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Prevalence and Multidimensional Risk Factors of Physical Frailty in Korean Community-Dwelling Older Adults: Findings from Korean Frailty and Aging Cohort Study

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Abstract: Frailty is defined as a state of increased vulnerability to stressors, and it predicts the disability and mortality in the older population. This study aimed to investigate standardized prevalence and multidimensional risk factors associated with frailty among the Korean community-dwelling older adults. We analyzed the baseline data of 2,907 adults aged 70–84 years (mean age 75.8±3.9 years, 57.8% women) in the Korean Frailty and Aging Cohort Study. The Fried frailty phenotype was used to define frailty. Analyzed data included sociodemographic, physical, physical function, biological, lifestyle, health condition, medical condition, psychological, and social domains. Data were standardized using the national standard population composition ratio based on the Korean Population and Housing Census. The standardized prevalence of frailty and pre-frailty was 7.9% (95% confidence interval [CI] 6.8–8.9%) and 57.2% (95% CI 45.1–48.8%), respectively. The following 14 risk factors had a significant association with frailty: at risk of malnutrition, sarcopenia, severe mobility limitation, poor social capital, rural dwellers, depressive, poor self-perceived health, polypharmacy, elevated high-sensitivity C-reactive protein, elevated glycosylated hemoglobin, low 25-hydroxy vitamin D level, longer timed up and go, and low short physical performance battery score ($p<0.05$). Physico-nutritional, psychological, sociodemographic, and medical factors are strongly associated with frailty.

Keywords: community-dwelling older adults; physical frailty; prevalence; risk factors

1. Introduction

Frailty is characterized by a significant decline in the functional reserve capacity of multiple organ systems with an increased vulnerability to stressors, leading to a higher risk of adverse health outcomes such as falls, disability, hospitalization, and mortality in older adults [1, 2]. In a systematic review, the prevalence of frailty in community-dwelling older adults aged ≥65 years was found to vary from 4.0 to 59.1% [3]. This wide range in prevalence among the studies is owing to the different definitions of frailty. Identifying frailty is important for individual health as well as from a social and public health perspective. Various frailty criteria, such as the Fried frailty phenotype (FFP) and frailty index (FI), have been used in large research studies [3, 4]. The most widely used frailty criterion was proposed by Fried, which has five components [1]. FFP has been adapted and modified according to the study design, settings, participants, and methodology.

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There is a rapid increase in the number of older adults aged ≥65 years globally [5]. According to Statistics Korea, the prevalence of older adults aged ≥65 years in Korea was 14.3% in 2018 and is expected to double by 2028 [6]. Recently, the Korean Longitudinal Study on Health and Aging Study performed in hospital-based populations residing in the city of Seongnam in Korea, reported that the prevalence of frailty and pre-frailty was 13.2% and 59.4%, respectively [7]. The aging study of Pyeongchang Rural Area in older adults of Pyeongchang reported the prevalence of frailty and pre-frailty as 17.4% and 52.6%, respectively [8]. They identified instrumental activities of daily living (IADL) and activities of daily living (ADL) disability, depression symptoms, dysmobility, malnutrition, incontinence, and medical aid as risk factors for frailty. However, these studies were restricted to a selected residential area in Korea, and do not represent the community-dwelling older adults.

Several risk factors for frailty have been identified. Previous studies have focused on sociodemographic factors such as age, sex, marital status, education level, and physical factors such as body composition and physical function [9-11]. However, more recent studies have identified a wider range of risk and protective factors, including biological, lifestyle, and psychological factors [12]. Since frailty is complex and has multiple domains, comprehensive risk factors must be investigated. It is necessary to find the influential risk factors comprehensively to prioritize targets.

This study aimed to investigate the age-, sex-, and residence- adjusted prevalence and characteristics of physical frailty in the Korean Frailty and Aging Cohort Study (KFACS). We also identified the risk factors with a significant association with physical frailty using multidimensional domains in the Korean community-dwelling older adults.

2. Materials and Methods

2.1 Study population

The KFACS is a nation-wide, longitudinal study, with the baseline survey conducted in 2016–2017 [13]. The KFACS recruited participants using quota sampling methods stratified by sex (male and female in a ratio of 1:1) and age (70–74, 75–79, and 80–84 years in a ratio of 6:5:4, respectively). The participants were recruited from among community-dwelling residents in urban and rural areas in 10 study centers covering different residential locations (urban, suburban and rural): three from Seoul Metropolitan Area, two from Gyeonggi Province and one from each of Gangwon Province, Chungcheong-buk Province, Jeolla-nam Province, Gyeongsang-nam Province and Jeju Island in South Korea. Of the 3,014 participants who were enrolled at 10 centers at baseline, 2,907 participants completed the assessment of 5 components of FFP and were selected for the final analysis, after excluding 109 with missing frailty assessment components. KFACS protocol was approved by the by the Clinical Research Ethics Committee of Kyung Hee University Hospital (IRB number: 2015-12-103). All participants were given prior explanations and signed consent forms. This study had an IRB approval from the Clinical Research Ethics Committee of Kyung Hee University Hospital (IRB number: 2020-06-062).

2.2 Frailty Assessment

Physical frailty was defined using FFP based on weight loss, weakness, slowness, exhaustion, and low physical activity with modified cutoff points [1, 13]. Physical frailty scores range from 0 to 5. Participants with scores ≥3, 1–2, and 0 were classified as frail, pre-frail, and robust, respectively.

2.3 Measurements

We obtained information on sociodemographic (age, sex, education level, living status, marital status, residential area, social security benefits, and occupation), lifestyle (smoking status, alcohol

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consumption, and sleep habits), self-perceived health status, history of fall and hospitalization in the past year, current use of prescription medications, oral health, and self-reported history of medical conditions based on Charlson's classification [14].

Underweight was defined as a body mass index (BMI) of <18.5 kg/m2. Appendicular skeletal muscle (ASM) was measured using dual-energy X-ray absorptiometry (DXA) (Lunar, GE Healthcare, Madison, WI, USA and Hologic DXA, Hologic Inc., Bedford MA, USA) or bioelectrical impedance analysis (InBody 72, InBody Co., Ltd., Seoul, Korea, and X-SCAN PLUS II, Jawon Medical Inc., Seoul, Korea). Low ASM mass was defined as the lowest 20% of the KFACS participants. Sarcopenia was defined according to the consensus report of the Asian Working Group for sarcopenia based on low muscle strength, low muscle mass, and/or low physical performance [15]. Low calf circumference was defined as <32 cm [16]. High waist circumference was defined as ≥102 cm for men and ≥88 cm for women [17].

Severe mobility limitation was defined if the patient found it "very difficult" or "impossible" to either walk about 400 meters or climb 10 steps without resting [18]. The disability of ADL was defined as answering at least one dependency in 7 domains (bathing, continence, dressing, eating, transfer, and washing face and hands). Disability of IADL was defined as answering two or more dependencies in 10 domains (food preparation, household chores, going out for a short distance, grooming, handling finances, laundry, taking personal medication, shopping, using public transportation, and using the telephone) [19]. Physical function assessed included timed up and go (TUG) [20], usual gait speed, grip strength [21], and short physical performance battery (SPPB) [22]. Nutritional status was assessed using the Korean version of the Mini-nutritional Assessment Short Form (MNA-SF) [23]. The risk of malnutrition was defined as an MNA-SF score of ≤11 [24].

Comorbidity was determined as ≥2 of the following chronic diseases: hypertension, diabetes, myocardial infarction, peripheral vascular disease, angina, cerebrovascular disease, congestive heart failure, dyslipidemia, rheumatoid arthritis, osteoarthritis, osteoporosis, asthma, or chronic obstructive pulmonary disease [14]. Polypharmacy was defined as taking ≥5 medications [25]. Hearing impairment was defined as the minimum pure-tone average value of >40 dB [26]. Visual impairment was defined as the maximum visual acuity of <0.3 [27]. Blood samples were tested at 8 am after fasting for 8 hours.

A participant was determined to depressive if she/he had a score of ≥6 on the Korean version of the Short Form Geriatric Depression Scale (SGDS-K) [28]. Global cognitive dysfunction was diagnosed if the Korean version of the Mini-Mental State Examination (MMSE-KC) score was <24 [29]. Cognitive impairment was defined as a score of 1.5 standard deviations below the score of the age, sex, and education–matched controls on the cognitive function tests: processing speed (trail making test A), executive function (Frontal Assessment Battery), verbal episodic memory (word list recall test), and working memory (digit span backward) [30]. Quality of life was determined using the EuroQol 5-dimension scale (EQ-5D) [31], EuroQol Visual Analogue Scale (EQ-VAS) [32], and 12-items Short Form Health Survey (SF-12) [33]. SF-12 was used to measure physical and mental health summary [34].

Poor social capital was defined by the lack of participation in social gatherings. Social support was assessed using the Enhancing Recovery in Coronary Artery Disease Social Support Instrument [35, 36]. The social network was assessed using the Practitioner Assessment of Network Type Instrument [37]. Interaction with family, friends, and neighbors was dichotomized as high (every day, 2–3/week, or ≥1/week) and low (≤1/month).

2.4 Statistical Analysis

We developed the age-, sex-, and residence-standardized prevalence. The KFACS population is of nation-wide community-dwelling older adults, but the quota sampling stratified by age and sex

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can limit generalization of prevalence rate. To ensure generalization, we performed post-stratification adjusting by using general population distribution data from the Korean Population and Housing Census conducted by Statistics Korea in 2017. We computed the post-stratification adjustments by calibrating the distribution of age (3 groups: 70–74, 75–79, and 80–84 years), sex (2 groups: male and female), and residence (2 groups: urban and rural) in the general population. We calculated mean with standard errors (SE) for continuous variables and frequencies with percentage and 95% confidence intervals (CIs) for categorical variables to investigate the prevalence and characteristics of frailty. We used analysis of variance tests for continuous variables and the Chi-square test for categorical variables.

In the unweighted sample, we performed multiple forward stepwise logistic regression analyses to identify the most influential risk factors for frailty. First, we identified the risk factors in each of the 9 domains. Then, we identified the risk factors with the strongest association with frailty using the variables selected in the 9 domains. We performed statistical analyses using SPSS version 25.0 (SPSS Inc., Chicago, IL, USA) and SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). We determined statistical significance by using a two-sided p value of <0.05.

3. Results

3.1. Sociodemographic characteristics of the study population

Sociodemographic characteristics of the unstandardized and standardized samples are shown in Table 1. The mean age was 75.8 years, and the majority of the participants were aged between 70–74 years in both the unweighted (39.7%) and weighted (41.8%) sample populations. There was a significant difference in the regional proportions between men and women in the unweighted sample ($p = 0.035$), but not in the weighted sample ($p = 0.72$).

3.2 Prevalance of frailty

In the standardized sample, the prevalence of frailty and pre-frailty was 7.9% (95% CI 6.8–8.9%) and 45.2% (95% CI 45.1–48.8%), respectively. Among the individual frailty components, the prevalence was highest for exhaustion (32.5%), followed by slowness (20.1%) and weakness (19.7%). There was a higher prevalence of exhaustion (40.8% vs. 21.0%) and weakness (21.0% vs. 18.0%) among women compared to men, respectively. However, there was no significant difference in low physical activity, slowness, and unintentional weight loss between women and men. Overall, 54.8% of participants had ≥1 frailty component (Table 2). The prevalence of frailty increased significantly in the 80–84 compared to 70–74 years (16.1% vs. 2.7%) (Figure 1). The prevalence of frailty was significantly higher in women than men in the unstandardized (8.5% and 7.1%) and standardized samples (9.2% and 6.0%) (Table 2 and Table S1). The prevalence of frailty was significantly higher in rural compared to cities in the unstandardized (12.0% and 6.2%) and standardized samples (12.7% and 6.0%) (Data not shown).

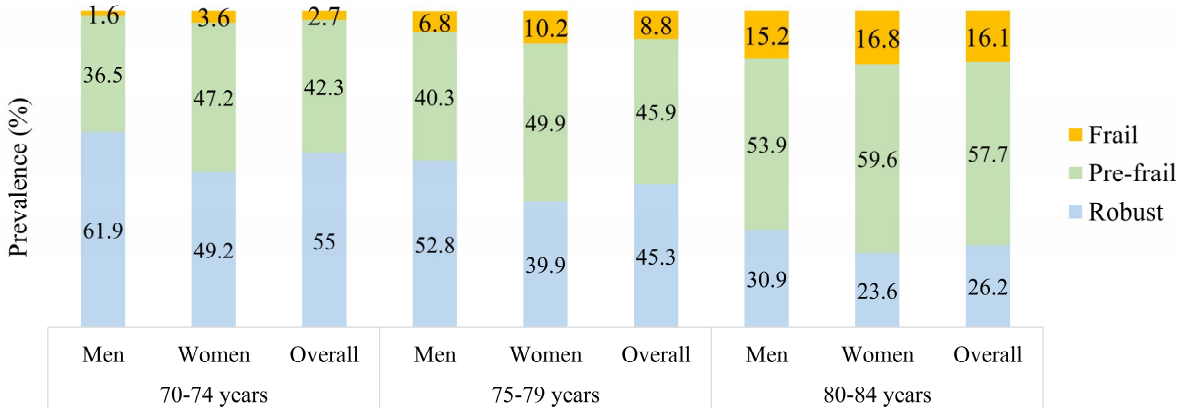

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Figure 1. Prevalence of frailty with age groups (standardized sample)

3.3 Characteristics of the study population across frailty status

The characteristics across frailty status in standardized sample are presented in Table 3. There were significant differences in sociodemographic (p <0.05), physical (p <0.05), physical function (p <0.001), health condition (p <0.05), and psychological (p <0.001) domains between the three groups. Biological domains, except serum creatinine, cortisol, vitamin B12, thyroid-stimulating hormone (TSH), and low-density lipoprotein (LDL) cholesterol were significantly different between the three groups (all, p <0.05). The prevalence of hypertension, diabetes, incontinence, cardiovascular disease, osteoarthritis, osteoporosis, rheumatoid arthritis, digestive system ulceration, and depressive disorder were significantly higher in the frail group (p <0.05). There was a significant difference in lifestyle domain except current smoking (p = 0.238) across frailty status. Social domain except for low interaction with neighbors (p = 0.294) and social activities (p = 0.491) was also was significantly different.

3.4 Risk factors associated with physical frailty

Table 4 shows the significant influential risk factors in a multivariate forward logistic regression analysis. Risk factors for frailty were at risk of malnutrition (odds ratio [OR] 2.51; 95% confidence interval [CI] 1.57–4.03), sarcopenia (OR 2.39, 95% CI 1.61–3.56), severe mobility limitation (OR 2.13, 95% CI 1.45–3.15), poor social capital (OR 1.99, 95% CI 1.13–3.56), rural residence (OR 1.89, 95% CI 1.13–3.18), depressive symptoms (OR 1.89, 95% CI 1.29–2.76), poor self–perceived health (OR 1.65, 95% CI 1.12–2.44), polypharmacy (OR 1.61, 95% CI 1.13–2.30), elevated high-sensitivity C-reactive protein (hs-CRP) (OR 1.29, 95% CI 1.07–1.55), elevated glycated hemoglobin (HbA1c) (OR 1.28, 95% CI 1.04–1.56), longer TUG time (OR 1.27, 95% CI 1.17–1.37), increasing age (OR 1.08, 95% CI 1.03–1.14). High 25-hydroxy vitamin D (OR 0.98, 95% CI 0.96–1.00), and high SPPB scores (OR 0.87, 95% CI 0.76–0.98) were preventable factors. Based on these results, the frequency and percentage of risk factors among frail individuals (n = 214) are shown in Figure 2. The risk factors of frailty were classified as physico-nutritional, psychological, sociodemographic, and medical domains. About one–third (27.1%) of the frail participants had all of the four risk domains. Overlapping physico-nutritional, psychological, and medical risk domains were found in 46.6% of participants. The prevalence of risk domains in frail participants was as follows: physico-nutritional (90.7%), medical (82.2%), psychological (78.0%), and sociodemographic (44.9%) (all, p <0.001) (Figure S1).

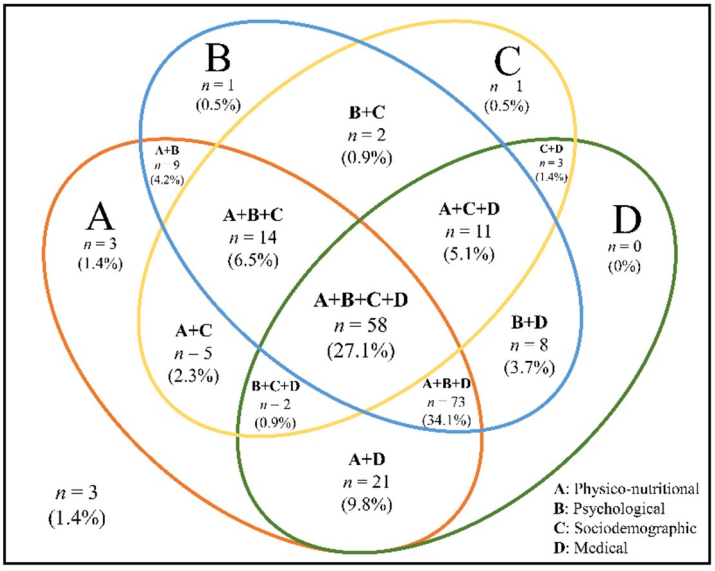

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Figure 2. Venn diagram displaying the extent of overlap of risk domains in the frail group (unstandardized sample; A total of 214 adults aged 70–84 years were frail. The physico-nutritional domain was defined as having ≥1 risk of malnutrition, sarcopenia, severe mobility limitation, longer timed up and go (>12 seconds), and low short physical performance battery (≤9 scores). The psychological domain was defined as having ≥1 depressive symptom and poor self-perceived health. The sociodemographic domain was defined as having ≥1 of rural residence and poor social capital. The medical domain was defined as having ≥1 of polypharmacy, elevated hs-CRP (≥3 mg/L), elevated HbA1c (≥6.5%), and low 25-hydroxyvitamin D (≤20 ng/mL).

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Table 1. Sociodemographic characteristics of the unstandardized and standardized study samples

	Unstandardized sample, n (%)						Standardized sample, (%)			
Variable	Overall n = 2,907		Men n = 1,383 (47.6%)		Women n = 1,524 (52.4%)	*p* Value	Overall	Men (42.2%)	Women (57.8%)	*p* Value
Age (years)										
70–74	1,154	(39.7)	505	(36.5)	649	(42.6)	41.8	45.4	39.2	
75–79	1,080	(37.2)	529	(38.3)	551	(36.2)	**<0.001**	36.1	35.8	36.3	**<0.001**
80–84	673	(23.2)	349	(25.2)	324	(21.3)		22.1	18.8	24.5	
Low education level (<7 years)	1,265	(43.5)	361	(26.1)	904	(31.1)	**<0.001**	45.5	25.5	60.5	**<0.001**
Live alone	659	(22.7)	120	(8.7)	539	(35.4)	**<0.001**	24.3	8.2	36.2	**<0.001**
Marital status (without partner)	948	(32.6)	145	(10.5)	803	(52.7)	**<0.001**	35.2	9.9	53.7	**<0.001**
Residence										
Urban	822	(28.4)	387	(28.1)	435	(28.7)		28.4	29.1	27.9	
Suburban	1,250	(43.2)	569	(41.4)	681	(45.0)	**0.035**	43.6	43.5	43.6	0.720
Rural	819	(28.3)	420	(30.5)	399	(26.3)		28.0	27.3	28.4	
Social security recipient	204	(7.0)	86	(6.2)	118	(7.8)	0.058	7.2	6.3	7.9	0.055
Current worker	758	(26.1)	425	(30.8)	333	(21.9)	**<0.001**	25.8	31.1	21.9	**<0.001**

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Table 2. Prevalence of frailty status and component (standardized sample)

	Overall		Men (42.2%)		Women (57.8%)		
Variable	%	(95% CI)	%	(95% CI)	%	(95% CI)	*p* Value
Frailty status							
Robust	45.2	(43.3–47.0)	52.8	(50.1–55.5)	39.6	(37.1–42.0)	
Pre-frail	47.0	(45.1–48.8)	41.1	(38.5–43.8)	51.3	(48.7–53.8)	**<0.001**
Frail	7.9	(6.8–8.9)	6.0	(4.9–7.2)	9.2	(7.7–10.7)	
Frailty component							
Exhaustion	32.5	(30.7–34.2)	21.1	(18.9–23.2)	40.8	(38.3–43.3)	**<0.001**
Low physical activity	10.2	(8.7–11.8)	10.7	(9.1–12.3)	10.5	(9.4–11.6)	0.695
Slowness	20.1	(18.6–21.6)	18.8	(16.8–20.8)	21.1	(19.0–23.2)	0.131
Weakness	19.7	(18.3–21.2)	18.0	(16.0–20.0)	21.0	(18.9–23.1)	**0.042**
Unintentional weight loss	4.9	(4.1–5.7)	5.2	(4.0–6.3)	4.6	(3.5–5.7)	0.527
Frailty score							
0	45.2	(43.3–47.0)	52.8	(50.1–55.5)	39.6	(37.1–42.0)	
1	32.1	(30.3–33.8)	28.8	(26.3–31.2)	34.5	(32.1–36.9)	
2	15.0	(13.6–16.3)	12.4	(10.7–14.1)	16.8	(14.9–18.7)	**<0.001**
3	5.8	(4.9–6.7)	4.5	(3.4–5.5)	6.8	(5.5–8.1)	
4	1.9	(1.4–2.4)	1.5	(1.0–2.1)	2.2	(1.4–2.9)	
5	0.1	(0.0–0.3)	0.1	(0.0–0.2)	0.2	(0.0–0.4)	

CI, confidence interval.

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Table 3. Characteristics of the standardized study sample according to frailty status

Variable	Overall	Robust (45.2%)	Pre-frail (47.0%)	Frail (7.9%)	*p* Value
Sociodemographic					
Age (years)	75.8 ± 0.07	74.9 ± 0.09	76.3 ± 0.10	78.5 ± 0.23	**<0.001**
70–74	41.8	51.0	37.7	14.5	
75–79	36.1	36.2	35.2	40.4	**<0.001**
80–84	22.1	12.8	27.1	45.2	
Female sex	57.8	50.6	63.1	67.5	**<0.001**
Low education level (< 7 years)	45.5	33.7	52.5	71.8	**<0.001**
Live alone	24.3	19.4	27.5	33.6	**<0.001**
Marital status (without partner)	35.3	29.3	39.2	46.2	**<0.001**
Residence					
Urban	28.4	34.2	25.5	13.2	
Suburban	43.6	43.9	43.6	41.7	**<0.001**
Rural	28.0	21.9	30.9	45.2	
Social security recipient	7.2	5.8	8.0	11.1	**0.017**
Current worker	25.8	26.2	26.6	17.9	**0.010**
Physical					
Underweight (BMI < 18.5 kg/m²)	1.6	1.1	1.7	4.0	**0.030**
Low appendicular skeletal muscle (lower 20%)	22.3	16.3	25.9	35.6	**<0.001**
Low calf circumference (< 32 cm)	27.6	19.5	31.9	48.1	**<0.001**
High waist circumference (M ≥ 102 cm; F ≥ 88 cm)	51.4	48.1	54.1	53.6	**0.007**
Sarcopenia (AWGS-defined)	10.1	1.1	14.6	34.5	**<0.001**
Severe mobility limitation	17.8	5.4	22.3	62.7	**<0.001**
ADL disability (> 1 point)	2.2	0.8	2.1	10.2	**<0.001**
IADL disability (> 2 points)	6.3	3.9	6.8	17.3	**<0.001**
Falls in the past year	20.6	16.0	22.3	36.6	**<0.001**
Physical function					
Timed Up and Go (seconds)	10.5 ± 0.05	9.4 ± 0.04	10.8 ± 0.1	14.9 ± 0.3	**<0.001**
Short Physical Performance Battery (score)	10.8 ± 0.03	11.4 ± 0.02	10.6 ± 0.04	8.6 ± 0.15	**<0.001**
Gait speed (m/s)	1.10 ± 0.00	1.22 ± 0.01	1.04 ± 0.00	0.76 ± 0.01	**<0.001**
Grip strength (kg)	25.7 ± 0.1	28.7 ± 0.2	24.0 ± 0.2	18.9 ± 0.4	**<0.001**
Biological					
Albumin (g/dL)	4.4 ± 0.00	4.4 ± 0.01	4.3 ± 0.01	4.3 ± 0.02	**<0.001**
Serum creatinine (mg/dL)	0.84 ± 0.01	0.83 ± 0.01	0.84 ± 0.01	0.87 ± 0.02	0.271
HbA1c (%)	6.0 ± 0.02	6.0 ± 0.02	6.0 ± 0.02	6.2 ± 0.08	**<0.001**
WBC (X1000/uL)	5.9 ± 0.03	5.7 ± 0.04	6.0 ± 0.05	6.2 ± 0.12	**<0.001**
RBC (Mil/uL)	4.4 ± 0.01	4.4 ± 0.01	4.3 ± 0.01	4.2 ± 0.03	**<0.001**

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Cortisol (ug/dL) at 8 am	10.1 ± 0.08	10.2 ± 0.10	10.1 ± 0.11	10.2 ± 0.30	0.740
hs-CRP (mg/L)	1.34 ± 0.04	1.29 ± 0.05	1.31 ± 0.05	1.85 ± 0.19	**<0.001**
Vitamin B12 (pg/mL)	610.1 ± 5.34	614.8 ± 7.77	608.3 ± 7.77	593.4 ± 22.02	0.551
TSH (ulU/mL)	2.8 ± 0.10	2.9 ± 0.20	2.6 ± 0.07	2.7 ± 0.22	0.306
Insulin (uU/mL)	8.0 ± 0.18	7.3 ± 0.20	8.3 ± 0.21	9.9 ± 1.41	**<0.001**
Triglyceride (mg/dL)	122.6 ± 1.15	120.3 ± 1.69	122.5 ± 1.60	137.1 ± 5.15	**0.001**
Total cholesterol (mg/dL)	174.6 ± 0.68	176.5 ± 1.01	173.1 ± 1.01	172.5 ± 2.26	**0.037**
HDL-cholesterol (mg/dL)	52.5 ± 0.26	53.4 ± 0.39	52.0 ± 0.38	50.5 ± 0.93	**0.003**
LDL-cholesterol (mg/dL)	108.2 ± 0.63	109.7 ± 0.95	107.1 ± 0.92	106.0 ± 2.10	0.069
25-hydroxy vitamin D (mg/mL)	23.2 ± 0.19	23.6 ± 0.28	23.2 ± 0.27	21.0 ± 0.56	**0.001**
eGFR (mL/min/1.73m^2) [a]	77.5 ± 0.27	78.9 ± 0.35	76.9 ± 0.41	73.3 ± 1.14	**<0.001**
Lifestyle					
Current smoker	5.2	4.7	5.3	7.7	0.238
Alcohol intake (≥ 2-3 time/week)	16.3	19.1	14.1	13.4	**0.001**
Sleep latency (> 1 hour)	4.3	3.1	4.9	7.0	**0.019**
Long night-time sleep (> 8 hours)	5.9	4.8	6.5	9.2	**<0.001**
Dairy products (not every day)	60.9	56.3	62.8	74.0	**<0.001**
Legumes and eggs intake (< 2 times/week)	19.7	13.8	22.8	33.5	**<0.001**
Meat, fish and poultry intake (not every day)	80.8	78.0	83.2	82.0	**0.045**
Risk of malnutrition (MNA score ≤ 11)	8.0	3.7	10.0	20.0	**<0.001**
Health condition					
Number of drugs	4.4 ± 0.06	3.9 ± 0.08	4.7 ± 0.09	5.7 ± 0.23	**<0.001**
Comorbidity (≥ 2 diseases)	55.6	48.3	61.3	63.2	**<0.001**
Polypharmacy (≥ 5 medications)	32.2	24.4	36.0	55.0	**<0.001**
Hospitalization in the past year	12.9	8.6	15.8	20.5	**<0.001**
Hearing impairment	15.3	13.9	15.7	21.2	**0.033**
Visual impairment	2.6	1.4	3.4	4.4	**0.002**
Low chewing ability	46.7	39.1	48.8	64.0	**<0.001**
Low pronouncing ability	25.0	18.9	27.4	45.5	**<0.001**
Medical condition					
Hypertension	58.4	54.0	61.4	66.2	**<0.001**
Diabetes	21.9	18.3	23.9	31.3	**<0.001**
Urinary incontinence	4.1	2.2	5.0	10.4	**<0.001**
Cardiovascular disease [b]	13.3	11.2	14.4	18.6	**0.004**
Dyslipidemia	33.6	34.2	33.7	29.1	0.326
Osteoarthritis	26.7	20.1	31.6	34.8	**<0.001**
Osteoporosis	17.5	13.2	20.6	23.4	**<0.001**
Rheumatoid arthritis	2.2	1.0	3.0	4.2	**<0.001**
Digestive system ulceration	6.3	4.9	7.5	7.2	**0.019**
Chronic obstructive pulmonary disease	0.9	0.9	0.8	1.3	0.703

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Allergic rhinitis	4.1	4.8	3.6	3.3	0.241
Bronchitis	1.5	1.0	1.9	2.1	0.137
Asthma	3.6	3.1	3.7	5.2	0.369
Thyroid disease	4.7	4.9	4.5	4.4	0.889
Kidney disease	1.5	1.0	1.8	2.8	0.087
Prostate disease	14.7	16.8	13.0	12.6	**0.011**
Depressive disorder	3.0	1.9	2.8	10.7	**<0.001**
Psychological					
EQ-5D index	0.88 ± 0.00	0.92 ± 0.00	0.86 ± 0.00	0.73 ± 0.01	**<0.001**
EQ-VAS	74.2 ± 0.33	79.6 ± 0.40	71.3 ± 0.49	60.1 ± 1.49	**<0.001**
SF-12	±	±	±	±	
Physical health	43.3 ± 0.21	48.1 ± 0.23	40.9 ± 0.30	30.7 ± 0.72	**<0.001**
Mental health	52.7 ± 0.20	55.6 ± 0.22	51.3 ± 0.32	44.7 ± 0.87	**<0.001**
Poor self-perceived health	31.0	17.2	37.9	68.9	**<0.001**
Depressive symptoms (GDS score ≥ 6)	22.7	9.4	29.8	57.0	**<0.001**
Cognitive dysfunction (MMSE score < 24)	22.3	12.4	27.3	49.6	**<0.001**
Cognitive impairment	24.4	17.9	27.7	41.7	**<0.001**
Social					
Social support	5.5 ± 0.02	5.5 ± 0.03	5.4 ± 0.04	5.3 ± 0.10	**0.026**
Poor social capital	6.4	5.2	6.3	13.7	**0.002**
Social network					
Low interaction with family	39.5	37.1	40.6	46.4	**0.019**
Low interaction with friends	23.1	17.1	25.8	41.9	**<0.001**
Low interaction with neighbor	28.7	30.2	27.6	26.9	0.294
Religious activities (none)	41.7	41.5	40.6	49.8	**0.044**
Social activities (none)	21.6	20.6	22.3	23.3	0.491

Values are presented as mean ± standard error or percentage.

[a] eGFR, estimated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) creatinine equation; M, male; F; female.

[b] Cardiovascular diseases were included myocardial infarction, congestive heart failure, angina, peripheral vascular disease, and cerebrovascular disease.

ADL, activities of daily living; IADL, instrumental activities of daily living; HbA1c, glycosylated hemoglobin; WBC, white blood cell; RBC, red blood cell; hs-CRP high-sensitivity C-reactive protein; TSH, thyroid-stimulating hormone; HDL-cholesterol, high-density lipoprotein; LDL-cholesterol, low-density lipoprotein; eGFR, estimated glomerular filtration rate; MNA, mini nutritional assessment; EQ-5D, EuroQol-5 dimension; EQ-vas, EuroQol visual analogue scale; SF-12, 12 item short form health survey; GDS, global deterioration scale; MMSE, mini-mental state exam.

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Table 4. Risk factors associated with physical frailty in the final forward logistic regression models (standardized sample)

Variable	*B*	S.E.	*p* Value	OR	95% CI	
					Lower	Upper
At risk of malnutrition [a]	0.922	0.240	<0.001	2.51	1.57	4.03
Sarcopenia [b]	0.872	0.202	<0.001	2.39	1.61	3.56
Severe mobility limitation [c]	0.758	0.199	<0.001	2.13	1.45	3.15
Poor Social capital [d]	0.687	0.287	0.017	1.99	1.13	3.49
Residence						
Urban	Ref.					
Suburban	0.571	0.259	0.027	1.77	1.07	2.94
Rural	0.673	0.265	0.016	1.89	1.13	3.18
Depressive [e]	0.634	0.194	0.001	1.89	1.29	2.76
Poor self-perceived health	0.502	0.199	0.012	1.65	1.12	2.44
Polypharmacy [f]	0.478	0.181	0.008	1.61	1.13	2.30
hs-CRP, mg/L	0.252	0.095	0.008	1.29	1.07	1.55
HbA1c, %	0.243	0.103	0.018	1.28	1.04	1.56
Timed Up and Go, sec	0.236	0.039	<0.001	1.27	1.17	1.37
Age, years	0.081	0.025	0.001	1.08	1.03	1.14
25-hydroxyvitamin D, ng/mL	-0.023	0.010	0.024	0.98	0.96	1.00
Short Physical Performance Battery	-0.144	0.064	0.025	0.87	0.76	0.98

Independent forward stepwise logistic regression analysis with adjustment for multiple comparisons. Controlled age, education level, residence, current worker, low calf circumference, sarcopenia, severe mobility limitation, ADL disability, IADL disability, fall in the past year, timed up and go, short physical performance battery, albumin, serum creatinine, hemoglobin A1c, HbA1c, red blood cell, free thyroxine, triglyceride, 25-hydroxyvitamin D, estimated glomerular filtration rate, risk of malnutrition, polypharmacy, hospitalization in the past year, low pronouncing ability, diabetes, urinary incontinence, osteoarthritis, rheumatoid arthritis, EuroQol-5 dimensions, depressive symptoms, cognitive impairment, social support, poor social capital, low interaction with friends, and social activities.

[a] At risk of malnutrition: Mini-nutritional Assessment Short Form score of ≤11.

[b] Sarcopenia: defined according to the consensus report of the Asian Working Group for sarcopenia.

[c] Severe mobility limitation: "very difficult" or "impossible" to either walk about 400 meters or climb 10 steps without resting.

[d] Poor social capital: any lack of participation in social gatherings.

[e] Depressive: a score of ≥6 on the Korean version of the Short Form Geriatric Depression Scale (SGDS-K).

[f] Polypharmacy: taking ≥5 medications.

hs-CRP, high-sensitivity C-reactive protein; HbA1c, glycosylated hemoglobin; *B*, regression coefficient; S.E., standard error; OR, odds ratio; CI, confidence interval.

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4. Discussion

Our study was designed to estimate the standardized prevalence of physical frailty using the national standard population composition ratio and to explore comprehensive risk factors for physical frailty among older adults in Korea. Our study showed that the age-, sex-, and residence-standardized prevalence of physical frailty among older adults aged 70–84 years in Korea is 7.9%, and increased with age, and is higher among women and those living in rural areas. Furthermore, our study indicates that physico-nutritional, medical, psychological, and sociodemographic risk domains were most relevant to physical frailty.

Our study used the FFP to define physical frailty that has been used in many countries and found to predict adverse health outcomes among the older population. In a systematic review, the prevalence of frailty using the FFP varied from 4.0–17.0% in community-dwelling older adults aged ≥65 years [3]. The prevalence of physical frailty among the Korean community-dwelling adults is comparatively lower than the pooled prevalence of 9.9% (95% CI 9.6–10.2%) in 15 studies [3]. Several studies have estimated the prevalence of frailty using population structure ratio. Recent epidemiological studies report that the weighted prevalence of frailty using the FFP in community-dwelling older adults varies from 5.2–15.2% in Asian countries [10, 38, 39]. The weighted prevalence of frailty among older adults aged ≥60 years in Singapore was 5.7% (95% CI 4.6–7.1%) and increased significantly with age with no difference among men and women [10]. In a longitudinal cohort study of a nationally representative sample of community-dwelling adults from 28 provinces in China, the weighted prevalence of frailty was 7.0%, and was higher among women compared to men (8.0% vs. 5.9%) [39]. This study also observed a geographic heterogeneity and urban-rural difference in the prevalence of frailty. In Sri Lanka rural areas, the weighted prevalence of frailty was 15.2% in community-dwelling adults aged ≥60 years, which was higher compared to high- and upper-middle-income countries [38]. The differences in prevalence across countries could be due to the modified components used to define frailty in different studies. The wide variation in the prevalence of frailty has been attributed to the characteristics of a population such as an environment, ethnicity, and social culture.

The KFACS recruited participants using quota sampling stratified by age and sex in 10 study centers. To avoid biased results caused by the disproportionate sampling design, adjusting was performed by adjusting for age, sex, and residential areas using the Korean Population and Housing Census conducted by Statistics Korea in 2017. Our study recruited men and women in a 1:1 ratio, with 47.6% men and 52.4% women. However, the proportion of women increased to 57.8% in the standardized sample. These results were consistent with the previous studies where the proportion of women increased after age- and sex-adjustment [38]. Further, the regional distribution of the overall sample is similar in unstandardized and standardized samples. However, the distribution of residence between men and women was significantly different in the unstandardized sample, but not in the standardized sample. Since the participants were recruited without considering the sex ratio of the residential areas, there may be differences in the residential distribution by sex between unstandardized and standardized samples. The prevalence of physical frailty in the overall samples, in urban and rural areas, was similar regardless of standardization. However, age-, sex-, and residence-adjusted prevalence of frailty was estimated to be lower in men and higher in women than in the unstandardized sample. Similarly, the prevalence of frailty differed after weighting in the community-dwelling aged ≥55 years in Beijing, China [40]. The overall weighted and unweighted prevalence of frailty was estimated at 9.1%, and 12.3%, respectively. Additionally, the prevalence of frailty according to sex and residential area was estimated to be lower after sex- and age-adjustment.

In this nation-wide community-dwelling population of Korean older adults, we found 7.9% of Korean adults aged 70–84 years were frail. A similar prevalence (7.8%) was reported in the Korean community-dwelling older adults aged 65 years and older using the data from the Living Profiles of

Older People Survey based on home visit in 2008 [41]. Contrary, the prevalence in our study was lower than reported by a previous Korean hospital based study [7]. This could be because our study population (70–84 years) was younger than that in the previous study population involving oldest–old (≥85 years). Moreover, the KFACS participants are ambulatory community-dwelling older adults who may be less frail compared to the hospital-based participants. Our study showed that the standardized prevalence of frailty in rural areas was 12.7% and it was lower compared to that in the Pyeongchang rural area in Korea (12.7% vs. 17.4%). However, the prevalence of pre-frailty was similar (52.0% vs. 52.6%) [8]. Both studies recruited ambulatory community-dwelling older adults. The prevalence of frailty may differ depending upon the residential areas.

Frailty is a multifactorial syndrome with diverse domains and dimensions. Our study shows that physico-nutritional, psychological, sociodemographic, and medical domains are risk factors for frailty in older adults. Our findings that the prevalence of frailty increased with increasing age, and was higher among women, participants with a low education level, and living alone are consistent with previous studies [3]. A higher prevalence among women could be due to a lower average muscle mass and strength compared with men [1]. Previous studies show that sarcopenia, which includes low muscle mass and physical function, has a significant overlap with frailty [42, 43]. Therefore, the prevalence of sarcopenia in frail older adults might be higher. Interestingly, gender was not a remaining risk factor after multivariate forward logistic regression with factors including sarcopenia. In previous reports, gender was not a strong risk factor for frailty [10, 44, 45]. Based on our results, gender has an effect on frailty, but interaction with other risk factors may offset its influence on frailty.

Our results show that malnutrition has the strongest association with frailty. This association is also reported in recent cross-sectional studies [46]. Malnutrition is an important pathogenic factor of frailty [47]. International clinical practice guidelines recommend a broad nutritional assessment as part of an appropriate approach to frailty [48-50]. Also, we report a relationship between a low concentration of 25-hydroxyvitamin D and frailty. Because vitamin D deficiency in older adults increases the risk of adverse outcomes such as osteoporosis and low muscle strength, vitamin D might be associated with frailty [51]. We observed a strong correlation between frailty and biological factors. Previous studies report a relationship between inflammatory markers and frailty [52-54] that is consistent with our results. Additionally, HbA1c, indicator of diagnosing diabetes was associated with frailty in our study. Several studies show that older adults with diabetes are more likely to be frail than those without diabetes [55, 56]. We show that social capital is related to frailty. Poor social capital can lead to social isolation and loneliness, and finally frailty among older adults [57]. Our findings of a strong correlation between frailty and age, residence, polypharmacy, and depressive symptoms is consistent with previous studies [10, 44, 58, 59]. Our study found that the prevalence of frailty was significantly higher among women than men, consistent with a previous systematic review [3].

There are several limitations to our study. Due to the cross-sectional design, a causal relationship between risk factors and frailty cannot be determined. The characteristics of the oldest-old (≥85 years) population were unexplored in this paper. Despite these limitations, we standardized the study population by sex, age, and residence based on the Korean Population and Housing Census conducted by Statistics Korea in 2017. Furthermore, we examined a comprehensive range of risk factors for frailty status in a homogeneous population. We determined the strongest risk factors associated with frailty.

5. Conclusions

In conclusion, our study estimated the standardized prevalence of physical frailty and identified he comprehensive risk factors in a nationally representative population of Korean older adults aged 70–84 years. Physical frailty increases with age, and is more common among women and in rural areas. Furthermore, our study shows that multiple domains such as physico-nutritional,

psychological, sociodemographic, and medical domains are strongly associated with physical frailty. Management of modifiable risk factors might help in multidimensional prevention and intervention to reduce frailty among the older population in Korea.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Figure S1: The proportion of risk domains across the frailty status (unstandardized sample), Table S1: Prevalence of frailty status and component (unstandardized sample).

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