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Estimation of sarcopenia prevalence using various assessment tools

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ABSTRACT

Background: Sarcopenia is defined as a progressive and generalized loss of muscle mass with either a loss of muscle strength or a loss of physical performance but there is no recommendation regarding the diagnostic tools that have to be used. In this study, we compared the prevalence of sarcopenia assessed using different diagnostic tools.

Methods: To measure muscle mass, muscle strength and physical performance, we used for each outcome two different diagnostic tools. For muscle mass, we used Dual Energy X-Ray Absorptiometry (DXA) and bioelectrical impedance analysis (BIA); for muscle strength, we used a hydraulic dynamometer and a pneumatic dynamometer; for physical performance we used the Short Physical Performance Battery test (SPPB test) and the walk speed. Eight diagnostic groups were hereby established.

Results: A total of 250 consecutive subjects were recruited in an outpatient clinic in Liège, Belgium. Estimated prevalence of sarcopenia varied from 8.4% to 27.6% depending on the method of diagnosis used. Regarding muscle mass, BIA systematically overestimated muscle mass compared to DXA (mean estimated prevalence with BIA = 12.8%; mean prevalence with DXA = 21%). For muscle strength, the pneumatic dynamometer diagnosed twice more sarcopenic subjects than the hydraulic dynamometer (mean estimated prevalence with PD = 22.4%; mean estimated prevalence with HD = 11.4%). Finally, no difference in prevalence was observed when the walking speed or the SPPB test was used. A weak overall kappa coefficient was observed (0.53), suggesting that the 8 methods of diagnosis are moderately concordant.

Conclusion: Within the same definition of sarcopenia, prevalence of sarcopenia is highly dependent on the diagnostic tools used.

1. Introduction

Sarcopenia is an aging-related condition defined by a progressive and generalized loss of muscle mass and function (Baumgartner et al., 1998; Cooper et al., 2012). This geriatric syndrome, now recognized as a major clinical problem for older people, is an increasing public health issue in our society. Indeed, sarcopenia is associated with some adverse clinical outcomes such as physical impairment, limitation of mobility, decreased quality of life, increased risk of falls, hospitalization and mortality (Lauretani et al., 2003; Janssen, 2006; Visser et al., 2005; Janssen et al., 2002; Rantanen, 2003; Lang et al., 2010; Rizzoli et al., 2013) but also with major co-morbidities such as type 2 diabetes, obesity and osteoporosis (Sayer et al., 2005).

The definition of sarcopenia has been largely modified since the term "sarcopenia" was firstly introduced by Rosenberg in 1989 (Rosenberg, 1997). Originally, definitions of sarcopenia were based on decreased muscle mass only. Progressively, a qualitative dimension was added to focus on decreases in muscle strength and physical performance. These definitions have obviously a major impact on the assessment of the prevalence of the disease. Recently, Bijlsma et al. (Bijlsma et al., 2013) assessed the impact of these different definitions on the prevalence of sarcopenia and showed that it ranged from 0% to 45.2% depending on the definition used.

Recently the progress has been made in this field with the practical and consensual clinical definition of sarcopenia developed by the European Working Group on Sarcopenia in Older People (EWGSOP) (Cruz-Jentoft et al., 2010). According to this European consensual definition, sarcopenia is defined by the presence of low skeletal muscle mass and either low muscle strength or low muscle performance.

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However, the EWGSOP does not recommend the use of specific tools to measure muscle mass, muscle strength and physical performance (Cooper et al., 2013). Indeed, the EWGSOP suggests two different methods to assess muscle mass in clinical practice (i.e. the Dual Energy X-Ray Absorptiometry (DXA) and the bio-electrical impedance analysis (BIA) but also two methods to assess the physical performance (i.e. the "Short Physical Performance Battery" test and the usual gait speed). The muscle strength is referenced to be assessed by the handgrip strength but no recommendation is given regarding the tools to be used for this measurement. However, the use of different diagnostic tools may lead to different prevalences of sarcopenia and may therefore have important consequences on clinical researches and development of therapeutic strategies. To our knowledge, no study has yet assessed the variation in prevalence of sarcopenia depending on the different tools used to measure the variables of muscle mass, muscle strength and physical performance. Therefore, through this cross-sectional study, we aim to assess the impact of the use of these different diagnostic tools on the estimated prevalence of sarcopenia.

2. Methods

2.1. Study population

Subjects were recruited consecutively in an outpatient clinic in Liège, Belgium in an osteoporotic and geriatric department but also by means of press advertisement. Volunteers had to be over 65 years old and had to read and sign an informed consent after being informed of the objectives and methods of the research. Subjects with an amputated limb, with a BMI above 50 kg/m^2 or wearing an electronic implant were excluded from the research.

The study was approved by the Ethics Committee of the University Teaching Hospital of Liège.

All subjects enrolled in this study were interviewed to gather their socio-demographic data and anamnesis. Anthropometric measurements (weight at the nearest 0.1 kg, height at the nearest 0.1 cm, calf, wrist and arm circumferences at the nearest 0.1 cm) as well as clinical measurements (walking speed, nutritional status with the "Mini-Nutritional Assessment", quality of life with the "Short-Form 36", cognitive status with the "Mini-Mental State Examination (MMSE)", depression with the "Geriatric Depression Scale", dependence in daily living activities with the "Lawton scale" and gait and body balance with the "Tinetti test") were also collected.

2.2. Diagnosis of sarcopenia

The definition of the EWGSOP was applied for this research (Cruz-Jentoft et al., 2010). According to these experts, sarcopenia diagnosis is based on the documentation of low muscle mass plus either low muscle strength or low physical performance.

Each variable was measured with 2 different tools, as presented in the following sections.

2.2.1. Assessment of appendicular muscle mass

We used the following two techniques to assess appendicular muscle mass.

Dual Energy X-Ray Absorptiometry (DXA) exams were performed with a Hologic Discovery A (Hologic, Inc., USA) device. This whole-body scan is able to distinguish fat, bone mineral and lean tissues and exposes the patient to minimal radiation. All evaluations were carried out by the same technician and the device was calibrated twice a week by scanning a spine phantom. Appendicular skeletal lean mass (ASM) was determined as the sum of the mass of the four limbs. Skeletal muscle mass index (SMI) was calculated by dividing appendicular lean mass by height squared. The cut-off informed by the EWGSOP group (Cruz-Jentoft et al., 2010) for the diagnosis of sarcopenia is fixed at 7.26 kg/m^2 for men and 5.5 kg/m^2 for women (Baumgartner et al., 1998). To find this cut-off, Baumgartner et al. (1998) developed in 1998 a population-based survey of 883 elderly subjects and compared results of body composition with a data set including 229 young subjects aged 18–40 years (Gallagher et al., 1997). They defined cut-off values for sarcopenia based on comparison of the distribution for muscle mass in young subjects versus elderly people. With this technique, they defined a SMI two standard deviations below the mean SMI of young male and female reference groups as the gender-specific cut-off point for sarcopenia. Sarcopenia, diagnosed using this approach, was significantly associated with disability and was independent of ethnicity, age, comorbidity, health behaviors and fat mass.

Bio-electrical impedance analysis (BIA) was performed with an InBody S10, Biospace device (Biospace Co., Ltd, Korea/Model JMW140). This non-invasive and easy to use method estimates the volume of fat and lean body mass based on the relationship between the volume of a conductor and its electrical resistance. Volunteers were seated on a chair and tactile electrodes were placed at 8 points on the body. All bio-electrical impedance analyses were carried out by the same technician. Cut-off criteria for sarcopenia, when using bio-electrical impedance analysis, were 8.87 kg/m^2 for men and 6.42 kg/m^2 for women (Chien et al., 2008), as recommended by the EWGSOP. These cut-offs were defined based on the comparison of a group of 302 individuals aged 65 years and older for the distribution of muscle mass with a group of 200 young subjects aged 18–40 years. Using a SMI of 2 standard deviations or more below the normal sex-specific means for young persons, they found a cut-off of 8.87 kg/m^2 for men and 6.42 kg/m^2 for women.

2.2.2. Assessment of muscle strength

We also used two types of dynamometer to assess handgrip strength, a pneumatic and a hydraulic dynamometer.

The hydraulic dynamometer used was a Hydraulic Hand Dynamometer, Saehan Corporation (MSD Europe Bvba, Belgium) and the pneumatic dynamometer used was a Squeeze Dynamometer, Saehan Corporation (MSD Europe Bvba, Belgium). Both dynamometers were calibrated for 10, 40 and 90 kg by the firm at the beginning of the recruitment period.

Subjects were asked to grip the two dynamometers as hard as they can three times with each hand. The maximum of the six measurements was recorded as the result, as recently recommended by Roberts (Roberts et al., 2011). We used the cut-off points for the diagnosis of sarcopenia, defined by the EWGSOP group (Cruz-Jentoft et al., 2010): 30 kg for men and 20 kg for women. These cut-offs were found by Lauretani et al. (2003) based on 1030 subjects aged 20–102 years. They found that 20 kg for women and 30 kg for men were the two thresholds that best discriminates subjects with mobility limitations. The EWGSOP also presented a BMI-dependant cut-off where cut-off points for subjects presenting a lower BMI are lower than those for subjects with a higher BMI (Fried et al., 2001). Given that the EWGSOP definition did not reach an international consensus regarding the cut-off to use for the diagnosis, we arbitrarily chose to use the cut-off of Lauretani et al. (2003).

2.2.3. Assessment of physical performance

We used the following two different methods to assess physical performance in our population, as recommended by the EWGSOP group.

The SPPB test is a composite of three separate tests: balance, 4-meter gait speed and chair stand tests. Each test is weighted equally with a score between 0 and 4 points. Sarcopenia diagnosis cut-off for this test, scored on 12 points, is below or equal to 8 points (Guralnik et al., 2000).

Usual gait speed was assessed by timing subjects asked to walk a 4-meter distance, at a comfortable speed. The cut-off point for a 4-meters course is set at 0.8 m/s (Lauretani et al., 2003). They chose this cut-off because, in their population of 1030 subjects aged 20–102 years, this

value corresponds to the lowest quintile threshold of the speed distribution.

3. Definition

Based to these 2 muscle mass measurements, 2 muscle strength measurements and 2 physical performance measurements, we established 8 diagnostic methods of sarcopenia. These methods are summarized in Table 1 and were used in our analysis.

4. Statistical analysis

Patients were defined as sarcopenic, or not, according to each of these eight diagnostic methods. Then, we estimated the percentage of sarcopenic subjects for each diagnostic method. Afterwards, the degree of concordance between each method was calculated and recorded in a frequency table. For each tool, we assessed the percentage of subjects distributed below the tools respective cut-off. The agreement between tools for identifying subjects below the cut-off was tested by Cohen's kappa coefficient; the closer the value to 1, the better the concordance. Scatter plots for each tool of diagnosis have also been performed to allow a visual representation of the distribution of subjects across the different cut-off points. Each point of the scatter plot corresponds to one individual. Several individuals can present the same value of measurement and are placed on the same line along the x-axis. The agreement between diagnostic methods was also assessed by Cohen's kappa coefficient.

We analyzed the differences in subject's characteristics according to the 8 diagnostic methods. Quantitative variables were expressed as mean ± standard deviation (SD) and qualitative variables were reported as absolute and relative frequencies (%). Each clinical characteristic was analyzed by a regression or an ordinal logistic model in order to assess if there was a difference between the patients defined sarcopenic by a method and those who weren't defined as sarcopenic by this method. Each method of diagnosis was considered as a binary variable (1 = patient was considered as sarcopenic, 0 = patient was not considered as sarcopenic). The p-value in the table is the overall p-value of the regression model whereas the asterisk (*) indicates the significant variables, in other words, the methods of diagnosis for which the patients considered as sarcopenic showed a clinical characteristic statistically different from those who weren't defined as sarcopenic by this method.

Analyses were performed using the SAS statistical package (version 9.3 for windows) and R statistical software (version 2.15 for windows). Results were considered statistically significant at the 5% critical level ($p < 0.05$).

Table 1
Estimated prevalence of sarcopenia according to the eight diagnosis method (for all population and stratified by sex).

	Number of subjects diagnosed as sarcopenic (prevalence) Total population	Prevalence of sarcopenia
DXA–HD–UGS	35	14%
DXA–HD–SPPB	37	14.8%
DXA–PD–UGS	69	27.6%
DXA–PD–SPPB	69	27.6%
BIA–HD–UGS	21	8.4%
BIA–HD–SPPB	21	8.4%
BIA–PD–UGS	43	17.2%
BIA–PD–SPPB	43	17.2%

DXA: Dual Energy X-Ray Absorptiometry; BIA: bio-electrical impedance analysis; HD: hydraulic dynamometer; PD: pneumatic dynamometer; UGS: usual gait speed; SPPB: Short Physical Performance Battery.

5. Results

5.1. Subject characteristics

250 subjects were recruited over a 6-month period in our outpatient clinic in Liège, Belgium. Most recruited patients were women (62.8%) and the mean age of the population was 74.1 ± 6.4 years.

5.2. Prevalence of sarcopenia according to diagnostic tools

The estimated prevalences of sarcopenia using the 8 methods of diagnosis are presented in Table 1. General prevalence of sarcopenia ranges from 8.4% with methods BIA–HD–UGS and BIA–HD–SPPB to 27.6% with methods DXA–PD–UGS and DXA–PD–SPPB.

Regarding muscle mass, it seems that BIA systematically overestimates muscle mass compared to DXA. Indeed, the mean sarcopenia estimated prevalence is 12.8% when using BIA, and 21% with DXA, and the mean appendicular muscle mass divided per height squared (ALM/ht^2) is 6.08 kg/m^2 for women and 7.93 kg/m^2 for men when assessed with DXA, and 7.63 kg/m^2 for women and 9.66 kg/m^2 for men with BIA.

For muscle strength, the pneumatic dynamometer diagnosed on average twice more sarcopenic subjects than the hydraulic dynamometer. The mean estimated prevalence with pneumatic dynamometer is 22.4% while the mean estimated prevalence with hydraulic dynamometer is 11.4%. When using the hydraulic dynamometer, the mean maximal strength of subjects is 27.5 kg but when using pneumatic dynamometer, the mean strength is 12.2 kg, which represents a difference of 15.3 kg.

Finally, no difference in prevalence was observed between the usual gait speed and the SPPB test. The mean estimated prevalence using usual walking speed is 16.8% and 17% when using the SPPB test. Results shows the same prevalence of sarcopenia for definitions DXA–PD–UGS and DXA–PD–SPPB, for definition BIA–HD–UGS and BIA–HD–SPPB and for definition BIA–PD–UGS and BIA–PD–SPPB, which means that in these three cases, estimated prevalence of sarcopenia is not dependant on the method used to measure physical performance.

5.3. Concordance between tools

Distribution of subjects across the different cut-off points for these tools has also been represented on scatter plots (Supplementary files, Fig. 2A, B and C). Regarding muscle mass, results indicate that 28.4% of subjects (27.9% of men and 28.6% of women) were distributed below the EWGSOP suggested cut-off when using DXA versus 17.6% when using BIA (26.9% of men, 12.1% of women). Kappa value for the concordance between BIA and DXA is 0.48 (CI 95%: 0.35–0.60).

For muscle strength, when using the hydraulic dynamometer, 34.8% of subjects (19.3% of men, 43.9% of women) were below the cut-off points versus 94.4% with the pneumatic dynamometer (92.5% of men, 95.5% of women). The concordance between the hydraulic dynamometer and the pneumatic dynamometer is low with a kappa value of 0.048 (CI 95%: 0.01–0.08). Moreover, compared to cut-off points of the hydraulic dynamometer, those of the pneumatic dynamometer should be decreased at 8 kg for women and 12 kg for men to reach the same percentage of subjects distributed below the value.

Finally, for physical performance, 23.2% of subjects (18.3% of men, 26.3% of women) were below the cut-off point of 0.8 m/s for gait speed and 20.4% below the cut-off of 8 points for the SPPB test (8.6% of men, 27.4% of women). Concordance between the SPPB test and the usual gait speed is strong with a kappa value of 0.72 (CI 95%: 0.61–0.82).

5.4. Concordance between methods of diagnosis

Table 2 shows the concordances between definitions. Concordance between methods DXA–PD–UGS and DXA–PD–SPPB, between methods BIA–HD–UGS and BIA–HD–SPPB and between methods BIA–PD–UGS and BIA–PD–SPPB is 1, which represents a perfect concordance. This

Table 2
Concordance between the eight methods of diagnosis.

	DXA–HD–UGS	DXA–HD–SPPB	DXA–PD–UGS	DXA–PD–SPPB	BIA–HD–UGS	BIA–HD–SPPB	BIA–PD–UGS	BIA–PD–SPPB
DXA–HD–UGS		0.97 (0.92–1.0)	0.60 (0.48–0.71)	0.60 (0.48–0.71)	0.60 (0.44–0.76)	0.60 (0.44–0.76)	0.36 (0.21–0.52)	0.36 (0.21–0.52)
DXA–HD–SPPB			0.63 (0.51–0.74)	0.63 (0.51–0.74)	0.58 (0.42–0.73)	0.58 (0.42–0.73)	0.35 (0.19–0.50)	0.35 (0.19–0.50)
DXA–PD–UGS				1	0.31 (0.19–0.43)	0.31 (0.19–0.43)	0.52 (0.40–0.65)	0.52 (0.40–0.65)
DXA–PD–SPPB					0.31 (0.19–0.43)	0.31 (0.19–0.43)	0.52 (0.40–0.65)	0.52 (0.40–0.65)
BIA–HD–UGS						1	0.61 (0.47–0.76)	0.61 (0.47–0.76)
BIA–HD–SPPB							0.61 (0.47–0.76)	0.61 (0.47–0.76)
BIA–PD–UGS								1

DXA: Dual Energy X-Ray Absorptiometry; BIA: bio-electrical impedance analysis; HD: hydraulic dynamometer; PD: pneumatic dynamometer; UGS: usual gait speed; SPPB: Short Physical Performance Battery.

means that the measure of physical performance with either the "Short Physical Performance Battery test" or the "usual walking speed" does not change the estimated prevalence of sarcopenia. The higher concordance is observed between DXA–HD–UGS and DXA–HD–SPPB (kappa coefficient of 0.97). Indeed, only two more subjects were diagnosed as sarcopenic when using the SPPB test instead of the usual gait speed for the physical performance measurement. The lowest kappa coefficient is observed between definition DXA–PD–UGS or DXA–PD–SPPB, using DXA to measure muscle mass and pneumatic dynamometer to measure muscle strength and definition BIA–HD–UGS or BIA–HD–SPPB, using BIA for muscle mass and hydraulic dynamometer for muscle strength. A weak overall kappa coefficient is observed (coefficient 0.53, 95% CI 0.18–0.89), which means that, globally the 8 definitions are moderately concordant.

We also numbered the subjects diagnosed as sarcopenic across the eight different diagnostic methods (Table 3). On the 250 subjects recruited for the study, 173 did not have sarcopenia according to any definition while 18 subjects were diagnosed sarcopenic by all the eight definitions. 17 subjects were diagnosed sarcopenic with only the four definitions using DXA to measure muscle mass while only 3 subjects were diagnosed as sarcopenic with the only four definitions using BIA. This distribution is represented visually in Fig. 1.

5.5. Clinical characteristics of sarcopenic subjects

We also decided to analyze sarcopenic subject's characteristics in the different subgroups. Results are presented in Table 4.

Age is significantly higher in subjects who were diagnosed sarcopenic by method DXA–HD–UGS ($p < 0.001$) and by method BIA–HD–UGS or BIA–HD–SPPB ($p = 0.034$) compared to non-sarcopenic subjects. BMI was lower in subjects who were diagnosed sarcopenic by method DXA–PD–UGS or DXA–PD–SPPB ($p < 0.001$). For subjects with sarcopenia detected by method DXA–PD–UGS or DXA–PD–SPPB, calf, arm and wrist circumferences were also lower ($p = 0.0025$, 0.012 and <0.001 respectively). MMSE was higher for subjects with sarcopenia diagnosed by method DXA–HD–UGS ($p < 0.001$) but was lower for those diagnosed sarcopenic by method DXA–HD–SPPB ($p < 0.001$). Subjects with sarcopenia diagnosed by method BIA–HD–UGS or BIA–HD–SPPB had higher walking speed ($p = 0.0042$) but a lower Tinetti value for walk ($p = 0.053$) than those who were not diagnosed by this method ($p = 0.0042$). Fat mass was lower for patients with sarcopenia detected by method BIA–PD–UGS or BIA–PD–SPPB ($p = 0.016$). No statistical association was found between methods of diagnosis and walking aid, number of drugs, number of comorbidities, nutritional status, Lawton scale, depression scale, quality of life and Tinetti scale for balance.

6. Discussion

Within the same definition of sarcopenia, recommended by the EWGSOP, estimated prevalence of sarcopenia seems highly dependent on the diagnostic tools used to measure the three variables: muscle mass, muscle strength and physical performance. Indeed, we found important differences of measured prevalence of sarcopenia whether BIA or DXA and whether a pneumatic dynamometer or a hydraulic dynamometer was used. On the contrary, whether the SPPB test or the usual gait speed is used to measure the physical performance, it does not result in a difference of prevalence. We also found significant differences regarding the clinical characteristics of sarcopenic subjects diagnosed with these methods. If the clinical characteristics of sarcopenic subjects are different depending on the tools used for the diagnosis of sarcopenia, the long-term clinical consequences of sarcopenia may also differ and therefore therapeutical strategies will not be easily evaluated and implemented. The identification of the most pertinent tools for the diagnosis of sarcopenia could therefore be of a great clinical and public health interest.

A wide range of techniques can be used to assess appendicular lean mass. Even if computed tomography (CT scan) and magnetic resonance imaging (MRI) are considered to be the gold standard in research, the EWGSOP suggests the use of Dual Energy X-Ray Absorptiometry (DXA) and bio-electrical impedance analysis (BIA) in clinical use because of their lower cost and larger availability. BIA is known to underestimate fat mass and overestimate muscle mass (Faria et al., 2014; Sillanpaa et al., 2014). Despite the recommended adaptation of cut-off for BIA, in our study, the overestimation of lean mass with the BIA device InBody S10 compared to DXA was much larger than expected, resulting in a

Table 3
Distribution of subjects according to the eight diagnostic methods.

DXA–HD–UGS	DXA–HD–SPPB	DXA–PD–UGS	DXA–PD–SPPB	BIA–HD–UGS	BIA–HD–SPPB	BIA–PD–UGS	BIA–PD–SPPB	Number	Frequency
0	0	0	0	0	0	0	0	173	69.2
1	1	1	1	1	1	1	1	18	7.2
0	0	1	1	0	0	1	1	17	6.8
1	1	1	1	0	0	0	0	17	6.8
0	0	1	1	0	0	0	0	15	6.0
0	0	0	0	0	0	1	1	5	2.0
0	0	0	0	1	1	1	1	3	1.2
0	1	1	1	0	0	0	0	2	0.8

DXA: Dual Energy X-Ray Absorptiometry; BIA: bio-electrical impedance analysis; HD: hydraulic dynamometer; PD: pneumatic dynamometer; UGS: usual gait speed; SPPB: Short Physical Performance Battery.

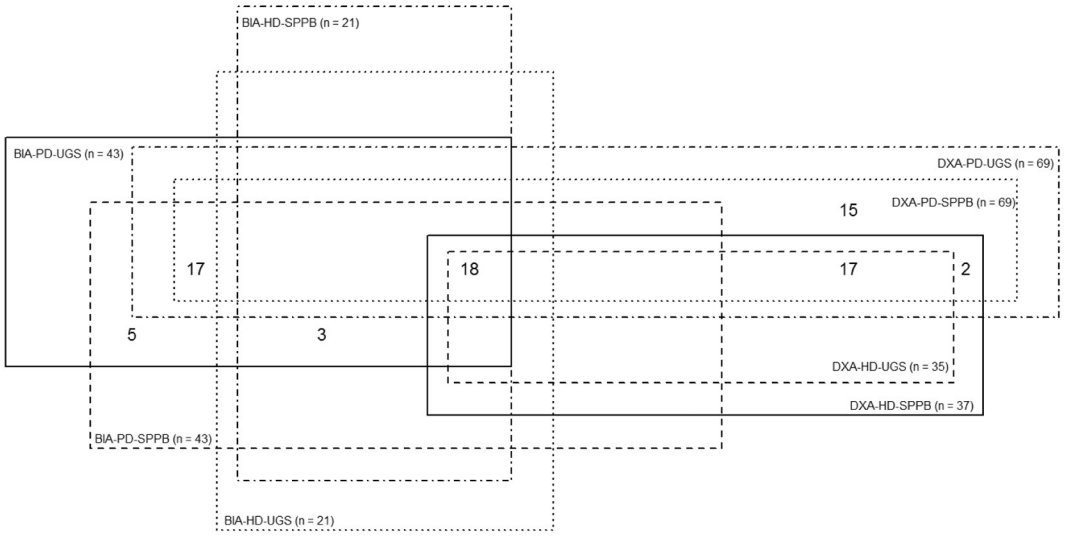

Fig. 1. Number of subjects diagnosed as sarcopenic according to the eight definitions. DXA: Dual Energy X-Ray Absorptiometry; BIA: bio-electrical impedance analysis; HD: hydraulic dynamometer; PD: pneumatic dynamometer; UGS: usual gait speed; SPPB: Short Physical Performance Battery.

high difference of prevalence of sarcopenia whether BIA or DXA was used. These results suggest that the adaptation of BIA cut-offs should be device dependant. Indeed, all types of BIA devices are probably not equal to each other. The device used to determine the cut-off discussed on the EWGSOP paper is a Maltron system (Maltron Bioscan 920, Rayleigh, UK) and our device is a InBody S10 Biospace device (Biospace Co., Ltd, Korea/Model JMW140). These two devices were based on the same method of measurement of muscle mass, i.e. the estimation of body composition using the difference of conductivity of the various tissues due to the difference of their biological characteristics. However, the Maltron system performed the analyses with an operating frequency of 50 Hz while for the InBody S10 system, a total of 30 impedance measurements are obtained using 6 different frequencies (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz, 1000 kHz). The fact that we used a different device than the one used to establish the cut-off points of the EWGSOP could explain our results. Interestingly, all types of commercially available BIA devices present differences in technical characteristics, such as the frequency used for the analysis. Researchers must be careful when they choose their tool to measure muscle mass and must make sure that this tool is validated against DXA for the diagnosis of sarcopenia.

EWGSOP also reviewed several methods to measure muscle strength. Because of its low cost, easy use and large availability,

Table 4
Clinical characteristics of sarcopenic subjects according to the eight diagnostic methods.

	DXA–HD–UGS (n = 35)	DXA–HD–SPPB (n = 37)	DXA–PD–UGS (n = 69)	DXA–PD–SPPB (n = 69)	BIA–HD–UGS (n = 21)	BIA–HD–SPPB (n = 21)	BIA–PD–UGS (n = 43)	BIA–PD–SPPB (n = 43)	Total n	p-Value
Age (years)	78.6 ± 6.3	78.0 ± 6.6	76.0 ± 6.5	76.0 ± 6.5	80.0 ± 7.0[a]	80.0 ± 7.0[a]	77.0 ± 7.4	77.0 ± 7.4	250	<0.0001
Sex										
Women	23 (65.7)	25 (67.6)	43 (62.3)	43 (62.3)	10 (47.6)	10 (47.6)	19 (44.2)[a]	19 (44.2)[a]	250	0.021
BMI (kg/m^2)	23.2 ± 2.4	23.4 ± 2.8	23.4 ± 2.8[a]	23.4 ± 2.8[a]	22.8 ± 2.7	22.8 ± 2.7	23.1 ± 3.2	23.1 ± 3.2	250	<0.0001
Walking aid										
Yes	6 (17.1)	6 (16.2)	7 (10.3)	7 (10.3)	5 (23.8)	5 (23.8)	7 (16.7)	7 (16.7)	250	0.17
Calf circumference (cm)	31.5 ± 2.6	31.7 ± 2.7	32.0 ± 2.6[a]	32.0 ± 2.6[a]	31.1 ± 2.7	31.1 ± 2.7	31.7 ± 2.7	31.7 ± 2.7	248	<0.0001
Arm circumference (cm)	25.1 ± 2.9	25.1 ± 2.8	25.6 ± 3.1[a]	25.6 ± 3.1[a]	24.5 ± 2.9	24.5 ± 2.9	25.3 ± 3.0	25.3 ± 3.0	248	<0.0001
Wrist circumference (cm)	15.8 ± 1.5	15.8 ± 1.4	16.1 ± 1.8[a]	16.1 ± 1.8[a]	16.3 ± 1.7	16.3 ± 1.7	16.3 ± 1.4	16.3 ± 1.4	248	0.0006
Drugs (nbr)	6.9 ± 2.7	6.8 ± 2.8	6.2 ± 2.9	6.2 ± 2.9	6.8 ± 2.4	6.8 ± 2.4	5.5 ± 2.7	5.5 ± 2.7	250	0.083
Comorbidities (nbr)	4.5 ± 2.5	4.6 ± 2.4	4.0 ± 2.3	4.0 ± 2.3	4.2 ± 2.1	4.2 ± 2.1	3.8 ± 1.9	3.8 ± 1.9	250	0.39
Mini-Nutritional Assessment										
Well nourish	24 (68.6)	26 (70.3)	50 (72.5)	50 (72.5)	13 (61.9)	13 (61.9)	31 (72.1)	31 (72.1)		
Risk of malnutrition	9 (25.7)	9 (24.3)	17 (24.6)	17 (24.6)	6 (28.6)	6 (28.6)	10 (23.3)	10 (23.3)		
Malnutrition	2 (5.7)	2 (5.4)	2 (2.9)	2 (2.9)	2 (9.5)	2 (9.5)	2 (4.6)	2 (4.6)	250	0.043
MMSE (/30 points)	26.9 ± 2.1[a]	26.5 ± 2.6[a]	27.2 ± 2.3	27.2 ± 2.3	26.5 ± 2.4	26.5 ± 2.4	27.3 ± 2.1	27.3 ± 2.1	250	0.0001
Lawton scale										
Men (/5 points)	4.2 ± 1.1	4.2 ± 1.1	4.5 ± 0.9	4.5 ± 0.9	4.2 ± 1.2	4.2 ± 1.2	4.5 ± 0.9	4.5 ± 0.9	93	0.11
Women (/8 points)	7.0 ± 1.3	7.1 ± 1.3	7.4 ± 1.1	7.4 ± 1.1	6.6 ± 1.2	6.6 ± 1.2	7.21 ± 1.1	7.21 ± 1.1	157	0.30
Geriatric Depression Scale (points)	4.4 ± 4.1	4.4 ± 4.0	3.7 ± 3.5	3.7 ± 3.5	4.7 ± 4.3	4.7 ± 4.3	3.8 ± 3.5	3.8 ± 3.5	244	0.54
SF-36 (/100)	59.9 ± 19.9	60.6 ± 19.6	65.0 ± 18.4	65.0 ± 18.4	57.4 ± 22.0	57.4 ± 22.0	64.1 ± 18.9	64.1 ± 18.9	244	0.12
Walk speed (m/s)	0.82 ± 0.32	0.83 ± 0.32	0.96 ± 0.29	0.96 ± 0.29	0.71 ± 0.34[a]	0.71 ± 0.34	0.91 ± 0.33	0.91 ± 0.33	249	<0.0001
Tinetti										
Balance (/16)	14.7 ± 2.3	14.8 ± 2.2	15.3 ± 1.7	15.3 ± 1.7	14.2 ± 2.7	14.2 ± 2.7	15.1 ± 2.1	15.1 ± 2.1	248	0.064
Walk (/12)	10.7 ± 2.1	10.7 ± 2.1	11.3 ± 1.7	11.3 ± 1.7	10.0 ± 2.1[a]	10.0 ± 2.1[a]	11 ± 1.8	11 ± 1.8	248	0.025
Fat mass (kg)	21.7 ± 8.0	21.7 ± 7.8	21.7 ± 6.8	21.7 ± 6.8	20.2 ± 9.7	20.2 ± 9.7	19.9 ± 7.9[a]	19.9 ± 7.9[a]	250	<0.0001

DXA: Dual Energy X-Ray Absorptiometry; BIA: Bio-electrical impedance analysis; HD: hydraulic dynamometer; PD: pneumatic dynamometer; UGS: usual gait speed; SPPB: Short Physical Performance Battery.

[a] Significant covariate.

handgrip strength is the suggested method, as also confirmed by another expert group (Cooper et al., 2013). Grip strength is usually assessed by means of a dynamometer, but different types of dynamometers currently exist. Some authors already compared a hydraulic dynamometer (Jamar) and a pneumatic one (Martin Vigorimeter) (Desrosiers et al., 1995; Li et al., 2010) and found a high correlation between the two device for measuring grip strength. Different types of pneumatic dynamometers currently exist and we chose the Squeeze Dynamometer because unlike the Martin Vigorimeter, results are expressed in kilograms and offered us thereby a pertinent comparison with the hydraulic dynamometer. However, in our study, contrary of the pre-cited authors, the pneumatic dynamometer diagnosed about twice more sarcopenic subjects than the hydraulic dynamometer. Our primary hypothesis was that the two devices do not measure the same muscle characteristic. Indeed, the pneumatic dynamometer is a pressure measure implying a pseudo-dynamic movement as opposed to the static strength measure of the hydraulic one. Previous published results showing a high correlation between the two types of dynamometer (Desrosiers et al., 1995; Li et al., 2010) are not favorable to this hypothesis, but the tested tools are not exactly those that we used in the present study. The different available pneumatic dynamometers do not seem identical in measuring grip strength and, consequently, authors must be careful when they chose a dynamometer for their researches. We can also note that, even if the calibration was performed by the company at the beginning and at the end of the recruitment period, a minor risk of inaccurate calibration remains. Complementary researches are needed to determine the most appropriate dynamometer, in this context, by identifying for example the group of diagnosed sarcopenic subjects presenting the most serious or the most important long term consequences. The choice of the cut-off can also be a point of concern. Indeed, the EWGSOP suggested two cut-off points for the diagnosis of sarcopenia regarding muscle strength, an absolute cut-off value of 20 kg for women and 30 kg for men, and a BMI-dependent cut-off. As no consensus has yet been reached about which cut-off has to be used for the diagnosis of sarcopenia, we chose the absolute values. In the meantime, we have shown that the prevalence of sarcopenia can range from 9.25% to 18% according to which cut-off from the EWGSOP definition has been used for the diagnosis (Beaudart et al., in press). The absence of strict cut-off criteria for the diagnosis of sarcopenia is currently pointed out as a limit of the EWGSOP definition.

Even if many tests of physical performance are available, EWGSOP recommends using the Short Physical Performance Battery (SPPB) test and the usual gait speed for the diagnosis of sarcopenia. According to our results, it seems that the two methods are relatively concordant. In the literature, there are as many studies using the SPPB as studies using the usual gait speed. It seems easier to use the usual gait speed but some authors defend the fact that the SPPB overviews more aspects of physical performance. We did not find a significant difference of estimated prevalence between both methods. Moreover, definitions A and B presented a kappa concordance equal to 0.97 and the concordance was perfect between other definitions assessing physical performance with SPPB or with usual gait speed.

7. Conclusion

This research reveals high differences of measured prevalence of sarcopenia depending on the diagnostic tools used. A consensus regarding the tools that must be used in the context of diagnosing sarcopenia is essential in order to make studies comparable. Regarding the measurement of muscle mass, we found a high difference in the prevalence of sarcopenia whether Dual Energy X-Ray Absorptiometry or bioelectrical impedance analysis was used. This result suggests that a pondered formula should be developed for each type of bio-electrical impedance analysis device. Concerning muscle strength, results of prevalence were discordant whether a pneumatic dynamometer or a hydraulic dynamometer was used. Future researches are needed to identify the most appropriate dynamometer to use in the context of sarcopenia. Finally, regarding physical performance, the two tools recommended by the EWGSOP do not influence the estimated prevalence of sarcopenia and seem both appropriate for the diagnosis. Validation of diagnostic tools is a crucial issue in clinical research. Indeed, unappropriated tools can lead to an over- or underestimation of prevalence of sarcopenia, with consequences that could be important, from a public health point of view. For example, the risk would be to give an unnecessary treatment to a false positive subject (i.e. without sarcopenia) and to deprive a false negative patient (i.e. with sarcopenia) of effective treatment.

Author's contributions

CB, OB, JP and JYR designed the study. CB, CS, AQ, JS and FB recruited the subjects and collected the data. CB and ND performed statistical analyses and interpreted data with OB and SG. All authors commented on the drafts and approved the final draft. CB is the manuscript's guarantor.

Declaration of interest

The authors indicate that they have no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.exger.2014.11.014.

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