

Development and validation of the sarcopenia composite index: A comprehensive approach for assessing sarcopenia in the ageing population

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ABSTRACT

Introduction: The diagnosis of sarcopenia relies on key indicators such as handgrip strength, walking speed and muscle mass. Developing a composite index that integrates these measures could enhance clinical evaluation in older adults. This study aimed to standardise and combine these metrics to establish a z score for the sarcopenia composite index (ZoSCI) tailored for the ageing population. Additionally, we explore the risk factors associated with ZoSCI to provide insights into early prevention and intervention strategies.

Method: This retrospective study analysed data between January 2017 and December 2021 from an elderly health programme in Taiwan, applying the Asian Working Group for Sarcopenia criteria to assess sarcopenia. ZoSCI was developed by standardising handgrip strength, walking speed and muscle mass into z scores and integrating them into a composite index. Receiver operating characteristic (ROC) curve analysis was used to determine optimal cut-off values, and multiple regression analysis identified factors influencing ZoSCI.

Results: Among the 5047 participants, the prevalence of sarcopenia was 3.7%, lower than the reported global prevalence of 3.9–15.4%. ROC curve analysis established optimal cut-off points for distinguishing sarcopenia in ZoSCI: -1.85 (sensitivity 0.91, specificity 0.88) for males and -1.97 (sensitivity 0.93, specificity 0.88) for females. Factors associated with lower ZoSCI included advanced age, lower education levels, reduced exercise frequency, lower body mass index and creatinine levels.

Conclusion: This study introduces ZoSCI, a new composite quantitative indicator for identifying sarcopenia in older adults. The findings highlight specific risk factors that can inform early intervention. Future studies should validate ZoSCI globally, with international collaborations to ensure broader applicability.

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Keywords: composite index, early diagnosis, elderly, risk factors, sarcopenia

CLINICAL IMPACT

What is New

- Z score for the sarcopenia composite index (ZoSCI), a novel composite index for diagnosing sarcopenia, is introduced.
- This study integrates grip strength, walking speed and muscle mass into a standardised single score.

Clinical Implications

- A more accurate clinical evaluation of sarcopenia in older adults is enhanced.
- This study highlights key risk factors, including advanced age, lower educational attainment, reduced exercise frequency, lower body mass index and decreased creatinine levels.
- This study also facilitates early prevention and the development of targeted intervention strategies for sarcopenia.

INTRODUCTION

Sarcopenia, characterised by a reduction in muscle mass and a progressive decline in muscle function, presents a significant and growing challenge to the health and well-being of older adults worldwide.¹

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Studies indicate that the prevalence of sarcopenia among community-dwelling older adults aged 60 years and above ranges from 3.9% to 15.4%, depending on the diagnostic criteria used, such as those from the European Working Group on Sarcopenia in Older People (EWGSOP) and the Asian Working Group for Sarcopenia (AWGS), as well as demographic variations.^{2,3} As global populations age, sarcopenia is increasingly recognised as a critical health concern linked to adverse outcomes, including hospitalisation, reduced quality of life, disability, falls and increased mortality.⁴ Thus, identifying high-risk groups and influencing factors, along with implementing early interventions, is crucial for reducing the risk of sarcopenia.^{5,6}

Since the 1980s, geriatricians worldwide have worked to establish diagnostic criteria and definitions for sarcopenia, continuously refining measurement methods, diagnostic protocols and threshold values to account for racial and sex differences.⁵⁻⁸ The EWGSOP initially developed diagnostic tools and cut-off points for sarcopenia classification.⁷ In 2018, EWGSOP2 updated these guidelines, incorporating the Strength, Assistance in walking, Rise from a chair, Climb stairs, and Falls (SARC-F) questionnaire to identify probable cases of sarcopenia. This revision redefined low muscle strength as indicative of probable sarcopenia (low grip strength), sarcopenia as low muscle quantity or quality combined with low muscle strength, and severe sarcopenia with the addition of low physical performance.⁵ Recognising regional physiological differences, the AWGS developed a criteria specifically tailored for Asian populations.⁸ In 2019, AWGS updated its classification to include probable sarcopenia (low grip strength or walking speed), sarcopenia and severe sarcopenia, using similar indicators adjusted for Asian contexts.⁶ Both EWGSOP and AWGS emphasise the assessment of grip strength, walking speed and muscle mass as core indicators, highlighting the importance of evaluating both muscle mass and function to comprehensively capture sarcopenia progression.

The screening process for sarcopenia typically begins with tests of grip strength and walking speed, with muscle mass evaluated if these initial measurements reveal declines. Diagnostic cut-offs for these indicators are then applied to determine whether values are within normal ranges or indicate deficiencies. Since both muscle function and muscle mass are crucial indicators for diagnosing sarcopenia, it is important to assess elderly individuals who may have normal muscle function but reduced muscle mass or low muscle function but preserved muscle mass. However, using

diagnostic cut-offs represents a categorical approach, which may not fully capture the continuum of sarcopenia severity across diverse populations. To address this issue, this study transformed measurements of grip strength, walking speed and muscle mass among elderly individuals into standardised scores. These scores were then combined to generate a z score of the sarcopenia composite index (ZoSCI). By quantifying sarcopenia indicators along a continuum, ZoSCI can capture subtle variations in sarcopenia risks, making it particularly useful for identifying at-risk populations globally. We also investigated the relationship between influencing factors and ZoSCI to identify sarcopenia risks and at-risk populations at an early stage.

METHOD

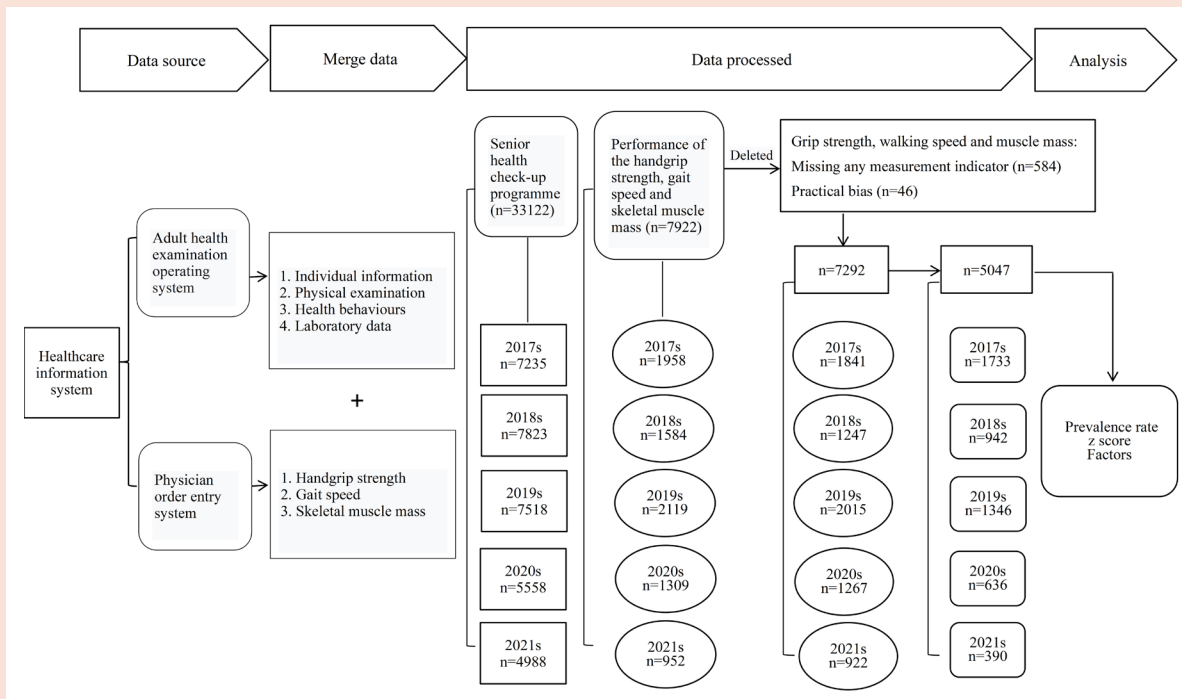
Participants and study design

This retrospective study collected data from individuals aged 65 years and older who participated in the elderly health service programme between January 2017 and December 2021. Data were obtained from the medical centre's system database in Taiwan and included basic demographic information, health-related behaviours, laboratory test results, grip strength, 6-meter walking speed, muscle mass and other relevant data.

Initially, 33,122 cases were included over the 5-year period. Participants with missing data on any of the 3 key measures (i.e. grip strength, walking speed or muscle mass) were excluded, resulting in a final sample size of 5047 cases for final analysis (Fig. 1). All procedures in the present study were approved by the institutional review board of the authors' hospital and conducted in accordance with the Declaration of Helsinki.

We specifically selected the AWGS criteria for diagnosing sarcopenia in this study, as these standards are tailored to Asian populations, accounting for regional differences in body composition, lifestyle and genetics.⁶ By using the AWGS criteria, we aimed to enhance the relevance and accuracy of our findings, ensuring alignment with the characteristics of the elderly population in Taiwan under investigation. Sarcopenia was evaluated using 3 key assessment criteria—(1) muscle strength: assessed via handgrip strength using a spring-loaded electronic grip strength meter (Smedley hand dynamometer FEI 12-0286, Fabrication Enterprises Inc, NY, US). The maximum value of 3 measurements was recorded, with cut-offpoints of <18 kg for women and <28 kg for men. (2) Physical performance: evaluated using the 6-meter walking speed test. A gait speed of <1 m/s indicated low physical fitness.

Fig. 1. Data processing flow chart.



(3) Muscle mass: measured using bioelectrical impedance analysis (Tanita BC-418, Tokyo, Japan). Skeletal muscle mass of the limbs divided by the square of height (ASM/ht^2), with cut-off points were $<5.7 \text{ kg}/\text{m}^2$ for women and $<7.0 \text{ kg}/\text{m}^2$ for men.⁶

Data collection and definitions

Collected data included demographic information (e.g. sex, age, education level) and health-related behaviours (e.g. smoking, drinking, exercise frequency). Body mass index (BMI) was calculated by dividing body weight by the square of height and was categorised as underweight ($<18.5 \text{ kg}/\text{m}^2$), healthy ($18.5\text{--}24 \text{ kg}/\text{m}^2$), overweight ($24\text{--}27 \text{ kg}/\text{m}^2$) and obese ($>27 \text{ kg}/\text{m}^2$).⁹ Laboratory test values included the following: (1) creatinine, with reference range of $0.6\text{--}1.2 \text{ mg}/\text{dL}$ for women and $0.7\text{--}1.3 \text{ mg}/\text{dL}$ for men; (2) estimated glomerular filtration rate (eGFR), categorised into 5 levels from normal renal function to end-stage renal disease;¹⁰ (3) fasting blood glucose ranging $70\text{--}99 \text{ mg}/\text{dL}$; (4) total cholesterol $<200 \text{ mg}/\text{dL}$; (5) triglycerides $<150 \text{ mg}/\text{dL}$; (6) low-density lipoprotein cholesterol (LDL-C) $<130 \text{ mg}/\text{dL}$; and (7) high-density lipoprotein cholesterol (HDL-C) of $>50 \text{ mg}/\text{dL}$ for women and $>40 \text{ mg}/\text{dL}$ for men.¹¹

Statistical analyses

The age- and sex-specific cut-offs for sarcopenia were developed to account for physiological

variations related to ageing and sex differences in muscle mass and function. This tailored approach ensures that the diagnostic criteria are sensitive to the distinct physical characteristics of each subgroup, thereby enhancing the accuracy of sarcopenia detection. To address age-related muscle decline and sex differences, measurement scores for grip strength, walking speed and muscle mass were standardised in 5-year age intervals. These intervals allowed us to adjust for physiological changes associated with ageing that influence sarcopenia risk.

To calculate these cut-offs, raw data were first converted to z scores using the formula: $Z = (x - \mu) / \sigma$, and these standardised scores were then summed to generate the ZoSCI. Optimal ZoSCI cut-off points for each age interval were determined through ROC curve analysis in conjunction with the AWGS criteria, with Youden's index applied to maximise the combined sensitivity and specificity for sarcopenia diagnosis. Youden's index, calculated as (sensitivity + specificity - 1), ranges from 0 to 1, with higher values indicating stronger discriminative ability. For each sex, Youden's index was computed across all points on the ROC curve, and the point with the maximum index value was selected as the optimal cut-off for ZoSCI. This method provided a precise, sex-specific threshold tailored to optimise diagnostic accuracy within the study population. Additionally,

Table 1. Characteristics of study participants.

Variables	Female				Male			
	65–69 years old	70–74 years old	75–79 years old	≥80 years old	65–69 years old	70–74 years old	75–79 years old	≥80 years old
	no. (%)	no. (%)	no. (%)	no. (%)	no. (%)	no. (%)	no. (%)	no. (%)
Education								
Elementary school	464 (47)	243 (60)	164 (69.5)	103 (81.1)	277 (33.6)	163 (36.1)	130 (52.4)	86 (50)
Junior high school	143 (14.5)	59 (14.6)	31 (13.1)	11 (8.7)	112 (13.6)	79 (17.5)	40 (16.1)	29 (16.9)
Senior high school	221 (22.4)	59 (14.6)	26 (11)	5 (3.9)	231 (28)	129 (28.5)	41 (16.5)	25 (14.5)
University or above	160 (16.2)	44 (10.9)	15 (6.4)	8 (6.3)	204 (24.8)	81 (17.9)	37 (14.9)	32 (18.6)
Health behaviours								
Smoke	28 (2)	7 (1.2)	6 (1.5)	2 (0.9)	162 (13.7)	47 (7.7)	44 (12.3)	23 (8.1)
Alcohol	25 (1.8)	6 (1)	1 (0.3)	0 (0)	177 (14.9)	51 (8.4)	35 (9.8)	18 (6.4)
Exercise								
No exercise	210 (14.9)	89 (14.9)	60 (15.3)	57 (26.4)	143 (12.1)	67 (11)	44 (12.3)	52 (18.4)
<150 minutes/week	1050 (74.5)	436 (73)	285 (72.9)	143 (66.2)	894 (75.5)	447 (73.4)	268 (74.9)	194 (68.6)
≥150 minutes/week	149 (10.6)	72 (12.1)	46 (11.8)	16 (7.4)	147 (12.4)	95 (15.6)	46 (12.8)	37 (13.1)
BMI, mean ± SD	24.88 ± 3.83	24.75 ± 3.82	24.74 ± 3.81	24.28 ± 3.8	25.52 ± 3.39	25.06 ± 3.36	24.73 ± 3.54	24.61 ± 3.33
Normal: 18.5–23.9 kg/m ²	595 (42.2)	243 (40.7)	157 (40.2)	89 (41.2)	380 (32.1)	219 (36)	133 (37.2)	108 (38.2)
Underweight: <18.5 kg/m ²	60 (4.3)	31 (5.2)	25 (6.4)	18 (8.3)	43 (3.6)	30 (4.9)	23 (6.4)	15 (5.3)
Overweight: 24–26.9 kg/m ²	391 (27.8)	174 (29.1)	107 (27.4)	61 (28.2)	388 (32.8)	191 (31.4)	111 (31)	93 (32.9)
Obese: ≥27 kg/m ²	363 (25.8)	149 (25)	102 (26.1)	48 (22.2)	373 (31.5)	169 (27.8)	91 (25.4)	67 (23.7)
Handgrip strength, mean ± SD	21.5 ± 3.82	20.04 ± 3.72	18.84 ± 3.95	16.97 ± 4.4	33.13 ± 6.06	31.01 ± 5.56	29.28 ± 5.43	25.47 ± 5.77
Gait speed, mean ± SD	1.03 ± 0.11	0.99 ± 0.11	0.94 ± 0.12	0.87 ± 0.13	1.05 ± 0.12	1.02 ± 0.11	0.99 ± 0.13	0.89 ± 0.13
Skeletal muscle mass, mean ± SD	6.85 ± 0.82	6.8 ± 0.87	6.88 ± 0.88	6.74 ± 1.03	8.57 ± 1.17	8.29 ± 1.14	8.23 ± 1.21	8.1 ± 1.29

Table 1. Characteristics of study participants. (Cont'd)

Variables	Female				Male			
	65–69 years old	70–74 years old	75–79 years old	≥80 years old	65–69 years old	70–74 years old	75–79 years old	≥80 years old
	no. (%)	no. (%)	no. (%)	no. (%)	no. (%)	no. (%)	no. (%)	no. (%)
Laboratory data								
Creatinine, mean ± SD	0.73 ± 0.31	0.76 ± 0.24	0.81 ± 0.28	0.96 ± 0.56	1 ± 0.24	1.06 ± 0.42	1.1 ± 0.34	1.21 ± 0.46
M: <0.7, F: <0.6 mg/dL	228 (17)	71 (12.6)	48 (12.9)	15 (7.4)	35 (3.1)	9 (1.5)	6 (1.8)	2 (0.8)
M: 0.7–1.3, F: 0.6–1.2 mg/dL	1091 (81.4)	475 (84.4)	302 (81.4)	160 (79.2)	1003 (88.8)	509 (87)	273 (82.2)	186 (70.7)
M: >1.3, F: >1.2 mg/dL	21 (1.6)	17 (3)	21 (5.7)	27 (13.4)	92 (8.1)	67 (11.5)	53 (16)	75 (28.5)
eGFR (mL/min/1.73 m²), mean ± SD	90.52 ± 21.76	84.84 ± 21.01	79.5 ± 21.04	69.78 ± 23.18	83.58 ± 19.19	78.47 ± 18.84	75.03 ± 19.94	67.11 ± 20.4
Stages 1–2	1267 (94.6)	503 (89.3)	313 (84.4)	132 (65.3)	1027 (90.9)	495 (84.6)	264 (79.5)	173 (65.8)
Stages 3a–3b	66 (4.9)	56 (9.9)	53 (14.3)	63 (31.2)	101 (8.9)	83 (14.2)	62 (18.7)	85 (32.3)
Stage 4	7 (0.5)	4 (0.7)	5 (1.3)	7 (3.5)	2 (0.2)	7 (1.2)	6 (1.8)	5 (1.9)
Glucose, mean ± SD	109.54 ± 27.23	110.26 ± 30.56	109.83 ± 27.42	113.89 ± 33.51	114.77 ± 29.67	113.07 ± 26.25	110.12 ± 22.17	108.16 ± 22.64
<70 mg/dL	3 (0.2)	0 (0)	0 (0)	0 (0)	1 (0.1)	1 (0.2)	1 (0.3)	0 (0)
70–99 mg/dL	522 (39)	220 (39.1)	154 (41.5)	78 (38.6)	347 (30.7)	172 (29.4)	123 (37)	99 (37.8)
≥100 mg/dL	815 (60.8)	343 (60.9)	217 (58.5)	124 (61.4)	782 (69.2)	412 (70.4)	208 (62.7)	163 (62.2)
Cholesterol, mean ± SD	189.77 ± 34.69	185.17 ± 31.83	180.16 ± 32.59	175.77 ± 34.39	172.99 ± 33.71	169.84 ± 33.23	169.24 ± 33.47	162 ± 32.26
≥200 mg/dL	472 (35.2)	176 (31.3)	89 (24)	42 (20.8)	226 (20)	102 (17.4)	61 (18.4)	31 (11.8)
Triglyceride, mean ± SD	132.89 ± 108.62	123.34 ± 57.97	127.44 ± 65.25	130.36 ± 59.1	132.8 ± 82.45	126.55 ± 80.26	118.63 ± 58.7	119.02 ± 69.77
≥150 mg/dL	363 (27.1)	138 (24.5)	97 (26.1)	64 (31.7)	337 (29.8)	161 (27.5)	69 (20.8)	59 (22.4)
LDL cholesterol, mean ± SD	103.77 ± 31.11	99.88 ± 29.16	95.15 ± 28.28	93.59 ± 32.63	97.23 ± 30.07	94.61 ± 29.69	94.42 ± 29.91	87.22 ± 28.39
>130 mg/dL	243 (18.2)	83 (14.7)	44 (11.9)	26 (12.9)	147 (13.1)	67 (11.5)	42 (12.7)	22 (8.4)
HDL cholesterol, mean ± SD	60.11 ± 15.28	60.92 ± 15.63	59.72 ± 16.19	56.18 ± 15.78	49.71 ± 13.11	50.44 ± 14.6	51.38 ± 14.57	51.05 ± 13.95
M: <40, F: <50 mg/dL	356 (26.6)	146 (25.9)	107 (28.8)	83 (41.1)	244 (21.6)	139 (23.8)	71 (21.4)	55 (20.9)

BMI: body mass index; eGFR: estimated glomerular filtration rate; F: female; HDL: high-density lipoprotein; LDL: low-density lipoprotein; M: male; SD: standard deviation

ZoSCI values were converted to percentile ranks to enhance comparability across populations. To assess the impact of independent variables on ZoSCI, forward selection multiple regression analysis was conducted. Data were analysed using SPSS version 22 (IBM Corp, NY, US), with statistical significance set at $P < 0.05$.

RESULTS

Demographic characteristics and prevalence of sarcopenia

A total of 5047 participants met the inclusion criteria, with an average age of 71.1 ± 5.92 years, ranging from 65 to 103 years. Participants were divided into 5-year age groups: 65–69 (51.4%), 70–74 (23.9%), 75–79 (14.9%) and 80+ years (9.9%). The sample included 2613 women (51.8%), with an average age of 70.69 ± 5.61 years, and 2434 men (48.2%) with an average age of 71.56 ± 6.27 years (Table 1). The overall prevalence of sarcopenia was 3.7%, with a higher rate in men (5.2%) than in women (2.3%); 1.3% of participants were classified as having severe sarcopenia. The prevalence of probable sarcopenia was 27.7%, increasing with age; nearly 50% of those aged over 75 years and 70% of those over 80 years were at risk. Approximately 2.7% exhibited muscle mass loss only (Fig. 2).

Generation of ZoSCI

The ZoSCI distribution was analysed using percentile ranking and AWGS diagnostic grading. ZoSCI values below the 50th percentile was negative, indicating values lower than average. At the 20th percentile, ZoSCI was approximately 1.5 standard deviation (SD) below the average, and within the 5th–95th percentile range, it ranged

around ± 3.2 SD. ZoSCI values were positive for the non-sarcopenia group, indicating values above average. For the probable sarcopenia group, ZoSCI values were approximately 1.5 SD below average, and for the sarcopenia group, ZoSCI values were 3–4 SD below average (Table 2 and Supplementary Tables S1–S3).

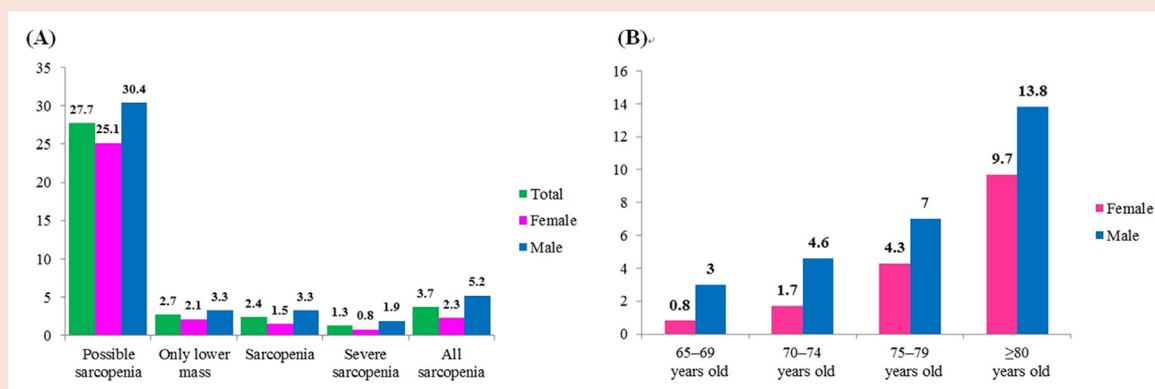
Optimal cut-offs point and accuracy of ZoSCI

Using the AWGS diagnostic criteria as the gold standard, the optimal ZoSCI cut-off for diagnosing sarcopenia in women was -1.97 , with a sensitivity of 0.932, specificity of 0.881 and an area under curve (AUC) of 0.962. Age-specific cut-offs for women were determined as follows: -2.07 for ages 65–69, -3.22 for ages 70–74, -2.26 for ages 75–79 and -1.35 for ages 80+ years, with sensitivity ranging from 0.839 to 0.941, specificity from 0.772 to 0.973 and AUC from 0.886 to 0.963. For men, the optimal cut-off was -1.85 , with sensitivity of 0.913, specificity of 0.880 and an AUC of 0.941. Age-specific cut-offs for men were established as -2.82 for ages 65–69, -1.21 for ages 70–74, -1.41 for ages 75–79 and -0.60 for 80+ years, with sensitivity ranging from 0.872 to 0.920, specificity from 0.775 to 0.964, and AUC from 0.864 to 0.972, respectively (Fig. 3).

Associated factors of ZoSCI

Multiple linear regression identified several factors affecting ZoSCI. For women, each 1-year increase in age was associated with a 0.12 decrease in ZoSCI (standard error [SE] 0.007, $P < 0.001$). Having a college education or higher increased ZoSCI by 0.34 (SE 0.12, $P = 0.004$). Engaging in less than 150 minutes and more than 150 minutes of exercise per week increased ZoSCI by 0.35

Fig. 2. Prevalence of sarcopenia.



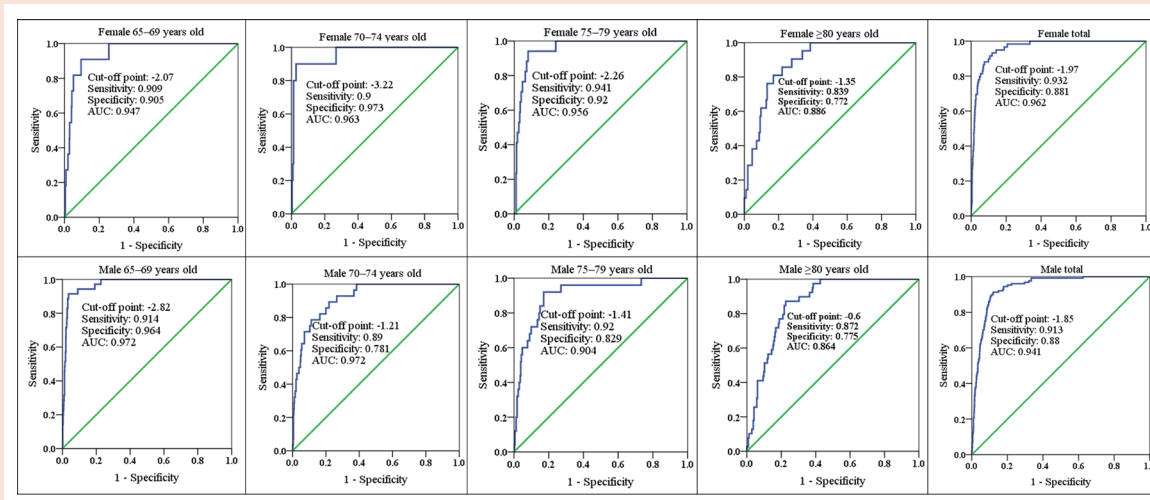
(A) Prevalence of possible sarcopenia, sarcopenia and severe sarcopenia, as well as the proportion of individuals with only low muscle mass, stratified by sex (total: green, female: pink, male: blue). (B) Prevalence of sarcopenia across different age groups (65–69, 70–74, 75–79 and ≥80 years), stratified by sex (female: pink, male: blue).

Table 2. ZoSCI distribution in percentile rank and AWGS diagnosis.

	Percentile rank of the sample							AWGS diagnosis			Non-sarcopenia	
	5th	15th	20th	50th	75th	85th	95th	Non-sarcopenia	Possible sarcopenia	All sarcopenia	Normal	Only lower mass
								Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)
Total												
Female	-3.27	-1.83	-1.39	-0.03	1.19	1.85	3.19	0.72 ± 1.5 (-2.77 to 7.4)	-1.71 ± 1.58 (-6.9 to 3.42)	-4.01 ± 1.44 (-8.39 to -0.61)	0.77 ± 1.47 (-1.88 to 7.4)	-1.07 ± 1.39 (-2.77 to 5.88)
Male	-3.39	-1.95	-1.54	0.001	1.31	2.04	3.21	0.91 ± 1.54 (-3.07 to 8.55)	-1.33 ± 1.66 (-8.48 to 5.32)	-3.42 ± 1.55 (-8.26 to 0.75)	1.02 ± 1.48 (-1.74 to 8.55)	-1.15 ± 1.06 (-3.07 to 3.29)
65–69 years old												
Female	-2.85	-1.72	-1.4	-0.13	1.12	1.86	3.27	0.35 ± 1.63 (-3.23 to 7.39)	-2.14 ± 1.63 (-6.96 to 3.08)	-3.33 ± 1.18 (-4.99 to -1.14)	0.41 ± 1.6 (-2.55 to 7.39)	-1.62 ± 1.26 (-3.23 to 1.49)
Male	-3.02	-1.86	-1.58	-0.03	1.23	1.94	3.1	0.5 ± 1.64 (-3.22 to 8.33)	-1.52 ± 1.66 (-8.3 to 4.95)	-3.72 ± 1.21 (-7.21 to -1.3)	0.56 ± 1.61 (-2.51 to 8.33)	-1.65 ± 1.35 (-3.22 to 2.92)
70–74 years old												
Female	-3.04	-1.73	-1.39	-0.13	1.18	1.85	3.12	0.7 ± 1.52 (-2.07 to 7.32)	-1.51 ± 1.51 (-7.37 to 2.49)	-3.98 ± 1.26 (-5.54 to -0.95)	0.73 ± 1.48 (-1.6 to 7.32)	-0.36 ± 2.44 (-2.07 to 6.87)
Male	-3	-1.75	-1.46	-0.06	1.3	1.96	3.08	0.74 ± 1.52 (-3.16 to 5.33)	-1.22 ± 1.61 (-7.25 to 4.03)	-3.1 ± 1.73 (-6.68 to -0.48)	0.9 ± 1.44 (-1.73 to 5.33)	-1.25 ± 0.92 (-3.16 to 1)
75–79 years old												
Female	-3.28	-1.98	-1.6	-0.07	1.36	1.84	2.93	1.14 ± 1.4 (-1.98 to 6)	-1.13 ± 1.46 (-5.69 to 2.82)	-3.5 ± 1.15 (-5.11 to -0.92)	1.24 ± 1.34 (-1.1 to 6)	-1.18 ± 0.38 (-1.98 to -0.65)
Male	-3.16	-1.82	-1.49	0.03	1.23	1.93	3.33	1.19 ± 1.51 (-2.05 to 6.17)	-0.8 ± 1.63 (-8.34 to 3.35)	-2.85 ± 1.75 (-7.86 to 1.23)	1.37 ± 1.45 (-1.17 to 6.17)	-0.39 ± 1.11 (-2.05 to 1.68)
≥80 years old												
Female	-2.98	-2.04	-1.66	-0.1	1.24	2.18	3.29	1.86 ± 1.16 (0.36 to 5.73)	-0.33 ± 1.59 (-4.36 to 4.29)	-2.34 ± 1.36 (-5.84 to -0.37)	1.88 ± 1.16 (0.36 to 5.73)	0.78
Male	-3.5	-2.17	-1.75	0.13	1.33	2	2.95	2.03± 1.15 (-0.5 to 6.12)	-0.24 ± 1.63 (-5.65 to 3.23)	-2.16 ± 1.46 (-6.28 to 0.14)	2.2 ± 1.03 (0.77 to 6.12)	0.61 ± 1.19 (-0.5 to 2.69)

AWGS: Asian Working Group for Sarcopenia; SD: standard deviation; ZoSCI: z score for the sarcopenia composite index

Fig. 3. Receiver operating characteristic curves for different age and sex groups.



AUC: area under curve

Note: The plots display sensitivity and specificity across age groups (65–69, 70–74, 75–79 and ≥80 years) for females (top), males (bottom) and the total population (rightmost). Each panel includes the cut-off, sensitivity, specificity and AUC.

(SE 0.12, $P=0.003$) and 0.63 (SE: 0.16, $P<0.001$), respectively. Underweight status was associated with a 0.52 decrease in ZoSCI (SE 0.18, $P=0.004$), while overweight and obese were associated with increases of 0.6 (SE 0.09, $P<0.001$) and 1.3 (SE 0.1, $P<0.001$), respectively. Age explained 14% of the variance in ZoSCI, with other factors contributing to a total of 24.2%.

For men, each 1-year increase in age was associated with a 0.14 decrease in ZoSCI (SE 0.007, $P<0.001$). Higher education levels increased ZoSCI by 0.36 (junior high), 0.32 (high school) and 0.47 (university) (SE 0.12, $P=0.002$; SE 0.1, $P=0.002$; SE 0.11, $P<0.001$, respectively). Engaging in less than 150 minutes and more than 150 minutes of exercise per week increased ZoSCI by 0.6 (SE 0.14, $P<0.001$) and 0.78 (SE 0.17, $P<0.001$), respectively. Overweight and obese were associated with increases in ZoSCI of 0.7 (SE 0.09, $P<0.001$) and 1.59 (SE 0.1, $P<0.001$), respectively. Creatinine levels below 0.7 mg/dL were associated with a 0.65 decrease in ZoSCI (SE 0.27, $P=0.014$). Age explained 22% of the variance in ZoSCI, with other factors contributing to a total of 34.5% (Table 3).

DISCUSSION

This retrospective study analysed data from 5047 participants over the past 5 years, revealing a sarcopenia prevalence of approximately 3.7% based on 2019 AWGS criteria, with higher rates in males than females (5.2% versus [vs] 2.3%). This prevalence is lower than global averages, typically reported between 3.9% and 15.4%.^{2,3,13–18} Several factors may account for this disparity. First,

the stricter cut-off points recommended by the AWGS for Asian populations¹⁹ could result in lower prevalence rates compared to studies using other criteria, such as EWGSOP. Second, lifestyle factors in Taiwan, including higher levels of physical activity and dietary habits supportive of muscle retention, may contribute to a healthier ageing population.²⁰ Third, our study focused on a relatively healthy elderly cohort, with 75% of the participants under 75 years old, potentially under-representing individuals with significant health issues that are more prevalent in older and less active populations. Sex differences in sarcopenia prevalence were also observed. This disparity may be attributed to greater age-related muscle loss in men, linked to hormonal changes such as testosterone decline.²¹ Cultural factors could also play a role, as older men in Taiwan tend to have higher sedentary rates than women, potentially exacerbating muscle loss.^{6,22} These findings highlight the importance of considering sex-specific risk factors in sarcopenia research and prevention, particularly in developing tailored intervention strategies for at-risk populations. Furthermore, probable sarcopenia was identified in 27.7% of participants, with significant progression in those over 75 years, while 3% exhibited isolated muscle mass loss, highlighting the need for a standardised score that integrates all indicators.

ZoSCI is a standardised score that integrates grip strength, walking speed and muscle mass into a single measure, offering a comprehensive assessment than individual measurements. At the 5th percentile, ZoSCI was approximately -3.2, which may not fully align with Seashore's standardi-

Table 3. Multiple linear regression analysis of factors affecting ZoSCI.

Variables (reference group)	Female		Male	
	β	SE	β	SE
Age (years)	-0.12 ^a	0.007	-0.14 ^a	0.007
Education (elementary school)				
Junior high school	NA	NA	0.36 ^b	0.12
Senior high school	NA	NA	0.32 ^b	0.1
University or above	0.34 ^b	0.12	0.47 ^a	0.11
Exercise (No exercise)				
<150 mins/week	0.35 ^b	0.12	0.6 ^a	0.14
≥150 mins/week	0.63 ^a	0.16	0.78 ^a	0.17
BMI (healthy body weight)				
Underweight	-0.52 ^b	0.18	NA	NA
Overweight	0.6 ^a	0.09	0.7 ^a	0.09
Obese	1.3 ^a	0.1	1.59 ^a	0.1
Creatinine (M: 0.7–1.3, F: 0.6–1.2 mg/dL)				
M: <0.7, F: <0.6 mg/dL	NA	NA	-0.65 ^c	0.27
Cumulative R2		0.24		0.35
Adjusted R2		0.24		0.34

^a $P < 0.00$; ^b $P < 0.01$; ^c $P < 0.05$

BMI: body mass index; NA: not applicable; SE: standard error; ZoSCI: z score for the sarcopenia composite index

sation principles.²³ For females, below-average ZoSCI values extended to the 50th percentile, while for males, values were positive from the 50th percentile onward. Among younger elders, ZoSCI remained negative at the 50th percentile, indicating that half had values below the mean, suggesting a need for early preventive interventions, such as nutrition, exercise and possibly pharmaceutical options. Further analysis by AWGS classification showed that some non-sarcopenic participants had negative ZoSCI values, reaching as low as 3 standard deviations below the mean. This could reflect performance variability among participants or isolated muscle mass loss. Similarly, some participants classified as “normal” also had negative ZoSCI values, indicating lower muscle mass or quality relative to their peers. These findings underscore the importance of early prevention strategies for sarcopenia.

In applying ZoSCI, ROC curve analysis identified optimal cut-off values for diagnosing sarcopenia, demonstrating high diagnostic accuracy. With increasing age, these cut-offs align more closely

with age group averages, suggesting greater ZoSCI variation among younger elders. The average participant age was 71.1 years, with 54.9% of those over 75 years diagnosed with sarcopenia and 23.5% classified as non-sarcopenic. ZoSCI scores decreased with age, consistent with studies showing increased odds of sarcopenia with age.^{13,16,24,25} This decline is linked to an annual muscle loss rate of approximately 0.5%, which accelerates to 1% per year after age 50 years, and further impacted by factors like inadequate nutrition and decreased physical activity.^{26,27} Furthermore, education level significantly influenced ZoSCI scores, with higher education associated with higher scores. Supporting this, Tyrovolas et al. found that higher education provides protection against sarcopenia, possibly due to better knowledge about diet and physical activity, which positively impacts health outcomes.²⁸ Insufficient physical activity is consistently associated with declines in muscle mass.^{16,18,24,25,29} This study found that higher exercise frequency significantly increased ZoSCI scores in both

sexes, suggesting the importance of regular physical activity in maintaining muscle function and mass, particularly as ageing contributes to muscle atrophy.³⁰ The World Health Organization recommends regular physical activity to mitigate sarcopenia and prevent disability.³¹ Our results showed that being overweight or obese was associated with higher ZoSCI scores across sexes, while being underweight was linked to lower scores among elderly females. This finding aligns with studies that associate low BMI and underweight status with a higher risk of sarcopenia.^{18,25,32} Low body weight may indicate poor nutrition, especially insufficient protein intake, while higher body weight may support muscle mass retention.^{18,33} However, sarcopenic obesity, characterised by excessive fat coupled with low muscle mass, presents additional health risks, including metabolic syndrome, cardiovascular disease and osteoporosis.^{34,35} Excess adipose tissue increases the production of cytokines and adipokines, leading to inflammation, insulin resistance and muscle breakdown, which contribute to muscle loss.³⁶ In this study, BMI was used to assess body composition but did not differentiate between types of fat, making it challenging to identify sarcopenic obesity among overweight or obese individuals. Further research should establish precise BMI cut-offs for sarcopenic obesity and enhance health databases for the elderly with measures of abdominal and visceral fat. Creatinine, a marker for eGFR, serves as an indicator of renal function. Elevated creatinine levels suggest reduced eGFR, while low levels may indicate muscle mass loss, as 90% of creatine phosphate is stored in muscle.^{37,38} In this study, lower creatinine levels were associated with reduced ZoSCI scores in elderly males. Sarcopenia diagnosis may benefit from assessing both muscle function and serum creatinine concentrations. Thongprayoon et al. identified a U-shaped distribution of serum creatinine, linking low muscle mass and renal dysfunction to higher mortality rates.³⁹

The study's findings highlight several advantages of using ZoSCI, which could substantially influence clinical pathways for sarcopenia diagnosis and intervention. First, ZoSCI uses continuous numerical values to assess sarcopenia indicators, allowing for more precise evaluation compared to categorical tools. This approach provides a nuanced understanding of each patient's condition, facilitating early detection of sarcopenia progression. Unlike the SARC-F questionnaire, which relies on subjective self-reports and is susceptible to variability, ZoSCI generates objective, quantifiable data that enhance diagnostic accuracy, particularly for mild cases that subjective assessments may overlook. Furthermore, ZoSCI offers a streamlined, single-score approach

in contrast to the multi-step EWGSOP process, making it more efficient for high-volume clinical settings. Another significant advantage of ZoSCI is its focus on early intervention from a preventive healthcare perspective, without prioritising whether muscle function or mass declines first. By providing a balanced risk profile, ZoSCI allows clinicians to identify at-risk individuals early and initiate targeted interventions at optimal stages. This emphasis on prevention and early intervention represents a shift from traditional sarcopenia assessments, supporting the integration of ZoSCI into routine screening and proactive care.

This study has some limitations that should be acknowledged. First, the retrospective design and exclusion of participants with incomplete data may have introduced selection bias, potentially resulting in a healthier sample and underestimating the prevalence of sarcopenia. Moreover, the final sample may represent a younger and generally healthier elderly demographic, biased toward individuals more inclined to participate in health check-ups. This limitation may affect the generalisability of the findings to the broader elderly population, particularly those with compromised health. Additionally, the study did not account for variables such as nutritional status, cognitive function and other lifestyle factors known to influence sarcopenia risk and progression.⁶ Future research should adopt a prospective design and incorporate these factors to provide a more comprehensive understanding of sarcopenia risk across diverse elderly populations. Second, while widely used sarcopenia diagnostic criteria, such as AWGS for East Asian populations and EWGSOP for Western populations, utilise similar measurement tools, they establish different cut-off points, leading to regional variations in sarcopenia prevalence. This variation underscores the global importance of sarcopenia research and highlights the potential for adapting ZoSCI for diverse populations. Based on AWGS criteria and data from an elderly Asian population, ZoSCI offers a valuable model for assessing sarcopenia among East Asian populations. Although these norms provide a strong foundation for use in Taiwan and similar demographic groups, further validation against international standards, such as EWGSOP, is essential to ensure compatibility and accuracy beyond East Asia. Future studies should investigate ZoSCI's adaptability across diverse regions and ethnic groups, making physiological calibrations as needed. Furthermore, international collaborations could facilitate standardisation efforts, enabling comparative studies and promoting ZoSCI's broader global application. Third, ZoSCI was developed by combining standardised scores for grip strength, walking speed and muscle mass

without assessing each component's individual contribution to the overall evaluation. Future research should investigate the impact of each component and evaluate their predictive value for adverse outcomes. Such studies would allow for adjustments in the weighting of each indicator, enhancing ZoSCI's accuracy and clinical relevance. Finally, while ZoSCI provides a standardised tool for diagnosing sarcopenia, its implementation may face challenges in resource-limited settings due to specific equipment requirements. However, ZoSCI's flexible framework allows for adaptation across diverse healthcare systems. In well-resourced settings, ZoSCI can be integrated into routine screening, whereas in lower-resource environments, alternative methods, such as simplified body composition measures, may approximate diagnostic criteria.⁶ Furthermore, variations in ZoSCI normative scores across healthcare systems highlight the need for regional calibrations.⁴⁰ Aligning ZoSCI with local tools, infrastructure and norms enhances its diagnostic utility, facilitating early sarcopenia detection across diverse contexts.

CONCLUSION

To the best of authors' knowledge, this study is the first attempt to develop and validate ZoSCI, a composite index that combines standardised scores of grip strength, walking speed and muscle mass to assess sarcopenia. ZoSCI's continuous, quantitative evaluation enhances diagnostic precision and facilitates early sarcopenia detection. By providing a standardised framework, ZoSCI supports consistent research across populations, helping to identify sarcopenia risk factors and guide targeted interventions. Its adaptability across various healthcare settings makes ZoSCI a valuable tool for global use. With international validation, ZoSCI has the potential to standardise sarcopenia assessment, foster preventive strategies and ultimately improve outcomes for ageing populations worldwide.

Supplementary materials

Table S1. Z handgrip strength distribution in percentile rank and AWGS diagnosis.

Table S2. Z gait speed distribution in percentile rank and AWGS diagnosis.

Table S3. Z muscle mass distribution in percentile rank and AWGS diagnosis.

Ethics statement

This study was approved by the Institutional Review Board of Far Eastern Memorial Hospital, New Taipei City, Taiwan (111059-F).

Declaration

The authors declare there are no affiliations with or involvement in any organisation or entity with any financial interest in the subject matter or materials discussed in this manuscript.

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