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Article

Sea Vegetables and Fruits as Novel Dietary Protective Factors for Sarcopenia and Muscle Function in Taiwan: A Cross-Sectional Study

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Abstract

Background/Objectives: Sarcopenia, age-related muscle loss, has been found to be influenced by nutrition and lifestyle in studies in the western countries. Little is known, however, about their effect on sarcopenia in Asia. This study examined the association between diet, clinical status, and clinical setting with sarcopenia and physical performance in older adults in Taiwan. **Methods:** We conducted a cross-sectional study of 588 individuals aged ≥65 years recruited from three hospitals in southern Taiwan (2018–2020). Questionnaire, medical chart, and laboratory data were used to study the association between demographic, dietary, nutritional status, and biochemical data with sarcopenia, defined as low muscle mass plus reduced strength or poor physical performance. Logistic regression was used to identify associated factors and linear regression was used to assess the contributions of these factors to grip strength, gait speed, and chair stand time. **Results:** Sarcopenia was identified in 159 (27.0%) of the 588 participants. Those with sarcopenia had lower education levels, poorer nutritional status, weaker grip strength, and slower mobility. Daily intakes of sea vegetables (adjusted OR = 0.45, 95% CI: 0.22–0.90) and fresh fruits (adjusted OR = 0.41, 95% CI: 0.23 – 0.76) were independently associated with reduced risk of sarcopenia. Those with increased risk were older (adjusted OR = 1.03, 95% CI: 1.01–1.05) and recruited from Pingtung Veterans General Hospital Longquan Branch (adjusted OR = 6.48, 95% CI: 3.16–13.3), compared with those recruited from Pingtung Hospital. Sea vegetable intake was positively associated with grip strength, while fruit intake was inversely associated with chair stand time. **Conclusions:** Dietary factors, nutritional status, and recruitment setting were significantly associated with sarcopenia risk and physical performance. Prevention efforts might want to focus on increasing consumption sea vegetables and fruits and addressing institutional disparities.

Keywords: sarcopenia; older Taiwanese adults; sea vegetables; fresh fruits

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1. Introduction

Sarcopenia affects approximately 10%–16% of older adults worldwide, with a higher prevalence among patient populations, ranging between 18% in those with diabetes and 66% in those with unresectable esophageal cancer. Sarcopenia, whose risk factors include inactivity, malnutrition, smoking, extreme sleep duration, and diabetes, has been associated with poorer survival, postoperative complications, prolonged hospitalization, falls, fractures, metabolic disorders, cognitive decline, and increased mortality [1]. One systematic review and meta-analysis of community-dwelling older adults reported significant associations between sarcopenia and age (OR = 1.12, 95% CI: 1.10–1.13), underweightedness (OR = 3.78, 95% CI: 2.55–5.60), and malnutrition or risk of malnutrition (OR = 2.99, 95% CI: 2.40–3.72) as well as a range of disease-related conditions, including diabetes, cognitive impairment, osteoporosis, osteoarthritis, depression, falls, anorexia, and anemia [2] . Evidence further indicates that the prevalence of sarcopenia varies markedly across care settings, ranging from 25% to 73.7% among older individuals in nursing homes and from 5.2% to 62.7% in community populations. Common determinants across these environments include male sex, BMI, malnutrition, and osteoarthritis, while additional factors in community settings involve poor nutritional status, reduced calf circumference, smoking, physical inactivity, cognitive impairment, diabetes, depression, and heart disease [3].

In Taiwan, one study of 173 older adults in eight daycare centers in Keelung City, northern Taiwan, reported an alarmingly high prevalence of this disease, with 47.4% classified as having possible sarcopenia and 50.9% as having confirmed sarcopenia [4]. That study identified BMI, calf circumference, malnutrition risk, dementia, and male sex as significant correlates [4]. Despite the growing recognition of sarcopenia as a major geriatric condition, few studies have investigated the association between specific dietary components, nutritional adequacy, and institutional settings to sarcopenia risk in Asia. Therefore, the present cross-sectional study was designed to investigate the associations between dietary patterns, nutritional status, and institutional factors with sarcopenia and functional performance among older adults in southern Taiwan.

2. Materials and Methods

Data source, Participants, and Study Design

This cross-sectional study included 588 participants aged 65 years and older recruited between September 2018 and May 2020. Participants were purposively sampled from three hospitals in southern Taiwan: Kaohsiung Veterans General Hospital (KVGH), Pingtung Veterans General Hospital Longquan Branch, and Pingtung Hospital. At KVGH and Pingtung Hospitals, the participants were recruited from the outpatient clinics of the endocrinology and metabolism departments. At Pingtung Veterans General Hospital Longquan Branch, the participants were recruited from the home care center.

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Measurement

This study used structured questionnaires to collect information on participants' demographic characteristics and health behaviors, which included smoking, drinking, and betel chewing. The questionnaires also collected dietary recall data, in which the participants' dietary intake including main foods, snacks, and drinks. For analytical clarity and consistency, specific food items were grouped into broader categories. The key categories were the following: sea vegetables (encompassing various edible algae such as seaweed and hair vegetables); fresh fruits (such as grapes, bananas, lychees, and longan); light-colored vegetables (such as radish and Chinese cabbage); dried small fish with bones (such as kissed larvae and other small, whole-eaten fish); other non-fish seafood (such as shrimp, flower sticks, and hairy crab); fish paste products (such as fish balls and fish soup); and processed meat products (such as gong balls and hot dogs). The structured questionnaire was used to collect participants' dietary intake using a semi-quantitative food frequency approach with consumption frequency measured across five categories, from less than once per month to at least once per day. Nutritional status was assessed using the Mini Nutritional Assessment (MNA), a validated screening tool for older adults. MNA scores ≥ 24 indicated normal nutritional status, while scores of 17–23.5 identified individuals at risk of malnutrition, requiring early nutritional intervention. Scores <17 indicated protein-energy malnutrition, necessitating a comprehensive nutritional assessment, including serum albumin and prealbumin levels, and dietary intake records.

Blood biochemical data were retrieved from the hospital's electronic medical records and were defined as the most recent values available at the time of study enrollment. Additionally, their most recent laboratory test results assessed during outpatient visits and hospital admission were used to identify chronic diseases such as diabetes, hypertension, or hyperlipidemia. We used multiple imputations to analyze missing values and tested the results with and without multiple imputations during the analysis.

Outcome

We assessed participants' anthropometric characteristics, including body mass index (BMI), arm circumference, and skinfold thickness. Body composition was evaluated by bioelectrical impedance analysis (BIA), which estimates the percentage of skeletal muscle mass relative to total body weight.

Handgrip strength was measured using a calibrated dynamometer (Tokyo, Japan). During measurement, participants sat with their feet shoulder-width apart and flat on the floor. Measurements were performed three times with their dominant hand at 30-second intervals; the highest value was used for analysis. Gait speed was assessed over a six-meter walk at each participant's usual pace, recording the time required to complete the distance. Functional mobility was further evaluated using the timed up-and-go test, wherein participants rose from an armless chair, walked three meters, turned, walked back, and sat down again. Based on total time taken, mobility was categorized as normal (< 10 seconds), mild impairment (10–20 seconds), moderate impairment (20–29 seconds), or severe impairment (> 29 seconds).

A diagnosis of sarcopenia was based on the criteria recommended by the Asian Working Group for Sarcopenia (AWGS) 2019 consensus [5]. Participants were first required to meet the low muscle mass criterion, defined as a skeletal muscle mass index (SMI) below 7.0 kg/m² in men or 5.7 kg/m² in women, as assessed by bioelectrical impedance analysis (BIA). In addition, they had to meet at least one of the following conditions: (i) low muscle strength, defined as handgrip strength < 28 kg for men or < 18 kg for women; (ii) poor physical performance, defined as gait speed < 0.8 m/s over a 6-meter walk; or (iii) impaired chair stand performance, defined as ≥ 12 seconds to complete five rises or inability to complete the test. Participants who did not meet these thresholds were classified as non-sarcopenic.

Statistics

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We used Chi-square (χ^2) and independent t-tests to compare the differences in categorical variables and continuous variables between groups. Multivariate logistic regression analysis was conducted to assess the association between risk factors and sarcopenia. Crude models included unadjusted risk estimates, whereas fully adjusted models accounted for potential confounders. Backward stepwise regression was employed for model selection. Multiple linear regression analysis was used to examine the impact of various factors on three sarcopenia indicators: muscle strength, TUG test performance, and gait speed. All statistical operations were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA). All tests were two-tailed, and significance was set at $p < 0.05$.

3. Results

A total of 588 participants were recruited for the study: 159 individuals diagnosed with sarcopenia (mean age, 81.1 years) and 429 without (mean age, 81.8 years). Those with sarcopenia were more likely to be male, though not significantly different from those without. They tended to be less educated (below high school level). They had significantly higher intakes of dried small fish with bones (kissed larvae, dried small fish), other non-fish seafood (shrimp, flower sticks, hairy crab), processed meat products (gong balls, hot dogs) compared to non-sarcopenic individuals, but significantly lower intakes of fish paste products (fish balls, fish soup), sea vegetables (algae) (sea vegetables, seaweed, hair vegetables), canned and salted frozen vegetables, and fresh fruits (grapes, bananas, lychees, longan). Biochemically, they had significantly higher levels of uric acid. We also found significant differences in the prevalence of this disease across recruitment sites (Table 1).

Table 1. The characteristics of subjects with or without sarcopenia.

	With sarcopenia	Without sarcopenia	
N,	159	429	p-value
Age, Mean (sd), years old	81.1 (14.6)	81.8 (17.8)	0.20
Gender			0.12
male	78 (49.1)	206 (48.0)	
female	81 (50.9)	223 (52.0)	
Smoking			
Never	144 (90.6)	334 (77.9)	0.93
Former	7 (4.4)	72 (16.8)	0.39
Current	8 (5.0)	23 (5.4)	0.14
Alcohol			
Never	156 (98.1)	385 (89.7)	0.54
> 1 per week	3 (1.9)	36 (8.4)	0.80
> 2 per week	0 (0.0)	8 (1.9)	0.37
Betel chewing			
Never	157 (98.7)	403 (93.9)	0.75
Former	1 (0.6)	22 (5.1)	0.80
Current	1 (0.6)	4 (0.9)	0.83
Education level			
Higher school and more	42 (26.4)	178 (41.5)	< 0.001
The skeletal muscle mass relative to total body weight, mean (sd)	8.6 (10.1)	9.3 (1.3)	0.2
Grip, mean (sd), kg	17.9 (7.0)	20.4 (7.6)	< 0.001
6-meter gait speed, mean (sd), meter/second	0.6 (0.3)	1.1 (4.8)	0.28
Chair stand test time, mean (sd), second	15.8 (11.1)	12.6 (11.7)	0.0035
Fish paste products (fish balls, fish soup)			

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3 per month	37 (23.3)	73 (17.0)	0.08
Dried small fish with bones (Kissed larvae, dried small fish)			
3 per month	65 (40.9)	103 (24.0)	< 0.001
Other non-fish seafood (shrimp, flower sticks, hairy crab)			
3 per month	17 (10.7)	82 (19.1)	0.015
Livestock and poultry offal (chicken liver, kidney)			
used	32 (20.1)	128 (29.8)	0.019
Processed meat products (gong balls, hot dogs)			
used	74 (46.5)	186 (43.4)	0.49
Light-colored vegetables (radish, Chinese cabbage)			
4-6 per Week	18 (11.3)	69 (16.1)	0.15
per day	44 (27.7)	174 (40.6)	0.004
Sea vegetables (algae) (sea vegetables, seaweed, hair vegetables)			
used	27 (17.0)	185 (43.1)	< 0.001
Canned and salted frozen vegetables			
used	13 (8.2)	88 (20.5)	< 0.001
Fresh fruits (grapes, bananas, lychees, longan)			
used	57 (35.8)	293 (68.3)	< 0.001
Mini Nutritional Assessment (MNA)			
≥ 24	111 (69.8)	317 (73.9)	0.32
Biochemical			
Albumin, mean(sd), mg/dL	4.7 (3.7)	5.1 (4.1)	0.35
Blood Urea Nitrogen, mean(sd), mg/dL	20.1 (10.6)	22.3 (13.0)	0.06
Serum creatinine, mean(sd), mg/dL	2 (2.5)	1.9 (3.0)	0.88
Glomerular filtration rate, mean(sd), min/ml/1.73 m²	65.5 (35.0)	59.9 (34.0)	0.08
Uric acid, mean(sd), mg/dL	5.7 (1.9)	6 (1.9)	0.039
Ante Cibum sugar, mean(sd), mg/dL	169.8 (613.9)	121.7 (141.0)	0.13
hemoglobin A1c, mean(sd), %	7.1 (1.4)	7.2 (1.4)	0.47
Total cholesterol, mean(sd), gm/dL	174.9 (37.4)	167.9 (36.4)	0.044
Triglyceride, mean(sd), mg/dL	115.1 (70.3)	119.4 (64.9)	0.49
Systolic blood pressure, mean(sd), mmHg	139 (22)	138 (22)	0.75
Diastolic blood pressure, mean(sd), mmHg	73 (10)	73 (15)	0.99
Kaohsiung Veterans General Hospital	36 (22.6)	221 (51.5)	< 0.001

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Pingtung Veterans general hospital Longquan Branch	12 (7.5)	89 (20.7)	0.002
Pingtung Hospital	111 (69.8)	119 (27.7)	0.11

sd: standard deviation.

Based on our crude logistic regression model, daily intake of light-colored vegetables (radish, Chinese cabbage), sea vegetables (algae) (sea vegetables, seaweed, hair vegetables), and fresh fruits (grapes, bananas, lychees, longan) as well as glomerular filtration rate of per 10 min/ml/1.73 m^2 were significantly less likely to have sarcopenia. Those recruited from Kaohsiung Veterans General Hospital (compared to Pingtung Hospital) were also significantly more likely to have sarcopenia. After adjustment for age, sex, education level, dietary habits, nutritional status, and recruitment site in the multiple logistic regression model, we found a significant association between daily intakes of sea vegetables (algae) (sea vegetables, seaweed, hair vegetables) and fresh fruits (grapes, bananas, lychees, longan) with a reduced risk of sarcopenia. The odds ratio and 95% confidence intervals were 0.45 (95% CI: 0.22 to 0.90, p=0.023) and 0.41 (95% CI: 0.23 to 0.76, p=0.004), respectively. Older participants and those recruited at Pingtung Veterans General Hospital Longquan Branch (vs. Pingtung Hospital) had a significantly higher risk of sarcopenia (Table 2).

Table 2. Multivariate logistic regression model analysis of factors associated with sarcopenia risk.

	Crude model		Adjusted model	
	Crude OR (95% confidence interval)	p-value	Adjusted OR (95% confidence interval)	p-value
Age	1.00 (0.99-1.01)	0.68	1.03 (1.01-1.05)	0.003
Male	1.04 (0.72-1.50)	0.82	1.61 (0.95-2.74)	0.08
Sea vegetables (algae) (sea vegetables, seaweed, hair vegetables)				
Used vs non-used	0.27 (0.17-0.43)	< 0.001	0.45 (0.22-0.90)	0.023
Light-colored vegetables (radish, Chinese cabbage)				
4-6 per Week	0.50 (0.28-0.89)	0.018	1.04 (0.47-2.28)	0.93
per day	0.48 (0.32-0.73)	0.001	0.87 (0.45-1.70)	0.69
Fresh fruits (grapes, bananas, lychees, longan)				
per day	0.26 (0.18-0.38)	< 0.001	0.41 (0.23-0.76)	0.004
Mini Nutritional Assessment (MNA)				
≥ 24	0.82 (0.55-1.22)	0.32	0.62 (0.35-1.11)	0.11
Glomerular filtration rate, per 10 min/ml/1.73 m^2	1.08 (1.01-1.15)	0.029	0.98 (0.90-1.08)	0.70
recruitment site (vs. Pingtung Hospital)				
Kaohsiung Veterans General Hospital	0.83 (0.41-1.66)	0.60	-	-
Pingtung Veterans general hospital Longquan Branch	5.73 (3.70-8.86)	< 0.001	6.48 (3.16-13.3)	< 0.001

Multiple logistic regression model adjusted for age, gender, education level, dried small fish with bones (kissed larvae, dried small fish), fish paste products (fish balls, fish soup), other non-fish seafood (shrimp, flower sticks, hairy crab), processed meat products (gong balls, hot dogs), livestock and poultry offal (chicken liver, kidney), light-colored vegetables (radish, Chinese cabbage), sea vegetables (algae) (sea vegetables, seaweed, hair vegetables), canned and salted frozen vegetables, fresh fruits (grapes, bananas, lychees, longan), Mini Nutritional Assessment (MNA) and glomerular filtration rate and enrolled institution.

Multivariable linear regression analysis was conducted to examine the factors associated with sarcopenia diagnostic criteria, including grip, 6-meter gait speed, and chair stand test time as

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dependent variables. Age, sex, intake of sea vegetables (algae) (sea vegetables, seaweed, hair vegetables), nutritional status, and estimated glomerular filtration rate (eGFR) were significantly associated with grip. Sex, light-colored vegetables (radish, Chinese cabbage) daily, fresh fruits (grapes, bananas, lychees, longan) daily, nutritional status, eGFR, and recruitment site were significantly associated with chair stand test time. Notably, sea vegetables (algae) (sea vegetables, seaweed, hair vegetables) used were significantly associated with greater grip. After adjustment for age, sex, education level, dietary habits, nutritional status, and recruitment site, the regression coefficient for sea vegetables (algae) (sea vegetables, seaweed, hair vegetables) was 1.9 (95% CI: 0.6-3.1, p = 0.003) for grip. Additionally, in the same model, the regression coefficient for the fresh fruits (grapes, bananas, lychees, longan) daily was -1.6 (95% CI: -3.1 to -0.2, p = 0.025) for chair stand test time (seconds) (Table 3).

Table 3. Multiple linear regression model analysis of factors related to grip (per kg), 6-meter walk time, and up and go time.

	grip (per kg)		6-meter gait speed, mean(sd), m/s		chair stand test time, mean(sd) , s	
grip	Regression coefficients (95% confidence intervals)[a]	P value	Regression coefficients (95% confidence intervals) [a]	P value	Regression coefficients (95% confidence intervals) [a]	P value
Age	< 0.1 (-0.1 to <0.1)	0.008	<0.1 (< 0.0 to 0.1)	0.53	< 0.1 (< 0.1 to 0.1)	0.12
Male	8.2 (7.1 to 9.2)	< 0.001	-0.3 (0-1.3 to 0.7)	0.56	-1.3 (-2.5 to -0.1)	0.037
Sea vegetables (algae) (sea vegetables, seaweed, hair vegetables)						
Used vs non-used	1.9 (0.6 to 3.1)	0.003	0.1 (-1.0 to 1.2)	0.85	0.2 (-1.2 to 1.5)	0.81
Light-colored vegetables (radish, Chinese cabbage)						
4-6 per Week	-1.3 (-2.9 to 0.4)	0.13	0.1 (-1.4 to 1.5)	0.94	1.3 (-0.5 to 3.1)	0.15
per day	-0.5 (-1.8 to 0.8)	0.44	-0.1 (-1.2 to 1.1)	0.91	1.7 (0.3 to 3.1)	0.018
Fresh fruits (grapes, bananas, lychees, longan)						
per day	0.8 (-0.5 to 2.1)	0.22	-0.4 (-1.6 to 0.8)	0.54	-1.6 (-3.1 to -0.2)	0.025
Mini Nutritional Assessment (MNA)						
≥ 24	2.8 (1.5 to 4.0)	< 0.001	0.3 (-0.8 to 1.4)	0.61	-3.0 (-4.3 to -1.6)	< 0.001
Glomerular filtration rate, per 10 min/ml/1.73 m2	0.2 (0.0 to 0.4)	0.018	0.1 (-0.1 to 0.3)	0.44	-0.1 (-0.4 to 0.1)	0.21

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Vs. Pingtung Hospital						
Kaohsiung Veterans General Hospital	-7.6 (-18.5 to 3.4)	0.17	0.3 (-9.5 to 10.1)	0.99	23.3 (11.3 to 35.2)	< 0.001
Pingtung Veterans general hospital Longquan Branch	0.3 (-1.1 to 1.7)	0.71	-0.6 (-1.9 to 0.7)	0.35	-11.0 (-12.5 to -9.4)	< 0.001

Multivariable linear regression model adjusted for age, gender, education level, dried small fish with bones (kissed larvae, dried small fish), fish paste products (fish balls, fish soup), other non-fish seafood (shrimp, flower sticks, hairy crab), processed meat products (gong balls, hot dogs), livestock and poultry offal (chicken liver, kidney), light-colored vegetables (radish, Chinese cabbage), sea vegetables (algae) (sea vegetables, seaweed, hair vegetables), canned and salted frozen vegetables, fresh fruits (grapes, bananas, lychees, longan), Mini Nutritional Assessment (MNA) and glomerular filtration rate and enrolled institution. .

4. Discussion

This cross-sectional study investigated dietary and nutritional factors in relation to sarcopenia among older adults in southern Taiwan. Individuals at increased risk of sarcopenia were older (adjusted OR = 1.03, 95% CI: 1.01–1.05) and recruited from Pingtung Veterans General Hospital Longquan Branch (adjusted OR = 6.48, 95% CI: 3.16–13.3, compared with those recruited from Pingtung Hospital). Daily intake of sea vegetables and fresh fruits was independently associated with lower risk of sarcopenia (adjusted OR 0.45, 95% CI: 0.22–0.90) and 0.41, 95% CI: 0.23–0.76). Together, these results find strong link between specific dietary components and overall nutritional adequacy, muscle strength, and functional performance, underscoring the central role of nutrition can play in the prevention and management of sarcopenia.

Our findings suggest that sea vegetable intake confers protective effects against sarcopenia. Sea vegetables are nutritionally dense foods providing protein (often 11–32% of dry weight), essential amino acids, minerals, vitamins, soluble fiber, and distinct marine bioactive. Their key compounds include fucoidan (a sulfated polysaccharide), phlorotannin (marine polyphenols), and fucoxanthin (a xanthophyll carotenoid). Collectively, these constituents exhibit anti-inflammatory, antioxidant, metabolic, and in some models anabolic/myogenic activities mechanistically relevant to sarcopenia. Recent reviews of edible seaweed nutrition and human trials report benefits on glycemia, blood pressure, body composition and select functional markers, supporting the biological plausibility that routine seaweed intake can contribute to healthier aging trajectories when integrated into balanced diets[6]. Notably, a recent clinical and preclinical trial found Ishige okamurae, a brown seaweed, to improve muscle strength and regeneration in both older adults and aging mice, with no evidence of toxicity, supporting the role of consuming edible seaweeds as a nutritional strategy for protecting against age-related muscle loss [7]. Recent reviews report the benefits of seaweed consumption on glycemic control, blood pressure, body composition, and functional outcomes [8]. The present study adds to this growing body of literature suggesting that regular integration of sea vegetables into the diet may help promote healthier aging.

One study demonstrated that Pyropia yezoensis protein (PYCP), which is derived from edible red algae, protects C2C12 myotubes against TNF-α-induced atrophy. It reversed reductions in myotube viability and diameter, suppressed inflammatory and proteolytic signaling (NF-κB, IL-6, atrogin-1, MuRF1), and enhanced myogenic markers such as MyoD and myogenin [9]. These findings suggest that seaweed proteins may counteract the muscle wasting processes involved in sarcopenia.

In one experimental study, aged rats were treated with a mixture of algae oil rich in omega-3 polyunsaturated fatty acids and extra virgin olive oil for 21 days. This treatment prevented age-related muscle loss, preserved myosin heavy chain expression, and reduced inflammation in skeletal muscle. These findings provided evidence that algae-derived nutrients could play a protective role

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against sarcopenia and are consistent with our observation that sea vegetable intake may help mitigate age-related muscle decline [10].

Our findings suggest that sea vegetable intake confers protective effects against sarcopenia. Specifically, daily sea vegetable consumption was significantly associated with a reduced risk of sarcopenia (Adjusted OR = 0.45, p= 0.023) and independently predicted greater grip strength (= 1.9, p= 0.003). A recent study demonstrated that fucosterol, a phytosterol derived from marine algae, attenuated skeletal muscle atrophy in both TNF-α-treated C2C12 myotubes and immobilized C57BL/6J mice. Fucosterol exerted its protective effects by suppressing protein degradation (via downregulation of atrogin-1 and MuRF1) and stimulating protein synthesis through activation of the PI3K/Akt/mTOR/FoxO3α signaling pathway [11]. These findings suggest the mechanism though which edible seaweed-derived compounds can potentially protect against muscle wasting and sarcopenia. Our population-based findings are consistent with cell and animal studies showing this protective effect and provide an important impetus for future clinical intervention research. A recent review [12] has revealed that macroalgae are a rich source of bioactive compounds, including polyphenols, carotenoids, and fucoidans. Future studies may be performed to identify which of these constituents contribute most to the prevention of sarcopenia.

This study also found an association between daily fruit consumption and reduced sarcopenia risk, suggesting that antioxidants may help preserve muscle mass. A meta-analysis of 14 observational studies has reported a significant inverse association between combined vegetable and fruit consumption and sarcopenia (OR = 0.61, 95% CI: 0.48–0.79) [13]. One cross-sectional study of 14,585 older adults (≥65 years) from six low- and middle-income countries found higher fruit consumption (highest vs. lowest quintile) to be associated with a 40% lower risk of sarcopenia, particularly in women, but not vegetable intake [14]. A recent Mendelian randomization study using data from the UK Biobank provided causal evidence linking fruit and vegetable intake with protective effects on sarcopenia-related phenotypes, including appendicular lean mass, grip strength, and walking pace [15]. That study found a clear association between fresh and dried fruit intake and lower risk of weakened muscle strength, lending further credence to our finding that daily fruit consumption correlates with a lower risk of sarcopenia [15]. Most of the available evidence for this relationship has been observational, so causality has been hard to establish. Moreover, results have not always been consistent when fruits and vegetables were analyzed separately. Moreover, differences in dietary culture, fruit type, and intake levels across populations may further influence outcomes. One in vitro study using C2C12 and L6C5 muscle cell lines demonstrated that vitamin C supports carnitine biosynthesis and protects muscle cells from oxidative stress by enhancing ascorbic acid transport and recycling [16]. These findings suggest that fruit-derived vitamin C may help preserve muscle integrity under oxidative conditions, supporting its protective role against sarcopenia. Recent experiments with C2C12 myoblasts have demonstrated that phloretin, a dihydrochalcone polyphenol abundant in fruits, protects against oxidative stress–induced damage [17]. In those experiments, phloretin reduced ROS production, restored mitochondrial membrane potential, and attenuated apoptosis while activating the LKB1/AMPK/Nrf2/HO-1 antioxidant pathway. These findings suggest the possible mechanism through which fruit-derived bioactives may help preserve muscle integrity and mitigate sarcopenia-related muscle loss. Food-derived carotenoids such as β-carotene and lycopene from tomatoes have been shown to activate the adiponectin–AMPK signaling pathway in C2C12 myotubes, thereby enhancing glucose uptake and energy metabolism [18]. Although not directly tested in sarcopenia, these findings suggest that fruit-derived carotenoids may contribute to muscle health through improved metabolic and antioxidant pathways, which are mechanistically relevant to sarcopenia. Likewise, our previous studies have found that quercetin, a fruit-derived flavonoid, promotes C2C12 myoblast migration and differentiation via IGF-1R/STAT3/AKT signaling [19] and kaempferol (KMP), another flavonoid present in many fruits and vegetables, enhances myoblast migration and differentiation through ITGB1/FAK/paxillin and IGF1R/AKT/mTOR pathways [20]. These findings portray fruit-derived

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flavonoids as bioactive compounds with direct myogenic effects, reinforcing the likelihood that fruit consumption may contribute to muscle health.

Nutritional adequacy emerged as a significant predictor of functional performance in our cohort, even though MNA scores did not differ significantly between participants with and without sarcopenia. Specifically, better MNA status was associated with higher grip strength (per kg) and faster chair stand performance, indicating that nutritional status may influence muscle quality and physical function before overt declines in muscle mass become apparent. This relationship aligns with previous findings showing that suboptimal nutrition contributes to functional impairment and mobility limitation in older adults [21-23]. Rather than serving solely as a diagnostic correlate of sarcopenia, the MNA appears to function as an indicator of functional reserve and physiological resilience. These observations underscore the importance of incorporating nutritional screening into sarcopenia prevention strategies. It can be used to identify those at high risk and intervene in its development before functional decline progresses.

Participants in this study were primarily recruited from hospital outpatient clinics and a home care center, which may not fully represent community-dwelling older adults. The inclusion of both outpatient and institutionalized populations could introduce heterogeneity in health status, comorbidity burden, and lifestyle factors. Such heterogeneity may partly explain the differences in sarcopenia prevalence we observed across study sites. For instance, patients in outpatient clinics might represent healthier and more mobile older adults, whereas those enrolled from a home care center may present with greater functional impairments or higher chronic disease burden. These differences could influence dietary behaviors, physical activity levels, and access to nutritional support, thereby contributing to variability in sarcopenia outcomes between institutions. Older adults recruited from the veteran-affiliated tertiary hospital and its home-care center were likely to have had greater multimorbidity, lower mobility, and poorer nutritional status than outpatient attendees at the regional hospital. These differences may partly account for the higher sarcopenia risk in patients enrolled from those sites.

In our study, participants recruited from Kaohsiung Veterans General Hospital (KVGH) and Pingtung Veterans General Hospital Longquan Branch had a significantly higher prevalence of sarcopenia than those from Pingtung Hospital. This discrepancy may reflect underlying differences in patient characteristics and healthcare settings, as veteran's hospitals typically care for older adults with greater comorbidity burden and functional limitations, including those residing in institutional care, whereas Pingtung Hospital serves a more community-based outpatient population. These findings are consistent with studies from other countries that show that sarcopenia's prevalence varies substantially across settings.

For example, Papadopoulou et al. (2020), in their systematic review and meta-analysis, reported sarcopenia to be prevalent in 11% in community-dwelling men and 9% in women, but much higher prevalence among nursing home residents (51% in men, 31% in women) and hospitalized patients (23–24%) [24]. Similarly, Smoliner et al. (2014) found that 6.6% of hospitalized older adults had sarcopenia and 18.7% had severe sarcopenia, with nutritional status strongly associated with sarcopenia risk [25]. Rodríguez-Rejón et al., reviewing residential care facilities in their systematic review analyzing studies from various countries, found prevalence estimates to range from 17.7% to 73.3%, further underscoring the vulnerability of institutionalized populations [26]. These findings support our observation that recruitment site is an important determinant of sarcopenia prevalence.

Study Limitations

This study has some limitations. One limitation is potential selection bias due to its use of a cross-sectional data to compare individuals with and without sarcopenia. We tried to minimize selection bias by recruiting participants from institutions of varying sizes and across different geographic regions. Another limitation is potential recall bias. To reduce this possibility, we required that the questionnaires be administered by trained interviewers using standardized protocols in a controlled,

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distraction-free environment. Standardized questionnaires and relevant blood tests were utilized to further reduce the impact of recall bias.

5. Conclusions

In summary, we found that sea vegetable and fruit intake, nutritional adequacy, and institutional differences to be significant determinants of sarcopenia among older adults in Taiwan. These results underscore the importance of promoting nutrition-focused interventions, ones encouraging the consumption of sea vegetables and fruits, ensuring nutritional adequacy, and addressing institutional disparities as strategies to reduce sarcopenia risk in aging populations.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to restrictions related to participant confidentiality.

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Abbreviations

The following abbreviations are used in this manuscript:

AWGS	Asian Working Group for Sarcopenia
BIA	bioelectrical impedance analysis
BMI	body mass index
CI	confidence interval
eGFR	estimated glomerular filtration rate
KVGH	Kaohsiung Veterans General Hospital
MNA	Mini Nutritional Assessment
OR	odds ratio
sd	standard deviation
SMI	skeletal muscle mass index
TSMH	Antai Tian-Sheng Memorial Hospital
TUG	timed up-and-go test

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