sciendo 10.2478/sjph-2025-0013 Zdr Varst. 2025;64(2):103-111

Puš K, Pišot S, Marušič U, Peskar M, Teraž K, Kalc M, Blažun Vošner H, Kokol P, Završnik J, Šimunič B. Prevalence of sarcopenia among Slovenian older adults and associated risk factors. Zdr Varst. 2025;64(2):103-111. doi: 10.2478/sjph-2025-0013.

PREVALENCE OF SARCOPENIA AMONG SLOVENIAN OLDER ADULTS AND ASSOCIATED RISK FACTORS

PREVALENCA SARKOPENIJE MED STAREJŠIMI ODRASLIMI V SLOVENIJI IN POVEZANI DEJAVNIKI TVEGANJA

Katarina PUŠ [1,2,3*], Saša PIŠOT [1], Uroš MARUŠIČ [1,2], Manca PESKAR [1,4], Kaja TERAŽ [1,5], Miloš KALC [1], Helena BLAŽUN VOŠNER [6], Peter KOKOL [6], Jernej ZAVRŠNIK [6], Boštjan ŠIMUNIČ [1]

[1] Science and Research Centre Koper, Institute for Kinesiology Research, Garibaldijeva ulica 1, Koper, Slovenia
[2] Alma Mater Europaea University, Department of Health Sciences, Maribor, Slovenska 17, 2000 Maribor, Slovenia
[3] Faculty of Sport, University of Ljubljana, Gortanova ulica 22, 1000 Ljubljana, Slovenia
[4] Biological Psychology and Neuroergonomics, Department of Psychology and Ergonomics, Faculty V: Mechanical Engineering and Transport Systems, Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany
[5] Clinical University Department of Medical, Surgical, and Health Sciences, University of Trieste, Strada di Fiume, 447, 34149 Trieste, Italy
[6] Community Healthcare Center Adolf Drolc, Ulica talcev 9, 2000 Maribor, Slovenia

Received: Sep 18, 2024
Accepted: Jan 07, 2025

Original scientific article

ABSTRACT

Introduction: Sarcopenia is a multifaceted condition affecting between 10 and 16% of the global population, and although multiple classification algorithms exist, no prevalence has been reported for a representative sample of the Slovenian population. Furthermore, multiple behavioural factors, such as malnutrition, physical inactivity, sedentary lifestyle and lower cognitive function, can contribute to the risk of sarcopenia. This study aims to: a) determine sarcopenia prevalence among Slovenian older adults according to different classification algorithms, b) compare the agreement among the algorithms and c) evaluate the relationship between proposed risk factors and sarcopenia.

Methods: 654 participants (≥60 years, 30.4% males) have been classified into sarcopenia groups according to eight algorithms, and agreement (Fleiss K) between them was calculated. Additionally, age, sex, nutritional status, physical activity, sedentary levels and cognitive function were assessed as sarcopenia risk/protective factors.

Results: The prevalence of sarcopenia according to EWGSOP2 was 4.1%, ranging from 2.1% to 15.3%, when classified by all eight algorithms. Overall agreement between algorithms was weak (K=.429; 95% CI .414 to .444) with 0.6% of participants classified as sarcopenic by all eight algorithms. Adequate nutrition and physical activity were identified as protective factors, while age, lower cognitive function and sedentary lifestyle were considered risk factors.

Conclusion: Sarcopenia prevalence among the Slovenian general population was lower than in the global population. We can conclude that different sarcopenia algorithms lead to a different prevalence of sarcopenia. It is of great importance to be cautious when comparing prevalences among studies and to further validate the classification algorithms.

Keywords:
Sarcopenia
Prevalence
Epidemiology
Classification algorithms
Risk factors

IZVLEČEK

Uvod: *Čeprav je sarkopenija kompleksna bolezen, ki prizadene med 10 in 16 % svetovnega prebivalstva in obstaja za njo več klasifikacijskih algoritmov, ki vnašajo širok razpon poročane prevalence, ne obstajajo poročila o prevalenci sarkopenije med splošno populacijo slovenskih starejših odraslih. K tveganju za razvoj sarkopenije lahko prispevajo dejavniki življenjskega sloga, kot so neustrezna prehranjenost, gibalna neaktivnost, sedeči življenjski slog in zmanjšana kognitivna funkcija. Namen raziskave je ugotoviti prevalenco sarkopenije med populacijo slovenskih starejših odraslih, ugotoviti ujemanje med različnimi klasifikacijskimi algoritmi in preveriti dejavnike tveganja ali preventivne dejavnike.*

Metode: *V raziskavi je sodelovalo 654 preiskovancev (≥ 60 let, 30,4 % moških). Uporabljeni so bili testi, ki so predlagani v EWGSOP2 (vprašalnik Sarc-F, jakost stisk pesti, 5-kratno vstajanje s stola, test vstani-in-pojdi, hitrost hoje, električna bioimpedance), preiskovanci pa so bili razvrščeni v skupine sarkopenije glede na osem različnih algoritmov (SDOC, EWGSOP, EWGSOP2, EWGSOP2 s SARC-F, EWGSOP2 brez SARC-F, EWGSOP2 s SARCalF, IWGS, FNIH). Poleg tega so bili zajeti tudi podatki o starosti, spolu, prehranjenosti (vprašalnik MNA), gibalni aktivnosti in sedentarnih navadah (vprašalnik GPAQ) ter kognitivni funkciji (TMT-a in TMT-b), ki lahko kažejo na tveganje za razvoj sarkopenije.*

Rezultati: *Prevalenca sarkopenije je 15,3 %, 11,8 %, 4,1 %, 4,4 %, 7,7 %, 7,7 % in 2,1 % ugotovljena z algoritmi SDOC, EWGSOP, EWGSOP2, EWGSOP2 s SarCALF in EWGSOP2 brez SARC-F, FNIH in IWGS. Ujemanje med algoritmi je nizko (K = 0,429, 95 % IZ od 0,414 do 0,444), in zgolj 0,6 % preiskovancev je sarkopeničnih po vseh osmih algoritmih. Ugotovili smo, da ustrezna prehranjenost in gibalna dejavnost zmanjšujeta tveganje za razvoj sarkopenije in predstavljata preventivna dejavnika, medtem ko so starost, zmanjšana kognitivna funkcija in sedeč življenjski slog dejavniki tveganja in povečujejo tveganje za razvoj sarkopenije.*

Zaključek: *Med slovensko populacijo starejših odraslih je opaziti manjšo pojavnost sarkopenije kot v svetovni populaciji, ne glede na uporabljen algoritem klasifikacije. Kljub temu je definicijo sarkopenije in s tem klasifikacijske algoritme potrebno poenotiti, poleg tega pa na razvoj sarkopenije vpliva več dejavnikov, ki jih je mogoče preprečiti. Z ustreznimi javnozdravstvenimi intervencijami jih je možno nadzorovati in s tem zmanjšati posledice sarkopenije.*

Ključne besede:
sarkopenija
prevalenca
epidemiologija
klasifikacijski algoritmi
dejavniki tveganja

***Correspondence:** katarina.pus@zrs-kp.si

1 INTRODUCTION

Sarcopenia has been shown to affect between 10 and 16% of the global population based on various classification algorithms (1). Multiple research groups have proposed algorithms for sarcopenia classification (2–7), resulting in discrepancies in the reported prevalence which could be attributed to the continuous revisions of the criteria for defining sarcopenia. The algorithms differ in the proposed methods to evaluate domains of strength, muscle mass or physical performance. Despite efforts to compare and reconcile these algorithms, a universal standard for sarcopenia classification has yet to be established, regardless of its recognition as a disease (8). A unified classification algorithm is needed for multiple reasons: diagnosis confirmation, accurate prognosis and effective treatment plans (9). This multifaceted problem has recently been highlighted and points to various contributing factors including limited measurement methods for muscle mass in large cohorts, lack of consensus, inconsistent evaluation of functional status in older adults and lack of public awareness (10). Sarcopenia prevalence has been assessed in different countries, however, there is no data on sarcopenia prevalence in a representative sample of Slovenian older adults.

In addition to the large prevalence variance and weak agreement between classification methods (11), sarcopenia is a complex condition resulting from various contributing factors. For effective prevention, it is imperative to know the factors that can affect sarcopenia development. The natural ageing process is inevitable and associated with a gradual loss of muscle mass and strength (12) and age has been recognised as the most important risk factor of sarcopenia (13, 14). Furthermore, there are lifestyle behavioural factors (physical inactivity or poor dietary habits) that can significantly contribute to the risk of developing sarcopenia and are modifiable through targeted interventions (15, 16). Malnutrition can be frequently associated with a reduction of muscle mass and muscle strength, but their causal relationship is not yet well established (2, 15). However, the risk of malnutrition increases with age due to inadequate nutritional intake and it has major impacts on individuals' independence and sarcopenia presence (17). Additionally, diminished physical activity with age, especially when coupled with increased physical inactivity, is a first modifiable but still prevalent risk factor of decreased muscle mass and function loss (18). It has been found that low levels of physical activity present a risk factor for sarcopenia onset among community-dwelling adults (19). Beyond physical factors, cognitive decline has been shown to have an association with sarcopenia (20), and the literature highlights the two-way association between cognitive and muscular deterioration, as it has been proposed that cognitive decline and sarcopenia share pathophysiological pathways (21).

This study aims to: a) determine sarcopenia prevalence among Slovenian older adults according to different classification algorithms, b) compare the agreement among the algorithms and c) evaluate the relationship between proposed risk factors and sarcopenia.

2 METHODS

2.1 Study design

This was a cross-sectional study conducted with older adults across 11 (out of 12) Slovenian regions between February 2022 and December 2023. Regional health centres were contacted and invited to take part in the study and to provide their institutions' facilities to conduct the testing.

2.2 Participants and eligibility criteria

The inclusion criteria were: a) minimum age of 60 years and b) signed informed consent.

Exclusion criteria were a) acute illnesses, b) exhaustion, c) cancer in terminal stages, d) infections, e) hospitalisation. Participants were randomly invited to participate via invitation by their chosen general practitioner and they gave preliminary informed consent at the local health centre. Based on region size, a representative sample was randomly selected and contacted to participate in the study via phone calls or e-mails. Altogether 1,184 informed consents were collected, 686 participants accepted the invitation and 654 attended the measurement day.

2.3 Screening protocol

We have followed the revised European working group on sarcopenia in older people (EWGSOP2) algorithm and used proposed tests with an addition of parameters of age, sex, nutritional status, physical activity and cognitive function. The protocol started with the screening tools Sarc-F (22) and Sarc-CalF (23). Muscle strength was assessed with a handgrip strength (HGS) test of the dominant hand using a hydraulic dynamometer (Jamar, Sammons Preston, USA) and a five-repetition sit to stand (5STS) test (3). HGS was measured in a seated position, elbow flexed at 90° and participants were instructed to squeeze the dynamometer three times with maximal effort. An average of three attempts was used for the analysis. In the 5STS test participants were instructed to stand up from the chair to a fully extended position five times as fast as possible with arms on the chest. Total time was measured with a stopwatch in seconds. Muscle mass was estimated with the tetrapolar electrical bioimpedance device BIA 101 Anniversary (Akern Srl, Florence, Italy) in a supine position. Appendicular skeletal mass (ASM), ASM normalised to height (ASM/ht2) and skeletal mass index (SMI) were used in the analysis. Where measures of muscle mass were not

possible, calf circumference was used (cut-off value for low muscle mass for men was ≤34 cm and for women ≤33 cm). Physical performance was assessed with gait speed over 4 metres and a timed up-and-go (TUG) test over 3 metres. For gait speed, two time measuring gates (Beam trainer timing system, Seedgrov d.o.o., Ljubljana, Slovenia) were set over the course of 4 metres (24). For both tests, an average of two repetitions was used for the analysis.

2.3.1 Nutritional status

The Slovenian version of Mini Nutritional Assessment (MNA) was used to evaluate nutritional status (25). The MNA is an internationally validated tool for assessing the risk of malnutrition and nutritional status in older adults and is scored with a maximum of 30 points, with the following indications: ≥24 points - being well-nourished, 17-23.5 points - risk of malnutrition, and <17 points - undernourished.

2.3.2 Physical activity

Physical activity level and sedentary behaviour were evaluated with the Slovenian version of the Global Physical Activity Questionnaire (GPAQ) (26), which comprises a 16-item assessment of three main domains: work, recreation and transport. Participants determine the intensity, duration and frequency of their physical activity from which we have calculated time spent in moderate to vigorous physical activity (MVPA). One of the items assessed sedentary behaviour over one day in minutes.

2.3.3 Cognitive function

Cognitive function was assessed with a Trail-making test (TMT) (27) with its normative values (28) to evaluate visual search speed and executive function. In TMT-a and TMT-b, participants are asked to connect 25 encircled numbers, or alternating numbers and letters, respectively, in an increasing fashion on a sheet of paper. The completion time (in seconds) for each part is recorded.

2.4 Sarcopenia algorithms

We have included both primary and secondary types of sarcopenia. Participants have been classified regarding the presence of sarcopenia, using eight algorithms validated in the European population (Table 1): Sarcopenia Definition and Outcomes Consortium (SDOC) (5), European working group on sarcopenia in older people (EWGSOP) (2), EWGSOP2 (3), EWGSOP2 with Sarc-CalF, EWGSOP2 without Sarc-F, International working group on sarcopenia (IWGS) (6) and Foundation for the National Institutes of Health (FNIH) (4).

2.5 Sample size calculation

Sample size was calculated at α=5%, error of 3% and expected prevalence of 15% according to the global prevalence data (1). A minimum of 544 participants would be necessary to carry out the present study.

2.6 Statistical analysis

Statistical analysis was conducted in SPSS software (IBM, Chicago, IL, USA), version 29.0. To compare multiple sarcopenia classification algorithms, Fleiss's Kappa test was used. For this, data was grouped into two categories – no sarcopenia (consisting of groups of non-sarcopenic and presarcopenic participants) and sarcopenia (consisting of groups of sarcopenic and severely sarcopenic participants). To interpret the agreement analysis, the following classification categories were considered: 0-0.20 represents no agreement; 0.21-0.39 minimal agreement; 0.40-0.59 weak agreement; 0.60-0.79 moderate agreement; 0.80-0.90 strong agreement; and >0.90 very strong agreement (29). To calculate risk factors, binary logistic regression was used, and participants were classified using the EWGSOP2 algorithm where the above-mentioned two categories were used. Due to missing values for cognitive function (50.3%), the logistic regression model was calculated separately for each parameter (age, sex, BMI, MNA, sedentary time, cognitive function, MVPA). The significance threshold used was $a<.05$.

3 RESULTS

3.1 Prevalence

Descriptive statistics of the sample (N=654; 30.4% males) are presented in Table 2. All participants had the data to be classified with at least one algorithm.

Table 1. Sarcopenia classification algorithms with cut-off points.

Algorithm name	Algorithm with cut-off points	Sarcopenia	Sarcopenia severity
SDOC (5)	**Physical performance** (<0.8m/s) **Muscle strength** (HGS; M:<35.5kg; F:<20kg)	- physical performance AND - muscle strength	NA
EWGSOP (severity algorithm) (2)	**Muscle mass** (BIA: ASM/ht^2; M:<8.87 kg/m^2, F:<6.42 kg/m^2) **Muscle strength** (HGS; M:<30 kg, F:<20 kg) **Physical performance** (gait speed<0.8 m/s)	- muscle mass AND - muscle strength OR - physical performance	- muscle mass AND - muscle strength OR - physical performance
EWGSOP (2)	**Physical performance** (gait speed≤0.8m/s) **Muscle mass** (BIA: ASM/ht^2; M:<8.87kg/m^2, F:<6.42 kg/m^2) **Physical performance** (gait speed>0.8m/s) **Muscle strength** (HGS; M:<30 kg, F:<20 kg) **Muscle mass** (BIA: ASM/ht^2; M:<8.87kg/m^2, F:<6.42kg/m^2)	- physical performance AND - muscle strength - normal physical performance AND - muscle strength AND - muscle mass	NA
EWGSOP2 (3)	**Positive screening test** (Sarc-F≥4) **Muscle strength** (HGS; M:<27kg; F:<16kg OR 5STS>15s) **Muscle quantity or quality** (BIA ASM/ht^2; M:<7.0kg/m^2; F:<5.5kg/m^2) **Physical performance** (gait speed≤0.8m/s OR TUG≥20s)	Positive screening test AND - muscle strength AND - muscle quantity AND/OR - physical performance	Positive screening test AND - muscle strength AND - muscle quantity AND/OR - physical performance
EWGSOP2 without Sarc-F	**Muscle strength** (HGS; M: <27kg; F: <16kg OR 5STS >15s) **Muscle quantity or quality** (BIA ASM/ht2; M:<7.0 kg/m^2; F:<5.5kg/m^2) **Physical performance** (gait speed≤0.8m/s OR TUG≥20 s)	- muscle strength AND - muscle quantity AND/OR - physical performance	- muscle strength AND - muscle quantity AND - physical performance
IWGS (6)	**Muscle quantity** (BIA ASM/ht2; M:<7.23kg/m^2; F:<5.67kg/m^2) **Physical performance** (gait speed<1.0m/s)	- physical performance AND - muscle quantity	NA
FNIH (4)	**Muscle quantity** (BIA ASMM; M<19.75kg; F<15.02kg) **Muscle strength** (HGS; M:<26kg; F:<16kg) **Physical performance** (gait speed<0.8m/s)	- muscle strength AND - muscle quantity	- muscle strength AND - muscle quantity AND - physical performance

Legend: EWGSOP: European Working Group on Sarcopenia in Older People; SDOC: Sarcopenia Definitions and Outcomes Consortium; IWGS: International Working Group on Sarcopenia; FNIH: Foundation for the National Institutes of Health; M: males; F: females; BIA: electrical bioimpedance; ASM/ht2: appendicular skeletal mass normalised to height; ASMM: appendicular skeletal muscle mass; TUG: timed up-and-go test; 5STS: five-repetition sit to stand test; HGS: hand grip strength; NA: not applicable

Table 2. Descriptive statistics.

	N	Minimum	Maximum	Mean	Std. deviation
Age	654	60	97	72.45	8.74
Body height (cm)	638	140.4	186.5	163.55	8.53
Body mass (kg)	638	44.0	133.89	77.04	14.28
BMI (kg/m^2)	637	17.35	52.13	28.76	4.78
5STS (s)	590	3.37	41.06	11.11	4.49
TUG (s)	629	3.60	66.97	8.47	5.91
HGS	645	1.00	76.00	27.44	11.32
Gait speed (m/s)	639	.12	2.64	1.14	.39
Calf Circumference (cm)	649	16.4	50.7	36.18	3.50
SARC-F	648	0	10	1.87	2.50
SARC-CalF	648	0	20	3.93	5.14
MNA	649	11.5	30	25.35	4.18
TMT-A (s)	524	13.38	314.70	49.38	31.00
TMT-B (s)	446	24.57	439.91	106.49	62.32
ASM/ht^2 (kg/m^2)	621	4.23	11.52	6.78	1.02

Legend: BMI: body mass index; 5STS: five-repetition sit to stand test; TUG: timed up-and-go test; HGS: hand grip strength; MNA: Mini Nutritional Assessment; TMT: trail-making test; SMI: skeletal muscle index; ASM/ht^2: appendicular skeletal mass normalised to height

The prevalence of sarcopenia severity was highest and lowest when estimated by SDOC (15.3%) and IWGS (2.1%), respectively (Table 3). We found weak agreement between eight described algorithms on the sample of 613 participants (K=.429 (95% CI .414 to .444), p<.001). Only 4 (0.6%) participants were classified as sarcopenic with all eight algorithms.

3.2 Protective and risk factors for sarcopenia

Adequate nourishment and physical activity were identified as protective factors, and age, lower cognitive function and sedentary lifestyle as risk factors for sarcopenia. Higher body mass index (BMI) represented a trend of a risk factor.

Table 3. Sarcopenia and sarcopenia severity prevalence.

	EWGSOP severity N (%)	EWGSOP N (%)	EWGSOP2 N (%)	EWGSOP2 without SARC-F N (%)	EWGSOP2 with SARC-CalF N (%)	SDOC N (%)	IWGS N (%)	FNIH N (%)
No sarcopenia	**553 (84.6)**	**546 (83.5)**	**627 (96.9)**	**602 (92.0)**	**625 (95.6)**	**539 (82.4)**	**599 (91.6)**	**567 (86.7)**
No sarcopenia	450 (68.8)		547 (83.6)	459 (70.2)	594 (90.8)			
Presarcopenia	96 (14.7)		80 (12.2)	143 (21.9)	31 (4.7)			
Sarcopenia	**77 (11.8)**	**77 (11.8)**	**27 (4.1)**	**50 (7.7)**	**29 (4.4)**	**100 (15.3)**	**14 (2.1)**	**50 (7.7)**
Sarcopenia	40 (6.1)		3 (.5)	19 (2.9)	9 (1.4)			15 (2.3)
Severe sarcopenia	37 (5.7)		24 (3.7)	31 (4.7)	20 (3.1)			35 (5.4)
Missing data	24 (3.7)	31 (4.7)	/	2 (.3)	/	15 (2.3)	41 (6.3)	37 (5.7)
Total	**654 (100.0)**	**654 (100.0)**	**654 (100.0)**	**654 (100.0)**	**654 (100.0)**	**654 (100.0)**	**654 (100.0)**	**654 (100.0)**

Legend: EWGSOP: European Working Group on Sarcopenia in Older People; SDOC: Sarcopenia Definition and Outcomes Consortium; IWGS: international working group on sarcopenia; FNIH: Foundation for the National Institutes of Health

Table 4. Factors of sarcopenia using logistic regression model.

	95% CI for odds ratio			
	Odds ratio	Lower	Upper	Sig.
Age	1.189	1.153	1.227	<.001
Sex	1.283	.804	2.048	.296
BMI	1.045	1.000	1.092	.049
MNA	.656	.598	.719	<.001
TMT-a	1.026	1.018	1.034	<.001
TMT-b	1.011	1.007	1.016	<.001
Sedentary	1.006	1.004	1.008	<.001
MVPA	.975	.966	.983	<.001

Legend: BMI: body mass index; MNA: Mini Nutritional Assessment; TMT: trail-making test; MVPA: moderate to vigorous physical activity

4 DISCUSSION

This study aimed to determine sarcopenia prevalence among Slovenian older adults according to different classification algorithms and its agreement and we found that sarcopenia is present between 2.1 and 15.3% of participants, while only 0.6% of participants were classified as sarcopenic across all eight used algorithms. The relationship between risk factors has been evaluated and it has been found that adequate nutrition and regular physical activity represent a protective factor, while age, lower cognitive function and sedentary lifestyle represent a risk factor for sarcopenia onset.

Sarcopenia prevalence depends on the classification algorithm being used and was between 2.1% (IWGS) and 15.3% (SDOC) among the general Slovenian population. Our findings are similar to the ones from a Spanish sample of community-dwelling older adults, which reported sarcopenia prevalence between 2.1 and 11.6% according to the EWGSOP2 algorithm, depending on the classification tests being used (30), and to prevalence in other European countries (France, Germany, Switzerland and Portugal) where sarcopenia was found in between 0.7 and 16.8% of older adults using different algorithms (31).

We found sarcopenia prevalence in 15.3% using the SDOC algorithm, which aligns with previous findings from the Hertfordshire cohort study (32,33). However, other population-based cohorts (33) reported lower prevalence for men using this algorithm while omitting the female population. The SDOC algorithm classified only 2% of the sample as sarcopenic among the community-dwelling population from four different European countries, of which there were no sarcopenic participants detected in Germany (31). Importantly, SDOC does not use muscle mass as a classification measure, which could result in higher prevalence in comparison to other classification algorithms.

The focus of the EWGSOP2 algorithm is on inclusion of the muscle strength component at the forefront of the algorithm and introduction to the muscle quality component, however in practice this one is often omitted. Similarly to the findings from Stuck et al. (31) we found that EWGSOP2 classifies less people as sarcopenic compared to other classifications – in our sample, this amounted to 4.1%. Other studies found even lower prevalences: 2.1% among community-dwelling older adults (31) and 1.1% among population-based cohorts (33). EWGSOP2 is relatively new, therefore not many studies have used it compared to the original EWGSOP which includes the muscle strength measure at a confirmatory level. Using EWGSOP, we found 11.8% prevalence of sarcopenia. Van Ancum et al. (34) pooled the data from multiple cohorts across European countries (the Netherlands, Denmark, United Kingdom, Finland, Estonia and France) and one Australian cohort using both the original EWGSOP and revised EWGSOP2, and also found lower sarcopenia prevalence when classified by EWGSOP2, at 16.7% and 11.4%, respectively. Sarcopenia prevalence using EWGSOP from 45 studies was between 20 and 25% (1), from which we can assume that our sample was less sarcopenic than the average of the global population when classified with either EWGSOP or EWGSOP2.

Swapping Sarc-F with Sarc-CalF in EWGSOP2 resulted in a 0.3% increase in sarcopenia prevalence, from 4.1% to 4.4%. Motivation for this was supported with previous findings, where Sarc-CalF showed enhanced sensitivity (35), higher diagnostic accuracy (36) and was able to detect more truly sarcopenic individuals (37) in comparison to Sarc-F.

Another modification in the EWGSOP2 was omitting the screening test – Sarc-F, based on the hypothesis that all of the screened participants are at risk of sarcopenia. This resulted in a 3.6% increase in sarcopenia prevalence to 7.7%. We can assume that Sarc-F excludes sarcopenic individuals due to the subjective observations of the individual's own physical status. Therefore, Sarc-F might be more suitable to rule out sarcopenia than to detect it (38).

The global prevalence of sarcopenia using FNIH has been reported to be 15 % and for IWGS 20% (1), however, the Slovenian sample showed 7.7% and 2.1%, respectively.

When comparing the agreement among eight classification algorithms, we have found that only 4 (0.6%) participants were consistently classified as sarcopenic. Weak agreement between algorithms has also been found by Bijlsma et al. (11) and recently by Montemurro et al. (30). The discrepancies could be seen due to different assessment methods (i.e. muscle mass can be estimated with BIA or dual-energy x-ray absorptiometry (DXA)) and different sequences of those within the algorithms. Therefore, algorithms for sarcopenia classification still warrant improvements in consistency to be a diagnostic tool. Indeed, the EWGSOP2 algorithm adds a component of muscle quality and points out a need for a valid assessment method (3).

Lastly, we have assessed individual sarcopenia risk factors and preventive factors, as it has been shown that multimorbidity is a risk factor for sarcopenia (39). The first factor we have assessed is age, as it has been previously shown that this is the primary risk factor for sarcopenia onset (14), which our findings have confirmed. We found adequate nutrition to be the most prominent factor in preventing sarcopenia onset, which aligns with SarcoPhAge findings (40). Even though our study did not focus on nutrition quality, these findings show that sufficient macronutrient intake could be important for overall health. A higher amount of MVPA is a protective factor among our sample, similar to the findings from Japan, where higher MVPA was associated with lower functional disability incidence (41). A recent review also found an association between a sedentary lifestyle and sarcopenia onset (16), similar to our findings where a sedentary lifestyle represents a risk factor for sarcopenia. As physical activity decreases among older adults in Europe (42), we can speculate that sarcopenia will become a more prominent challenge in the future mostly due to physical inactivity. Our results indicate that higher BMI is a risk factor for sarcopenia development. The literature suggests that higher BMI values are also associated with adverse outcomes, especially when accompanying already developed sarcopenia, resulting in sarcopenic obesity which has higher mortality rates (43). The relationship between myokines, which regulate brain functions, such as mood, learning, locomotor activity and neuronal injury protection and skeletal muscle, points to the existence of muscle-brain cross-talk (44). Characterised by the progressive degeneration of muscle mass and function, sarcopenia could be conducive to or be associated with impaired cognitive function, as also observed in the present study. However, it is important to note that the relationship between sarcopenia and cognitive function is yet to be determined. Compared to the findings of a recent meta-analysis (45), the odds ratios were lower in our sample, although they still followed a similar trend: malnutrition is the largest behavioural risk factor (hence, adequate nutrition works as a preventive factor), while physical activity has positive effects on sarcopenia presence and aging, physical inactivity and cognitive function decline present a risk factor for sarcopenia.

This study has some limitations - although we aimed to recruit a representative sample of the general Slovenian population, we cannot rule out the possibility that the sample is biased towards the more active older adults who are more likely to respond to invitations to participate. However, we tried to avoid this at the preliminary recruitment phase. Secondly, tests for cognitive decline presented a large amount of missing data, therefore we were not able to use multivariate logistic regression models. Thirdly, our findings could be more conclusive if longitudinal study design were applied.

5 CONCLUSIONS

Sarcopenia prevalence in the Slovenian general population, classified by most algorithms (EWGSOP, EWGSOP2, FNIH, IWGS), is lower than global sarcopenia prevalence and similar to the European countries for which data exists, however prevalence strongly depends upon the classification algorithm being used. Physical activity and adequate nutrition were identified as preventive factors while age, cognitive decline, sedentary lifestyle and BMI are risk factors, pointing to possibilities for effective public health interventions. Addressing these methodological inconsistencies could improve sarcopenia identification, while the promotion of an active lifestyle could improve the quality of life of older adults.

ACKNOWLEDGEMENTS

We are sincerely grateful to all the healthcare centres staff for participant recruitment and the participants for generously taking the time to participate in the study.

CONFLICTS OF INTEREST

The authors declare that no conflicts of interest exist.

FUNDING

The authors acknowledge financial support from the Slovenian Research Agency (research core funding No. P5-0381 and J7-2605 – Validation of a new muscle quality marker for the diagnosis of sarcopenia). UM and MP acknowledge funding from the European Union's Horizon 2020 (No. 952401) as well as Horizon Europe under grant agreement No. 101120150.

ETHICAL APPROVAL

Research has been performed in accordance with the Declaration of Helsinki. The study protocol was approved by the Medical Ethics Committee of Slovenia (ID: 0120-76/2021/6).

AVAILABILITY OF DATA AND MATERIALS

The data and materials utilised in this study were collected, anonymised and securely stored in a coded access personal computer at the facilities of the Science and Research Centre, Koper. Requests for data availability should be discussed with the project team and will be considered on a reasonable basis.

ORCID

Katarina Pus:
https://orcid.org/0000-0002-2892-5318

Saša Pišot:
https://orcid.org/0000-0002-7597-8105

Uroš Marušič:
https://orcid.org/0000-0002-7420-2137

Manca Peskar:
https://orcid.org/0000-0001-8524-5346

Kaja Teraž:
https://orcid.org/0000-0002-4184-8791

Miloš Kalc:
https://orcid.org/0000-0001-7002-2924

Helena Blažun Vošner:
https://orcid.org/0000-0003-1998-7346

Peter Kokol:
https://orcid.org/0000-0001-9102-9359

Jernej Završnik:
https://orcid.org/0000-0002-5023-0483

Boštjan Šimunič:
https://orcid.org/0000-0003-1565-7833

REFERENCES

1. Petermann-Rocha F, Balntzi V, Gray SR, Lara J, Ho FK, Pell JP, et al. Global prevalence of sarcopenia and severe sarcopenia: A systematic review and meta-analysis. J Cachexia Sarcopenia Muscle. 2022;13(1):86-99. doi: 10.1002/jcsm.12783.
2. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing. 2010;39(4):412-423. doi: 10.1093/ageing/afq034.
3. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: Revised European consensus on definition and diagnosis. Age Ageing. 2019;48(1):16-31. doi: 10.1093/ageing/afy169.
4. Studenski SA, Peters KW, Alley DE, Cawthon PM, McLean RR, Harris TB, et al. The FNIH sarcopenia project: Rationale, study description, conference recommendations, and final estimates. J Gerontol A Biol Sci Med Sci. 2014;69(5):547-558. doi: 10.1093/gerona/glu010.
5. Bhasin S, Travison TG, Manini TM, Patel S, Pencina KM, Fielding RA, et al. Sarcopenia definition: The position statements of the Sarcopenia Definition and Outcomes Consortium. J Am Geriatr Soc. 2020;68(7):1410-1418. doi: 10.1111/jgs.16372.
6. Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, Newman AB, et al. Sarcopenia: An undiagnosed condition in older adults. Current consensus definition: Prevalence, etiology, and consequences. International working group on sarcopenia. J Am Med Dir Assoc. 2011;12(4):249-256. doi: 10.1016/j.jamda.2011.01.003.
7. Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K, et al. Asian Working Group for Sarcopenia: 2019 Consensus Update on Sarcopenia Diagnosis and Treatment. J Am Med Dir Assoc. 2020;21(3):300–307. doi: 10.1016/j.jamda.2019.12.012.
8. Anker SD, Morley JE, von Haehling S. Welcome to the ICD-10 code for sarcopenia. J Cachexia Sarcopenia Muscle. 2016;7(5):512-514. doi: 10.1002/jcsm.12147.
9. Anand A, Mohta S, Agarwal S, Sharma S, Gopi S, Gunjan D, et al. European Working Group on Sarcopenia in Older People (EWGSOP2) Criteria with population-based skeletal muscle index best predicts mortality in Asians with cirrhosis. J Clin Exp Hepatol. 2022;12(1):52-60. doi: 10.1016/j.jceh.2021.03.015..
10. Evans WJ, Guralnik J, Cawthon P, Appleby J, Landi F, Clarke L, et al. Sarcopenia: No consensus, no diagnostic criteria, and no approved indication-How did we get here? Geroscience. 2024;46(1):183-190. doi: 10.1007/s11357-023-01016-9.
11. Bijlsma AY, Meskers CGM, Ling CHY, Narici M, Kurrle SE, Cameron ID, et al. Defining sarcopenia: The impact of different diagnostic criteria on the prevalence of sarcopenia in a large middle aged cohort. Age (Dordr). 2013;35(3):871-881. doi: 10.1007/s11357-012-9384-z.
12. Sayer AA, Syddall H, Martin H, Patel H, Baylis D, Cooper C. The developmental origins of sarcopenia. J Nutr Health Aging. 2008;12(7):427-432. doi: 10.1007/BF02982703.
13. Han P, Kang L, Guo Q, Wang J, Zhang W, Shen S, et al. Prevalence and Factors Associated With Sarcopenia in Suburb-dwelling Older Chinese Using the Asian Working Group for Sarcopenia Definition. J Gerontol A Biol Sci Med Sci. 2016;71(4):529–535. doi: 10.1093/gerona/glv108.
14. Gao Q, Hu K, Yan C, Zhao B, Mei F, Chen F, et al. Associated factors of sarcopenia in community-dwelling older adults: A systematic review and meta-analysis. Nutrients. 2021;13(12):4291. doi: 10.3390/nu13124291.
15. Liguori I, Curcio F, Russo G, Cellurale M, Aran L, Bulli G, et al. Risk of malnutrition evaluated by mini nutritional assessment and sarcopenia in noninstitutionalized elderly people. Nutr Clin Pract. 2018;33(6):879-886. doi: 10.1002/ncp.10022.
16. Mo Y, Zhou Y, Chan H, Evans C, Maddocks M. The association between sedentary behaviour and sarcopenia in older adults: a systematic review and meta-analysis. BMC Geriatr. 2023;23(1):877. doi: 10.1186/s12877-023-04489-7.

17. Sieber CC. Malnutrition and sarcopenia. Aging Clin Exp Res. 2019;31(6):793-798. doi: 10.1007/s40520-019-01170-1.
18. Pišot R, Marusic U, Biolo G, Mazzucco S, Lazzer S, Grassi B, et al. Greater loss in muscle mass and function but smaller metabolic alterations in older compared with younger men following 2 wk of bed rest and recovery. J Appl Physiol (1985). 2016;120(8):922-929. doi: 10.1152/japplphysiol.00858.2015.
19. Hämäläinen O, Tirkkonen A, Savikangas T, Alén M, Sipilä S, Hautala A. Low physical activity is a risk factor for sarcopenia: a cross-sectional analysis of two exercise trials on community-dwelling older adults. BMC Geriatr. 2024;24(1):212. doi: 10.1186/s12877-024-04764-1.
20. Peng TC, Chen WL, Wu LW, Chang YW, Kao TW. Sarcopenia and cognitive impairment: A systematic review and meta-analysis. Clin Nutr. 2020;39(9):2695-2701. doi: 10.1016/j.clnu.2019.12.014.
21. 21.Sui SX, Williams LJ, Holloway-Kew KL, Hyde NK, Pasco JA. Skeletal muscle health and cognitive function: A narrative review. Int J Mol Sci. 2020;22(1):255. doi: 10.3390/ijms22010255.
22. Malmstrom TK, Morley JE. SARC-F: A simple questionnaire to rapidly diagnose sarcopenia. J Am Med Dir Assoc. 2013;14(8):531-532. doi: 10.1016/j.jamda.2013.05.018.
23. Barbosa-Silva TG, Menezes AMB, Bielemann RM, Malmstrom TK, Gonzalez MC. Enhancing SARC-F: Improving sarcopenia screening in the clinical practice. J Am Med Dir Assoc. 2016;17(12):1136-1141. doi: 10.1016/j.jamda.2016.08.004.
24. Podsiadlo D, Richardson S. The timed "Up & Go": A test of basic functional mobility for frail elderly persons. J Am Geriatr Soc. 1991;39(2):142-148. doi: 10.1111/j.1532-5415.1991.tb01616.x.
25. Vellas B, Guigoz Y, Garry PJ, Nourhashemi F, Bennahum D, Lauque S, et al. The Mini Nutritional Assessment (MNA) and its use in grading the nutritional state of elderly patients. Nutrition. 1999;15(2):116-122. doi: 10.1016/s0899-9007(98)00171-3.
26. Armstrong T, Bull F. Development of the World Health Organization Global Physical Activity Questionnaire (GPAQ). J Public Health (Bangkok). 2006;14(2):66–70.
27. Reitan RM. Validity of the trail making test as an indicator of organic brain damage. Percept Mot Skills. 1958;8:271–276.
28. Tombaugh TN. Trail Making Test A and B: Normative data stratified by age and education. Arch Clin Neuropsychol. 2004;19(2):203-214. doi: 10.1016/S0887-6177(03)00039-8.
29. McHugh ML. Interrater reliability: The kappa statistic. Biochem Med (Zagreb). 2012;22(3):276-282.
30. Montemurro A, Ruiz-Cárdenas JD, Martínez-García MDM, Rodríguez-Juan JJ. Consequences of applying the different criteria of the EWGSOP2 guideline for sarcopenia case-finding in Spanish community-dwelling older adults. Arch Gerontol Geriatr. 2023;109:104964. doi: 10.1016/j.archger.2023.104964.
31. Stuck AK, Tsai LT, Freystaetter G, Vellas B, Kanis JA, Rizzoli R, et al. Comparing prevalence of sarcopenia using twelve sarcopenia definitions in a large multinational European population of community-dwelling older adults. J Nutr Health Aging. 2023;27(3):205-212. doi: 10.1007/s12603-023-1888-y.
32. Syddall HE, Aihie Sayer A, Dennison EM, Martin HJ, Barker DJ, Cooper C. Cohort profile: The Hertfordshire cohort study. Int J Epidemiol. 2005;34(6):1234-1242. doi: 10.1093/ije/dyi127.
33. Westbury LD, Beaudart C, Bruyère O, Cauley JA, Cawthon P, Cruz-Jentoft AJ, et al. Recent sarcopenia definitions-prevalence, agreement and mortality associations among men: Findings from population-based cohorts. J Cachexia Sarcopenia Muscle. 2023;14(1):565-575. doi: 10.1002/jcsm.13160.
34. Van Ancum JM, Alcazar J, Meskers CGM, Nielsen BR, Suetta C, Maier AB. Impact of using the updated EWGSOP2 definition in diagnosing sarcopenia: A clinical perspective. Arch Gerontol Geriatr. 2020;90:104125. doi: 10.1016/j.archger.2020.104125.
35. Xu Z, Zhang P, Chen Y, Jiang J, Zhou Z, Zhu H. Comparing SARC-CalF With SARC-F for screening sarcopenia in adults with type 2 diabetes mellitus. Front Nutr. 2022;9:803924. doi: 10.3389/fnut.2022.803924.
36. Ishimoto T, Hisamatsu K, Matsudaira N, Fujimoto T, Yano M, Hashimoto R, et al. Accuracy of determining sarcopenia using SARC-CalF in community-dwelling older adults aged 75 years and older. Clin Nutr ESPEN. 2022;52:317-321. doi: 10.1016/j.clnesp.2022.09.012.
37. da Luz MCL, Pinho CPS, Bezerra GK de A, da Conceição Chaves de Lemos M, da Silva Diniz A, Cabral PC. SARC-F and SARC-CalF in screening for sarcopenia in older adults with Parkinson's disease. Exp Gerontol. 2021;144:111183. doi: 10.1016/j.exger.2020.111183.
38. Piotrowicz K, Głuszewska A, Czesak J, Fedyk-Łukasik M, Klimek E, Sánchez-Rodríguez D, et al. SARC-F as a case-finding tool for sarcopenia according to the EWGSOP2. National validation and comparison with other diagnostic standards. Aging Clin Exp Res. 2021;33(7):1821-1829. doi: 10.1007/s40520-020-01782-y.
39. Veronese N, Smith L, Cereda E, Maggi S, Barbagallo M, Dominguez LJ, et al. Multimorbidity increases the risk for sarcopenia onset: Longitudinal analyses from the English Longitudinal Study of Ageing. Exp Gerontol. 2021;156:111624. doi: 10.1016/j.exger.2021.111624.
40. Beaudart C, Sanchez-Rodriguez D, Locquet M, Reginster JY, Lengelé L, Bruyère O. Malnutrition as a strong predictor of the onset of sarcopenia. Nutrients. 2019;11(12):2883. doi: 10.3390/nu11122883.
41. Chiba I, Lee S, Bae S, Makino K, Shinkai Y, Katayama O, et al. Difference in sarcopenia characteristics associated with physical activity and disability incidences in older adults. J Cachexia Sarcopenia Muscle. 2021;12(6):1983-1994. doi: 10.1002/jcsm.12801.
42. Gomes M, Figueiredo D, Teixeira L, Poveda V, Paúl C, Santos-Silva A, et al. Physical inactivity among older adults across Europe based on the SHARE database. Age Ageing. 2017;46(1):71-77. doi: 10.1093/ageing/afw165.
43. Benz E, Pinel A, Guillet C, Capel F, Pereira B, De Antonio M, et al. Sarcopenia and sarcopenic obesity and mortality among older people. JAMA Netw Open. 2024;7(3):e243604. doi: 10.1001/jamanetworkopen.2024.3604.
44. Scisciola L, Fontanella RA, Surina, Cataldo V, Paolisso G, Barbieri M. Sarcopenia and cognitive function: Role of myokines in muscle brain cross-talk. Life (Basel). 2021;11(2):173. doi: 10.3390/life11020173.
45. Yuan S, Larsson SC. Epidemiology of sarcopenia: Prevalence, risk factors, and consequences. Metabolism. 2023;144:155533. doi: 10.1016/j.metabol.2023.155533.