people suffer from chronic diseases, often with two to four conditions overlapping, including high blood pressure, diabetes, and cardiovascular health problems. These three health problems also affect each other's health status, leading to the possibility of reducing skeletal muscle mass. Insulin resistance and poor glycemic control can minimize skeletal muscle mass and strength due to lipotoxicity, as demonstrated by Meex et al. [38] and Joo et al. [39]. Furthermore, smoking is associated with insulin resistance, indirectly affecting muscle mass and strength. Our study highlights the importance of managing chronic diseases and avoiding unhealthy lifestyle factors such as smoking to prevent sarcopenia and maintain muscle mass and strength in hemodialysis patients.

Study Limitations and Recommendations for further study. Limitations of this study should be considered when interpreting the results and future research directions. Firstly, the study design was cross-sectional, which may limit the ability to establish causality between sarcopenia, frailty, and hemodialysis. A longitudinal study design would provide a more comprehensive understanding of the development of sarcopenia and frailty among hemodialysis patients and facilitate the implementation of preventive measures. Secondly, the study sample was taken from a single organization only, which may limit the generalizability of the findings. A more extensive and diverse selection from multiple organizations would enhance the external validity of the results. Future studies may explore additional factors that contribute to the health outcomes of hemodialysis patients.

5. Conclusions

This study highlights the interrelationships between demographic and health-related factors and their impact on muscle mass and strength (sarcopenia) and frailty among hemodialysis people. Age and chronic diseases are the common factors influencing the incidence of sarcopenia and frailty. While age is an organic variable that cannot be controlled, chronic diseases can be prevented by adopting a healthy lifestyle and eating habits. Thus, the study recommends that health policies focus on health promotion and disease prevention to reduce the incidence of chronic diseases and comorbidities among hemodialysis people. Future research should explore the impact of chronic diseases and other factors, such as medication use, on the development of sarcopenia and frailty in this population. Additionally, an effective and comprehensive screening tool should be developed to assess frailty among the hemodialysis population, which can help in early detection and intervention to improve the quality of life.

Author Contributions: **S-F Liu** designed and organized the original study, data collection and analysis, and the study grant holder. **C-C Lin** was **S-F Liu**'s study supervisor. **C-C Lin** worked with **S-F Liu** from the beginning of the study to design and organize the original study and data analysis and drafted the initial manuscript. **S-L Hwang** did the data analysis with the SPSS and provided recommendations for the data analysis process. **C-Y Han** contributed to the process of data collection and the final draft. **Y-L Huang** conducted quantitative data analysis and interpretation and proofreading. **L-C Chen** assisted in organizing the study site and approaching participants in the data collection process**.** All authors reviewed the manuscript.

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Data Availability Statement: The data presented in this study are available from the corresponding author upon reasonable request.

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