Nutrition 78 (2020) 110815

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied Nutritional Investigation

Identification of sarcopenia and dynapenia in CKD predialysis patients with EGWSOP2 criteria: An observational, cross-sectional study

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ARTICLE INFO

Article History:
Received 4 October 2019
Received in revised form 14 January 2020
Accepted 1 March 2020

Keywords:
Chronic kidney disease
Dynapenia
Sarcopenia
Hemoglobin
Serum albumin
Glomerular filtration rate

ABSTRACT

Objectives: Using the new European Working Group on Sarcopenia in Older People (EWGSOP2) criteria, we identified sarcopenic and dynapenic patients in a cohort of predialysis patients with chronic kidney disease (CKD), and evaluated their clinical and laboratory characteristics.
Methods: The study population consisted of 85 (55 men) clinically stable predialysis CKD patients (92.9% in stages 3–5), with a median age of 65.0 (52.5–72.0) y. We classified as sarcopenic the patients with handgrip strength (HGS) and muscle mass both lower than the respective EWGSOP2 cutoff values and as dynapenic those in whom only HGS was less than these reference values. HGS was measured with a hand dynamometer, whereas muscle mass was measured by bioimpedance analysis. Renal function was evaluated as Modification of Diet in Renal Disease estimated glomerular filtration rate.
Results: The prevalence of sarcopenia and dynapenia was, respectively, 7.1% and 17.6%. As reported in previous studies, serum albumin and hemoglobin were lower in sarcopenic patients than in patients with preserved muscle mass and strength. However, unlike in these studies, sarcopenia prevalence did not increase with CKD stage, and estimated glomerular filtration rate was similar between groups. Moreover, no difference was identified in any of the aforementioned parameters between dynapenic patients and patients with preserved muscle mass and strength.
Conclusions: The EWGSOP2 criteria identified sarcopenia in CKD with a prevalence similar to previous diagnostic criteria. In addition, they found that dynapenia was highly prevalent. Nevertheless, the EWGSOP2 criteria could be better adapted to CKD patients to improve their ability to detect high-risk sarcopenic and dynapenic patients.

Introduction

Sarcopenia is a clinical condition in which mass, strength, and function of skeletal muscles become slowly and progressively lower than normal [1]. Alhough originally described in aging, sarcopenia also occurs in serious systemic diseases such as metastatic cancer, hepatic cirrhosis, heart failure, and chronic kidney disease (CKD) [2–7]. In all these conditions the appearance of sarcopenia predicts a bad prognosis and a higher mortality. For instance, Kim et al. [8] found that sarcopenia is a major predictor of death and cardiovascular events in hemodialysis patients, whereas Souza et al. [9] reported that the prevalence of sarcopenia was higher in predialysis CKD patients with worse renal function. Interestingly, recent evidence suggests that the loss of muscle strength is the main negative prognostic factor in CKD, in which it is associated with higher mortality, shorter time to end-stage renal disease, and lower plasma concentrations of serum albumin [10,11]. There is therefore a great interest in correctly diagnosing sarcopenia and dynapenia—that is, isolated reduction in muscle strength with no change in muscle mass— to investigate causative factors linking these conditions to disease progression and severity. However, because of the lack of universally shared, harmonized criteria,

BG, MDM, and MC wrote the paper; MDL, TDL, RT, and AM collected the data; BG, MDM, and MC analyzed the data; MS and AB supervised the study and contributed to data interpretation. All authors read and approved the final manuscript. The authors declare that they have no competing interests.

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https://doi.org/10.1016/j.nut.2020.110815
0899-9007/

different diagnostic approaches have been used in the past, making the different studies performed so far hardly comparable. To address this point, in 2010 the European Working Group on Sarcopenia in Older People (EWGSOP) issued the first version of its "consensus on definition and diagnosis," which rapidly became the reference standard for sarcopenia diagnosis [12]. In this document it was clearly stated that the diagnosis of sarcopenia requires that both a low muscle mass and a low muscle function (in terms of strength or physical performance) are demonstrated by the combined use of instrumental techniques such as dual-energy X-ray absorptiometry, nuclear magnetic resonance spectroscopy, or bioelectrical impedance analysis (BIA) for the former, and either instrumental (handgrip measurement) or physical tests (gait speed or Short Physical Performance Battery) for the latter [12]. The isolated loss of muscle mass with preserved muscle strength was defined as *presarcopenia* in this consensus and identified as an early stage of sarcopenia [12].

An important limitation of the 2010 EWGSOP consensus was that it "did not advise specific cut-off points" among the many that had been proposed before its publication [12]. Recently a revised version of the European Consensus on Definition and Diagnosis of Sarcopenia (EWGSOP2) has been released in which clear-cut cut-offs have been introduced for diagnosis. Another major change in EWGSOP2 criteria is that they give a much higher relevance in sarcopenia diagnosis to the loss of muscle strength than the 2010 EWGSOP criteria. More specifically, EWGSOP2 recommends that patients suspected to be sarcopenic are first screened by assessing muscle strength either measuring handgrip strength (HGS) or chair stand and, if low values are found, that sarcopenia diagnosis is confirmed by measuring muscle mass. The consensus also states that the sole demonstration of a subnormal muscle strength is enough to start treatment. This leaves open the question on whether dynapenia should be considered a disease status. Indeed, neither 2010 EWGSOP nor EWGSOP2 did classify this condition as a separate clinical entity, although experimental evidence indicates that muscle function may be impaired with no apparent loss of mass in aging and in systemic diseases possibly because of the dysfunction of neuromuscular transmission [13,14].

The original 2010 EWGSOP criteria were developed for sarcopenia of aging but have been widely used also for the diagnosis of sarcopenia of chronic diseases even though specific validation studies have not been performed. Likewise, information about the applicability of the EWGSOP2 diagnostic criteria in systemic diseases such as CKD is still missing. In the present study we used the new EWGSOP2 criteria to measure the prevalence of sarcopenia and dynapenia in CKD, and we evaluated their clinical and laboratory characteristics.

Materials and methods

Study design and inclusion and exclusion criteria

The design of the present study was cross-sectional observational. Patients with CKD and in regular nutritional follow-up at the Unit of Nutrition in CKD and Transplantation, Department of Medicine of the Federico II University of Naples, were proposed to take part to the study and enrolled after signing the informed consent if they met the inclusion criteria detailed later. At the time of referral to our unit all the patients were receiving standard of care pharmacologic and nutritional treatment for CKD according to their residual kidney function. After enrollment, patients underwent a complete diagnostic evaluation for sarcopenia according to the EGOWSP2 guidelines through the assessment of muscle strength by handgrip dynamometry and of muscle mass by BIA as detailed in the following paragraphs. Based on the results obtained with these tests, patients were classified in four subgroups: patients with normal muscle mass and strength, patients with loss of muscle mass but not of muscle strength, dynapenic patients with isolated muscle strength loss, and sarcopenic patients with loss of both muscle strength and mass. The diagnostic evaluation also included a comprehensive nutritional and functional assessment with biochemistry, anthropometry, and dietary recall.

Inclusion criteria were age older than 18 y and estimated glomerular filtration rate (eGFR) between 6 and 90 mL/min (stage 1–5 CKD, according to the Kidney Disease Outcomes Quality Initiative CKD classification). Patients with kidney transplant or with severe infections, malignancy, or edema were excluded.

The primary endpoint of the study was to measure the prevalence of sarcopenia and dynapenia. Secondary endpoints were to establish whether there was any difference in the values of eGFR, hemoglobin, or albumin concentration among patients with normal muscles, low muscle mass, dynapenia, or sarcopenia.

The experimental protocol was approved by the Ethics Committee of the School of Medicine of the Federico II University of Naples (protocol number 181/18); procedures were performed according to the World Medical Association Helsinki Declaration as revised in 1996.

Anthropometry and body composition analysis

Height and weight were determined with a calibrated stadiometer and scale. Body mass index (BMI) was defined as the weight in kilograms divided by squared height (in meters).

Body composition was assessed with BIA using a tetrapolar 50-kHz bioelectrical impedance analyzer (BIA 101 RJL, Akern Bioresearch, Firenze, Italy) [15]. Total body water, fat mass, and fat free mass were extrapolated from the values of reactance and resistance obtained at BIA by using specific prediction equations.

Appendicular skeletal muscle mass (ASM) was extrapolated by BIA-measured resistance and reactance using the Kyle prediction equation [16]:

$$-4.211 + (0.267 \times height^2 \div resistance) + (0.095 \times weight) + (1.909 \times sex) + (-0.012 \times age) + (0.058 \times reactance)$$

where sex = 1 in men and 0 in women. ASM was normalized to height and expressed as appendicular muscle/height^2 (ASM/h^2) [17].

Hand grip strength

Hand grip strength (HGS) was measured on the dominant hand to the nearest kilogram using a hand dynamometer (78010; Lafayette Instrument Company, Lafayette, IN, USA). Measurement was performed while keeping the patient in an upright position with the arms unsupported and parallel to the body. The average of three consecutive measurements obtained at an interval of 30 s rest between each measurement was used for the analysis.

Diagnosis of sarcopenia and dynapenia

Sarcopenia was defined as the simultaneous presence of low muscle strength and low muscle mass, according to EWGSOP2 recommendations [18]. More specifically, we classified as sarcopenic all patients showing both an HGS lower than 27 kg (men) or 16 kg (women) and ASM/h^2 lower than 7.0 kg/m^2 (men) or 6.0 kg/m^2 (women), whereas patients with only ASM/h^2 less than the aforementioned thresholds were classified as low muscle mass patients [18]. We also classified as an additional category that we called dynapenia, which included the patients with low HGS strength and normal ASM/h^2.

Dietary nutrient intake

Dietary intake was assessed using 3-d food records [19]. All patients received detailed instructions on how to fill their journals at home. After 7 d, study participants returned their food records that were checked for accuracy by a licensed renal dietitian. Energy intake and macronutrient composition of the diet were analyzed using the food composition tables of the Italian National Institute of Nutrition, the Souci's Food Composition Tables, and the Nutrition Tables and the European Institute of Oncology [20–22].

Blood chemistry tests

The following blood chemistries were determined by standard laboratory procedures: urea nitrogen, creatinine, albumin, hemoglobin, total cholesterol, triacylglycerols, and glucose. In all patients, eGFR was calculated using the Modification of Diet in Renal Disease formula [23].

Sample size determination and statistical analysis of the data

Sample size was calculated based on the primary endpoint—that is, the measurement of sarcopenia prevalence in our population of predialysis CKD patients. Specifically, assuming an expected prevalence of 5%, we estimated that at least 83 patients should have been evaluated to assess sarcopenia prevalence with a 5% precision and no correction for small population size [24].

Statistical analysis was performed with Sigmaplot for Windows Version 11 (Systat Software, San Jose, CA, USA) and with IBM SPSS 20.0 for Windows (Armonk, NY, USA), setting the threshold for significance at 0.05. Data were examined for

normality using the Shapiro-Wilk test and reported as mean and standard deviation of the mean or as median and interquartile range as appropriate. For normally distributed data statistical comparisons among multiple groups were performed with one-way analysis of variance and Bonferroni post hoc correction for multiple comparisons. In the case of non–normally distributed data, we used the Kruskal-Wallis nonparametric analysis of variance followed by Dunn test for multiple comparisons. Partial correlation analysis was used to evaluate the association between muscle mass or strength and either eGFR, hemoglobin, or serum albumin concentration while controlling for age or eGFR.

Results

Study population

The study population consisted of 85 (55 men) clinically stable CKD patients (92.9% in stage 3–5) with a median age of 65.0 (52.5–72.0) y and a median BMI of 26.4 (23.3–30.8) kg/m^2. The main laboratory and body composition characteristics of the patients are summarized in Table 1. A total of 19 patients (22.4% of total population) were diabetic and under pharmacologic treatment and 17 patients were treated with diuretics (all in stage 3–5, 22% of the stage 3–5 group). Energy and protein intakes were in the range of the current recommendations for CKD patients on conservative treatment [25].

Correlation between muscle mass or strength and eGFR, hemoglobin, or serum albumin

To establish whether in our group of CKD patients the loss of muscle mass or muscle strength was associated with a more severe impairment in renal function, we performed a correlation analysis between HGS or ASM/h^2 and either eGFR, hemoglobin or serum albumin. The results obtained indicated that HGS positively correlated with eGFR (r = 0.25; P = 0.02 after adjustment for age), serum albumin (r = 0.28; P = 0.01 after adjustment for age and eGFR), and hemoglobin (r = 0.53; P = 0.00 after adjustment for age and eGFR), whereas ASM/h^2 only correlated with hemoglobin (r = 0.23; P = 0.04 after adjustment for age and eGFR).

Table 1
Anthropometric characteristics, body composition and blood chemistries of the whole study population

Sex (male; *n*, %)	55 (64.7%)
Age (y)	65.0 (52.5–72.0)
CKD vintage (mo)	60.0 (24.0–132.0)
BW (kg)	72.6 (63.8–85.0)
BMI (BW/m^2)	26.4 (23.3–30.8)
eGFR (mL/min × 1.73 m^2)	31.0 (18.8–46.0)
CKD stage 1–2 (*n*, %)	6 (7.1)
CKD stage 3–5 (*n*, %)	79 (92.9)
Creatinine (mg/dL)	2.0 (1.5–3.0)
BUN (mg/dL)	63.0 (48.0–108.3)
Albumin (g/dL)	4.1 (3.9–4.4)
Hemoglobin (g/dL)	12.9 ± 1.8
Cholesterol (mg/dL)	170.5 ± 35.1
Triglycerides (mg/dL)	119.5 (92.0–169.0)
Glucose (mg/dL)	89.5 (81.5–109.5)
Diabetes (*n*, %)	19 (22.4)
FFM (% BW)	71.2 ± 9.4
FM (% BW)	29.2 ± 9.8
Phase angle (degrees)	5.5 (4.8–6.5)
ASM/h^2 (kg/m^2)	7.8 (7.0–8.7)
Hand grip (kg)	27.4 ± 9.8

ASMI, ASM/h^2; BMI, body mass index; BUN, blood urea nitrogen; BW, body weight; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; FFM, fat free mass; FM, fat mass

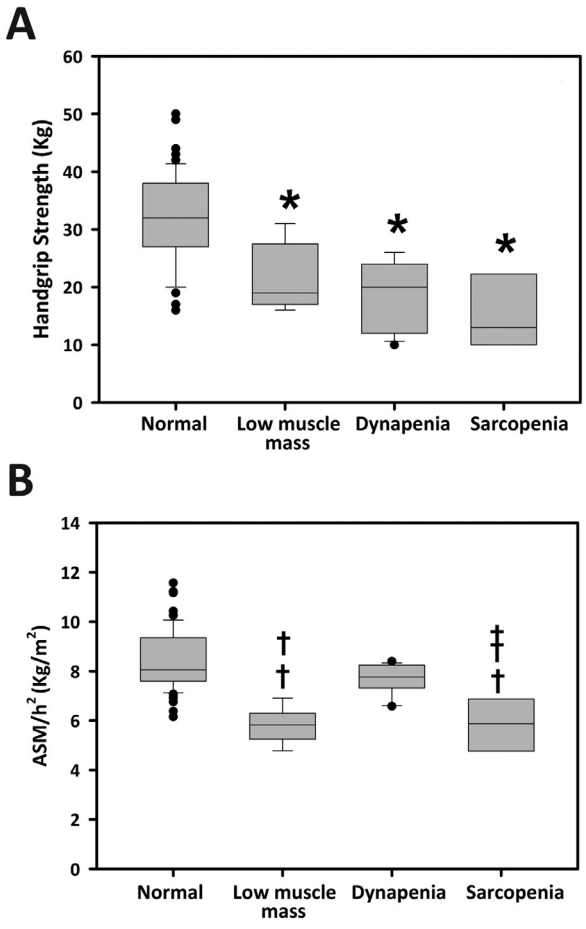

Fig. 1. Handgrip (A) and ASM/h^2 (B) in the four groups of patients identified with the revised European Working Group on Sarcopenia in Older People criteria. *P < 0.05 and; †P< 0.001 versus normal; ‡P < 0.05 versus normal and dynapenia groups. ASM, appendicular skeletal muscle mass.

Prevalence of sarcopenia and dynapenia

According to the EWGSOP2 cutoff values, patients were stratified in four groups: patients with normal muscle mass and strength (who will be designed as *normal* in the rest of the text), patients with low muscle mass, patients with dynapenia, and sarcopenic patients. More specifically, 55 patients were normal (41 men, 64.7% of the whole population), 9 had a low muscle mass (2 men, 10.6% of the whole population), 15 were dynapenic (9 men, 17.6% of the whole population), and only 6 patients were sarcopenic (3 men, 7.1% of the whole population). Importantly, there was no significant difference in HGS between dynapenic and sarcopenic patients or in ASM/h^2 between patients with low muscle mass and sarcopenic patients (Fig. 1). Conversely, ASM/h^2 was significantly lower in patients with low muscle mass than in normal and dynapenic groups. HGS was significantly lower than in normal patients not only in dynapenic and in sarcopenic but also in low muscle mass patients, in whom, however, it remained greater than the cutoff points for the diagnosis of dynapenia (Fig. 1). The prevalence of sarcopenia and of dynapenia did not significantly increase with the severity of CKD. Indeed, the number (and percentages) of sarcopenic and dynapenic patients, respectively, were 4 out of 39 (10.25%) and 6 out of 39 (15.4%) stage 3; 1 out of 26 (3.84%) and 5 out of 26 (19.2%) stage 4; and 1 out of 14 (7.1%) and 3 out of 14 (15.4%) stage 5. The prevalence of diabetes was significantly higher in patients

with sarcopenia than in patients with dynapenia, in those with low muscle mass, and in those with normal muscle mass and strength (66.7%, 33.3%, 11.1%, and 16.4%, respectively; $P < 0.05$).

Nutritional status and renal function in sarcopenic and dynapenic patients

Patients of the four groups had a similar CKD duration, and although the median age was higher in sarcopenic and dynapenic groups than in the other two groups of patients, this difference did not reach statistical significance. BMI was significantly higher in the normal group compared with the low muscle mass and sarcopenic groups. No difference was identified in fat mass percentage and in fat free mass percentage. Remarkably, also the total body water/fat free mass ratio was similar among the four groups, suggesting a similar hydration status. Phase angle was significantly higher in the normal group compared with the other groups (Table 2).

There was no difference among groups in renal function as estimated with eGFR and in energy and protein intake based on self-reported energy and protein intakes. Conversely, hemoglobin and serum albumin concentrations were significantly lower in sarcopenic patients than in the other groups of patients (Table 2; Fig. 2).

Discussion

In the present study we used the new EWGSOP2 criteria [18] to measure the prevalence of dynapenia, low muscle mass, and full-blown sarcopenia in predialysis CKD patients. We also compared body composition, renal function, and nutritional status in these groups of patients. The main finding of our study was that about 10% of the patients had a low muscle mass, 18% were dynapenic, and 7% were sarcopenic; we also found that there was no difference in the CKD stage among the different groups of patients.

Only few studies reported the prevalence of sarcopenia in predialysis CKD patients so far, with variable results depending the methods used to assess muscle mass and strength and the cutoff points used for diagnosis. Specifically, Souza et al. [9], who used dual-energy x-ray absorptiometry, found a sarcopenia prevalence of 11.9% with the EWGSOP 2010 criteria and 28.7% with the criteria of the Foundation for the National Institutes of Health Sarcopenia Project [26], whereas Pereira et al. [27], reported a prevalence of 9.8%, 9.4%, and 5.9% depending on whether midarm muscle circumference, Subjective Global Assessment of Muscle Performance, or Skeletal Muscle Mass Index estimated with BIA was used for diagnosis. To our knowledge the present study is the first to use the EWGSOP2 criteria to identify sarcopenia in predialysis CKD patients. The first version of the EWGSOP criteria, which were issued in 2010 and have been extensively used in the past also in studies on sarcopenia in CKD, had the important limitation that it used a New Mexico aged population as a reference standard [28] and that it did not specify unequivocal cutoff values for diagnosis. In the 2019 revised EWGSOP2 criteria that we used in the present study, cutoff values specifically developed for the European population were reported [18]. The prevalence of sarcopenia that we found in our study population (about 7%) was close to the figures of the aforementioned studies, suggesting that the use of the new

Table 2
Anthropometric characteristics, body composition, and blood chemistries in the four groups of patients identified on the basis of the EGWSOP2 cutoff values for muscle mass and strength

	Normal	Low muscle mass	Dynapenia	Sarcopenia
No. of patients (*n*, %)	55 (64.7)	9 (10.6)	15 (17.6)	6 (7.1)
Sex (male/female)	41/14	2/7	9/6	3/3
Age (y)	61.0 (50.0–68.8)	66.0 (48.3–71.5)	74.0 (62.0–79.0)	70.0 (68.0–75.0)
CKD vintage (mo)	60.0 (24.0–132.0)	24.0 (15.0–129.0)	60.0 (18.0–138.0)	30.0 (24.0–36.0)
BW (kg)	81.9 (71.7–94.2)	55.9 (48.5–57.6)*	66.7 (58.7–72.5)*	54.7 (45.0–62.4)*
BMI (kg/m^2)	28.6 (25.9–33.1)	22.8 (21.6–23.4)*	25.0 (23.4–28.5)	20.9 (18.9–21.8)*
eGFR (mL/min · 1.73 m^2)	33.0 (20.5–47.0)	19.0 (9.8–30.8)	24.0 (16.0–42.3)	37 (29.0–46.0)
CKD stage 1–2 (*n*, %) [†]	5 (83.3)	–	1 (16.6)	–
CKD stage 3–5 (*n*,%)[‡]	50 (63.2)	9 (11.3)	14 (17.7)	6 (7.5)
Creatinine (mg/dL)	1.9 (1.5–2.8)	2.1 (1.9–3.6)	2.3 (1.4–3.7)	1.6 (1.2–2.0)
BUN (mg/dL)	65.0 (47.3–108.8)	50.0 (44.5–78.5)	62.0 (49.3–117.0)	73.0 (49.0–81.0)
Albumin (g/dL)	4.2 (4.0–4.5)	4.1 (4.0–4.4)	4.1 (3.6–4.3)	3.8 (3.5–4.0)[§]
Hemoglobin (g/dL)	13.2 ±1.8	12.6 ± 1.4	12.1 ± 1.8	11.5 ± 0.8[§]
Cholesterol (mg/dL)	172.1 ± 38.5	175.5 ± 26.6	159.7 ± 28.6	175.8 ± 31.0
Triglycerides (mg/dL)	121.0 (95.0–176.3)	100.0 (79.8–143.5)	120.0 (110.0–162.0)	106.5 (81.0–138.0)
Glucose (mg/dL)	90.5 (84.0–109.0)	82.0 (65.5–87.0)	84.0 (76.3–118.3)	109.5 (960–124.0)[‖]
Diabetes (%)	16.4	11.1	33.3	66.7*,[‖]
FFM (% BW)	70.1 ± 9.1	73.3 ± 10.6	73.6 ± 10.8	72.0 ± 8.0
FM (% BW)	29.8 ± 9.2	32.9 ± 11.8	26.4 ± 10.8	24.6 ± 5.9
TBW/FFM	0.7 ± 0.1	0.877 ± 0.03	0.8 ± 0.5	0.8 ± 0.02
Phase angle (degrees)	6.0 ± 1.1	5.0 ± 0.8[§]	5.0 ± 0.9[§]	4.0 ± 0.5*
ASM/h^2 (kg/m^2)	8.4 ± 1.2	5.8 ± 0.6*,[¶]	7.6 ± 0.6	5.7 ± 1.1*,[¶]
Handgrip strength (kg)	32.1 ± 8.0	21.7 ± 5.9[§]	18.1 ± 5.9[§]	15.5 ± 6.6[§]
Energy (kcal/kg per day)[#]	26.3 (23.2–30.6)	29.7 (28.5–32.7)	27.5 (23.9–28.6)	31.3 (29.6–35.6)
Protein (g/kg per day)[#]	0.8 (0.6–1.0)	0.7 (0.6–0.9)	0.7 (0.6–0.9)	0.8 (0.6–0.9)

ASM, appendicular skeletal muscle mass; BMI, body mass index; BUN, blood urea nitrogen; BW, body weight; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; FFM, fat free mass; FM, fat mass; IBW, ideal body weight; TBW, total body water
Data are reported as mean ± SD or as median (interquartile ratio) as appropriate
*$P < 0.001$ versus normal.
[†]Percentages were calculated respect to the total of patients in CKD stage 1–2.
[‡]Percentages were calculated respect to the total of patients in CKD stages 3–5.
[§]$P < 0.05$ versus normal.
[‖]$P < 0.05$ versus low muscle mass.
[¶]$P < 0.05$ versus dynapenia.
[#]Energy and protein intake were normalized on IBW (kg).

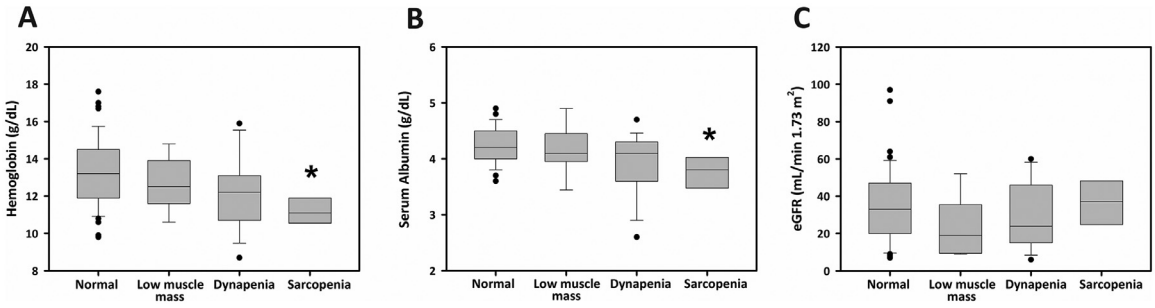

Fig. 2. (A) Hemoglobin, (B) serum albumin, and (C) estimated glomerular filtration rate (eGFR) in the four groups of patients identified with the revised European Working Group on Sarcopenia in Older People criteria. $^{*}P < 0.05$ versus normal. ASM, appendicular skeletal muscle mass.

sarcopenia diagnostic criteria did not impose major changes on the estimates of the occurrence of this condition in CKD. Moreover, as already reported in previous investigations, our sarcopenic patients had lower levels of serum albumin and hemoglobin, two important markers of the nutritional status in CKD. An additional similarity between our population of sarcopenic CKD patients and those of previous investigations was the high prevalence of diabetes, a clinical condition that can contribute to the development of sarcopenia [29,30]. However, in contrast with studies performed with previous diagnostic criteria such as those on the NHANES III (Third National Health and Nutrition Examination Survey) [31] and KNHANES (Korean National Health and Nutrition Examination Survey) IV–2, 3 and V–1, 2 cohorts [32,33], in our series of patients we did not identify a higher prevalence of sarcopenia in the most advanced stages of CKD. The latter result suggests that the EWGSOP2 criteria might be less effective in segregating high-risk sarcopenic patients from the whole population of predialysis CKD patients.

An important point of uncertainty in the field of sarcopenia concerns the loss of muscle strength with preserved muscle mass, which in the present paper we defined as dynapenia. The 2010 version of the EWGSOP criteria did not consider the isolated loss of muscle strength as a separate clinical entity or suggest a treatment for it. A major change in the new EWGSOP2 criteria was not only that the measurement of muscle strength became the primary step in the algorithm for sarcopenia diagnosis but, in the presence of muscle strength reduction, treatment for sarcopenia was recommended regardless from whether a muscle mass reduction was detected or not. This change could be of great relevance for CKD. Indeed, data from long-term follow-up studies found that renal outcome in CKD patients depends much more on the loss of muscle strength than on the loss of muscle mass [10,11,34]. Nevertheless, to the best of our knowledge the prevalence of dynapenia in CKD patients has not been investigated so far. By using the EGWSOP2 criteria in our study we found that about 18% of predialysis patients were dynapenic, a percentage higher than full-blown sarcopenia or the isolated loss of muscle mass. It is also worth noting that about 50% of the dynapenic patients were in CKD stage 2 or 3, suggesting that dynapenia could occur early in the course of this disease. Interestingly, previous studies found that muscle strength declines much more rapidly than muscle mass, indicating that the pathophysiological mechanism of dynapenia could be different from that of sarcopenia. In agreement with the hypothesis of a strong association between the loss of muscle strength and the severity of CKD, in our series of patients HGS significantly correlated with eGFR and with the concentration of hemoglobin and serum albumin. Nevertheless, the group of patients that we classified as dynapenic on the basis of the EWGSOP2 criteria did not differ from those with normal muscle strength either in CKD stage or in eGFR or in the concentrations of hemoglobin and serum albumin. These results suggest that also in dynapenia, as we discussed earlier for sarcopenia, the EWGSOP2 cut off values could be not so effective in segregating high risk patients from the rest of the CKD population. The EWGSOP criteria were, however, developed for the diagnosis of aging and not CKD-related sarcopenia, and these two conditions could have substantially different pathophysiological mechanisms. Therefore the results of our study add new arguments to the idea that specific diagnostic criteria should be developed for CKD to be used for prognostic purposes.

The present study has several limitations. First, the number of patients enrolled was quite small and they came from a restricted geographic area. Second, we did not perform a long-term follow-up to assess the relationship between sarcopenia or dynapenia and prognosis, but we used indirect biomarkers that also could have been affected by other concomitant confounders such as the nutritional status of the patients or the drug therapy they were taking. Finally, our dynapenic and sarcopenic patients were older (though not significantly) than those of the other two groups (i.e., the normal group with preserved muscle mass and strength and the group of those with low muscle mass and preserved muscle strength). Because aging is a causative factor of sarcopenia and dynapenia, it may have partially contributed to the development of these conditions in our patients independently from CKD.

Conclusions

By using the EGWSOP2 cutoff points in CKD we were successful not only in identifying sarcopenia with a prevalence similar to previous studies but also in detecting dynapenia, which was highly prevalent, occurring in about 18% of the study population. However, these criteria were not effective in segregating high-risk sarcopenic and dynapenic patients. These results add new arguments to the idea that CKD-specific criteria should be developed to be used in clinical practice.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Bruna Guida: Conceptualization, Data curation, Formal analysis, Writing - original draft, Writing - review & editing, Project administration. **Martina Di Maro:** Writing - original draft. **Mariastella Di Lauro:** Investigation. **Teresa Di Lauro:** Investigation. **Rossella Trio:** Investigation. **Mariarosaria Santillo:** Supervision,

Project administration. **Annamaria Belfiore:** Supervision, Project administration. **Andrea Memoli:** Investigation. **Mauro Cataldi:** Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing.

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