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Original Article

The diagnostic cut-off points for components of sarcopenia in Finnish Caucasian women: A retrospective cross-sectional study

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Abstract

Objectives: To determine the diagnostic cut-off values of components for sarcopenia in Caucasian women. **Methods**: The present retrospective cross-sectional study based on the REFERENCE sample included 400 healthy women aged 20 to 40 years, and the OSTPRE sample included 344 women aged 63 to 75. The subjects of the OSTPRE population were re-measured five and ten years later after the baseline. Both samples underwent grip strength (GS), quadriceps strength (QS), and total-body DXA (TB-DXA) measurements, from which Relative Skeletal Muscle Mass Index (RSMI) was calculated. **Results**: In the REFERENCE population, the -1 SD / -2 SD cut-off points were for RSMI 5.8 kg/m^2 / 5.1 kg/m^2, for GS 32.0 kg / 26.4 kg, and for QS 39.8 kg / 29.8 kg. The prevalence of under -2 SD distributions in REFERENCE were: RSMI 1.8%, GS 1.3%, and QS 2.0%, and in OSTPRE (15/20/25 years measurements): RSMI 1.2 %/1.9 %/0.5 %, GS 52.2%/42.3%/48.8%, and QS 47.4%/55.2%/not available. The distributions of GS and QS were statistically significantly different between REFERENCE and all OSTPRE measurement points ($p<0.001$ in Chi-squared). **Conclusions**: The diagnostic cut-offs for components of sarcopenia are RSMI 5.1 kg/m^2, grip strength 26.4 kg, and quadriceps strength 29.8 kg in Finnish Caucasian women.

Keywords: Body composition, Grip strength, Muscle mass, Muscle strength, Sarcopenia

Introduction

Sarcopenia is a progressive and generalized skeletal muscle disorder that is associated with an increased likelihood of adverse outcomes, including falls, fractures, physical disability, and mortality[1]. Sarcopenia is related to a higher risk of falls and fractures, impairment in activities of daily living, and cardiac, respiratory, and cognitive impairment. Furthermore, it impairs mobility, lowers the quality of life, and increases mortality. Some other studies have also found higher incidences of morbidity, mortality, falls, fractures, poor quality of life, and hospitalization[2–7].

The prevalence of sarcopenia has been reported to be between 2% and 50% based on global data[8–13]. The variety in prevalence has been suggested to originate essentially from various cut-off points used to diagnose the disease[8].

The European Working Group on Sarcopenia in Older People (EWGSOP) established in 2010 an operational definition and diagnostic strategy for sarcopenia that has become the most used around the world[8]. They stated that the correlation between muscle mass and muscle strength is not linear. Therefore, the diagnosis of sarcopenia requires measuring of muscle mass, muscle strength, and physical performance.

In 2018, EWGSOP updated the definition, diagnostic methods, and criteria of sarcopenia based on scientific

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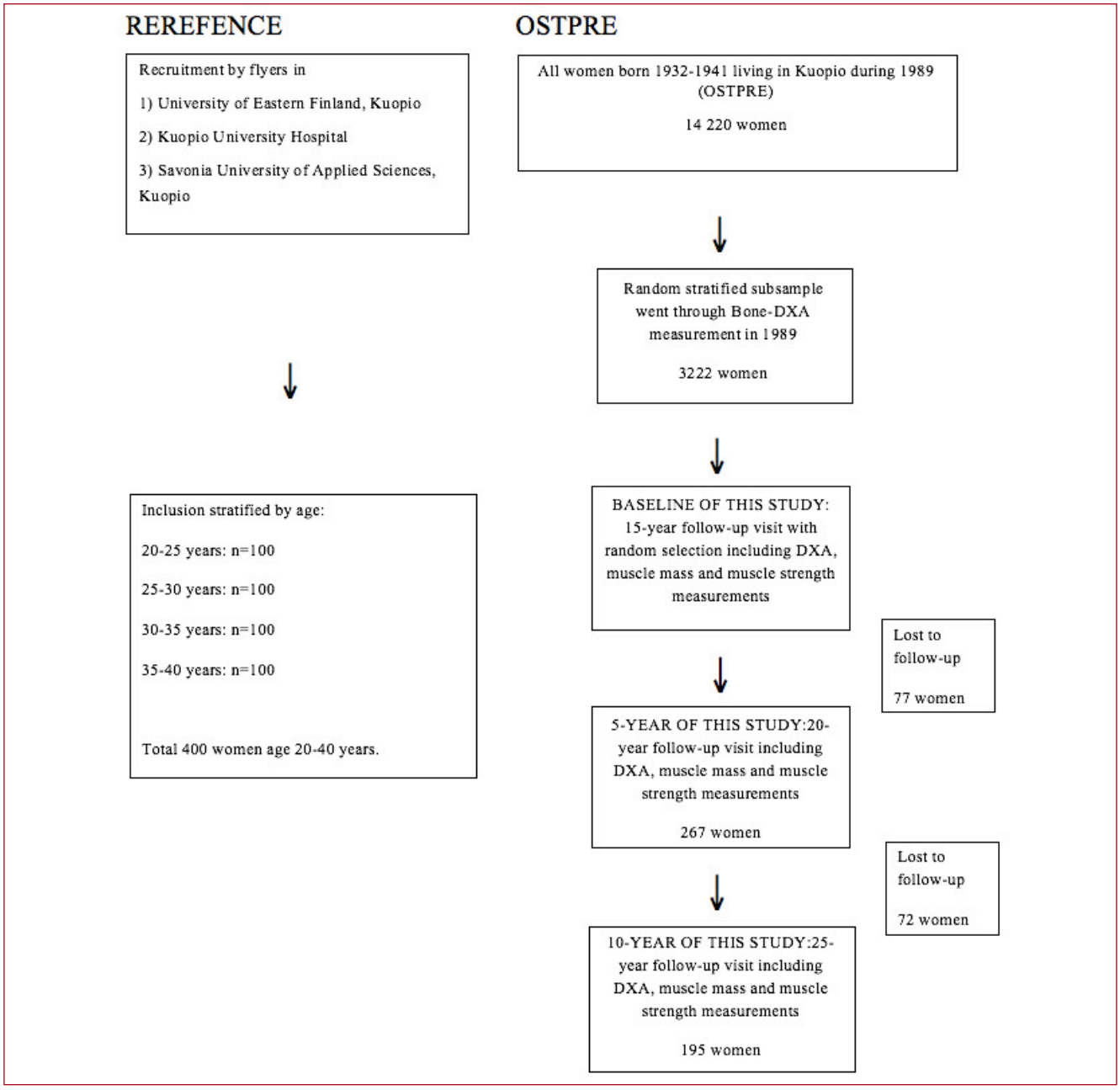

Figure 1. Study population selection.

evidence that had accumulated since the last statement[1]. They stated that muscle strength is the main criterion for a diagnosis of sarcopenia. Muscle quantity (measured, e.g., with Appendicular Skeletal Mass (ASM) or quality is a secondary diagnostic method for diagnosing sarcopenia. Different indexes have been introduced to adjust ASM, such as BMI, height, and weight. ASM divided by the square of height is the Appendicular Skeletal Muscle Index (ASM), i.e., Relative Skeletal Muscle Mass Index (RSMI). Fat mass divided by the square of height was determined as the Fat Mass Index (FMI). However, there is no well-established consensus for the best adjusting method for the fat mass. ASMI (ASM/squared height) has been suggested to be more reliable in comparison to others[14].

Muscle quantity can be determined with Dual-Energy X-ray Absorptiometry (DXA), Bioelectrical Impedance

Analysis (BIA), computed tomography (CT), or magnetic resonance imaging (MRI). Muscle quality can be determined in an accurate way with MRI and CT tools, which both can detect intramuscular fat infiltration. The severity of sarcopenia is determined by measuring physical performance, which can be determined by operating gait speed, SPPB (Short physical performance battery), TUG (Timed-up-and-go-test), or 400m walking test. In addition, EWGSOP 2 recommends establishing gender-specific and region-specific studies of sarcopenic components (gait speed, muscle mass, and strength) to improve the diagnostic accuracy of sarcopenia. After EWGSOP's and especially after EWGSOP2's recommendations, the -2 SD below the mean of the young reference values has been the most used[1,15–18].

Consequently, the main purpose of this study was to determine the cut-off points for components of sarcopenia based on the young reference population (aged 20-40 years) in the Finnish female population. The present cross-sectional retrospective study follows the recommendation by EWGSOP2 by using grip strength and reference values for body composition as diagnostic criteria for sarcopenia[1]. The second aim of the study was to investigate the prevalence of components for sarcopenia in older women (aged over 60 years) in different age groups with a cross-sectional study design.

Materials and Methods

Study design

The study setting is a retrospective cross-sectional study. A study cohort from a previously defined young reference population (REFERENCE) was used to define diagnostic cut-off for sarcopenia. As suggested by EWGSOP2, we used -1 and -2 standard deviations below the mean of healthy young adults as a cut-off point for sarcopenia[1]. Using the cut-off value, we studied the prevalence of sarcopenia in older women from the Kuopio Osteoporosis Risk Factor and Prevention study (OSTPRE). The OSTPRE and REFERENCE study sets have been accepted by the Ethics Committee of Kuopio University (The previous name of the University of Eastern Finland).

Study populations

Young reference population (REFERENCE)

The young reference population (REFERENCE) included 400 young, healthy females (20–40 years, mean age 30 years) living in Kuopio, Eastern Finland (Figure 1). The population was recruited between 2011–2014 using electronic and conventional paper flyers. It consisted of students and persons from the University of Eastern Finland, Kuopio, Kuopio University Hospital, and Savonia University of Applied Sciences, Kuopio. The participants for the study were required to fit the following criteria: 1) no chronic disease or permanent medication, 2) no orthopedic or other major implants inside the body, 3) age 20-40 years, 4) not currently pregnant, 5) no previous bilateral oophorectomy. Research nurses confirmed that the participants met the inclusion criteria. In addition, all participants gave informed consent for participation in the study. During the recruitment REFERENCE population was recruited by stratifying it by age as follows: (20–25 years: n=100, 25–30 years: n=100, 30–35 years: n=100, 35–40 years: n=100). In the REFERENCE population, 11.8% exercised once a week or less, 42% 2-3 times per week, 37.5% 4-6 times per week, and 8.8% daily[19]. No chronic diseases were allowed in the participants for the REFERENCE sample. The socioeconomic data was not gathered for the young reference sample. However, the young reference population has been described earlier in detail[19].

Study group consisting of older women (OSTPRE)

The study participants represent total-body dual-energy x-ray absorptiometry (DXA) scans from the Kuopio Osteoporosis Risk Factor and Prevention Study (OSTPRE) densitometry sample. OSTPRE is an ongoing prospective cohort study with over 30 years of follow-up.

The initial target population of OSTPRE included all women born between 1932 and 1941 (*n* = 14 220) living in Kuopio Province, Finland, in 1989 (Figure 1). A random stratified subsample (n = 3,222) of the study population underwent DXA densitometry at baseline and has been followed at 5-year intervals. However, the muscle mass and muscle strength measurements were both performed for the same women for the first time after a 15-year follow-up in 2004-2007. For the present study, we chose to include only follow-up visits, where all three (DXA, muscle mass, and muscle strength) measurements were performed. Thus, baseline, 5-year, and 10-year DXA measurements were not studied. A random subsample of 506 women underwent a total-body scan and was invited to 15-year follow-up densitometry between October 2004 and October 2007. Valid DXA data were obtained from 344 (69 %) out of these randomly selected women. Their ages varied between 63 and 75 years, and the mean age was 69 years. At the 20-year follow-up in 2009–2012, 267 women were measured with DXA. Their ages ranged between 69 and 79 years, and the mean age was 74. One hundred ninety-five women were measured with DXA in OSTPRE 25 in the years 2014-2016, and their mean age was 77 years. In the OSTPRE sample, the mean number of chronic diseases was 4.6 (3.0 SD) in a 15-year follow-up, 5.4 (3.5) in a 20-year follow-up, and 7.0 (4.3 SD) in a 25-year follow-up. They also underwent muscle strength (handgrip and quadriceps strength measurements) and functional tests (walking speed, standing on one leg, and ability to squat). In OSPTRE 25, quadriceps strength was not measured in those women who were measured with DXA. In the OSTPRE sample, all women were community-dwelling pensioners at the time of the measurements. Trained personnel performed muscle strength and anthropometric measurements.

Total body DXA

The total body dual-energy absorptiometry (TB-DXA) measurements were performed by trained nurses. The fat mass and muscle mass were determined with DXA. The TB-DXA measurements were performed between 2011 and 2014 in the Kuopio Musculoskeletal Research Unit (KMRU), University of Eastern Finland, Kuopio. In REFERENCE, 206 women were measured with Lunar Prodigy DXA, and 194 women were measured with Lunar iDXA, with the imaging and analysis protocols provided by the manufacturer (Lunar Co, Madison, WI, USA), as described earlier[20,21]. The repeatability and reliability of this method have been reported previously[22,23]. These two DXA machines were cross-calibrated[24]. In the OSTPRE 15-year follow-up, the DXA measurement was performed for a random subsample which included 344 women. In the 20-year follow-up for 267 women and in the 25-year follow-up, 195 women were measured with Lunar Prodigy (GE Medical Systems, Lunar, Liegen, Belgium). The Lunar iDXA measurements were cross-calibrated with Lunar prodigy measurements using different mathematical formulas described in the previous study[24].The muscle mass of arms as measured by Lunar Prodigy was converted based on the formula: 0.999 x iDXA muscle mass. The muscle mass of the legs, as measured by Lunar Prodigy, was converted based on the formula: 0.867 x iDXA muscle mass + 1.33. The total body fat mass as measured by Lunar Prodigy was converted based on the formula: 1.010 x iDXA fat mass – 0.74. The study nurses double-checked the automated region of interest (ROIs) of every measurement. The automated ROIs were based on the algorithm provided by the manufacturer. Phantom calibration was performed on a daily basis. All quality control procedures were done according to the DXA manufacturer.

Muscle strength measurements (REFERENCE and OSTPRE)

Strength measurements included grip and isometric knee extension strength measurements. Subjects were encouraged to maximize their effort in both tests.

Grip strength was measured with a hand-held dynamometer (JAMAR™ handgrip dynamometer; Sammons Preston, Bolingbrook, IL) and reported in kg[25]. Grip strength was measured from the dominant hand while sitting on a bench, with the forearm flexed from the elbow at a 90° angle near the torso. Three attempts were recorded, with rest periods of approximately 30 seconds taken between attempts. Close attention was paid to making all three attempts similar, with a focus on a fixed posture. The best attempt out of the three was recorded as the maximal result.

Quadriceps strength (QS) was measured with a knee extensor bench and reported in kg[25]. Isometric knee extension strength was measured three times on both legs, with a knee flexion of approximately 65° (dynamometer chair; Metitur Oy, Jyväskylä, Finland). Participants extended the leg against the ankle strap with maximal effort, and the peak force was recorded. Between each attempt, there were approximately 30 seconds of rest. Participants were helped into a straight sitting position with an adjustable backrest and hip belt. An ankle strap was adjusted to meet the distal end of the lateral malleolus of an individual in the performing leg to minimize anthropometric bias. The average of the three attempts per leg was recorded. The results from both legs were then summed and divided by two, forming the overall quadriceps strength score used in the analysis.

Body composition variable definitions

The weight of each participant was measured with a calibrated scale (Philips Type HF 351/00) and reported in kg. Height was measured with a calibrated stadiometer (Harpenden stadiometer), and reported in cm.

Based on the measurements, information on body composition, such as muscle mass, fat mass, and bone mass were used as independent variables. Based on the recommendation of several working groups for the definition of sarcopenia, the following indicators for sarcopenia were used[8,26,27]. Appendicular skeletal muscle mass (ASM, kg) was defined as the sum of muscle mass of both arms and legs. Relative skeletal muscle index (RSMI, kg/m^2) was calculated as ASM divided by the square of height[12].

Fat Mass Index (FMI, kg/m^2) was calculated as total body fat mass divided by the square of height[28].

Statistical analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS ver. 22, SPSS Inc., Chicago, Illinois, USA) for Windows. In the present study, the diagnostic cut-off for sarcopenia was set under -2 SD of the mean of REFERENCE. In addition, the diagnostic cut-off values -1SD to – 2SD of REFERENCE were set as the criterion for presarcopenia[8]. The study population was divided according to body composition and muscle strength values into under -2 standard deviation (SD) and under -1 standard deviation groups. The distributions were shown per cent for each parameter. The statistical significance of standard deviation distributions of components for sarcopenia in different study populations was analyzed by Chi-squared homogenous test without Yates' correction. Only women who were able to perform all measurements (DXA and muscle strength) were included in the analyses.

The sample size of the present study was estimated as described by Wellek et al.[29]. If we use the formula [mean ± 2 x standard deviation], the minimum required sample size for a 95% confidence interval with a precision of ±1.5% is 302 observations. For non-parametric reference value calculations, our sample of 400 observations allows for a precision of ±2% for a 95% confidence interval.

	Young reference	OSTPRE 15	OSTPRE 20	OSTPRE 25
N (number)	400	344	267	195
Age (years)	30.4 (6.0)	68.6 (2.9)	73.6 (2.7)	77.3 (2.7)
Height (cm)	166.6 (5.9)	158.8 (5.2)	158.3 (5.2)	157.2 (5.4)
Weight	64.1 (11.2)	73.1 (12.2)	71.8 (12.9)	71.0 (12.3)
BMI	23.1 (3.7)	29.0 (4.8)	28.6 (5.2)	28.4 (4.9)
RSMI (kg/m^2)	6.6 (0.7)	6.7 (0.8)	6.6 (0.9)	6.9 (0.9)
Grip strength (kg)	37.6 (5.6)	26.3 (6.3)	27.6 (5.6)	26.7 (5.5)
Quadriceps strength (kg)	49.8 (10.0)	30.5 (7.8)	28.8 (7.9)	not measured
Fat Mass Index (kg/m^2)	7.0 (2.8)	11.8 (3.6)	11.6 (3.6)	11.8 (3.5)

RSMI = Relative skeletal muscle mass index; BMI = Body Mass Index.

Table 1. The Characteristics of the Young Reference (REFERENCE) and OSTPRE samples.

	Mean	-1 SD	-2SD
RSMI (kg/m^2)	6.6	5.8	5.1
Grip strength (kg)	37.6	32.0	26.4
Quadriceps strength (kg)	49.8	39.8	29.8
Fat Mass Index (kg/m^2)	7.0	4.3	1.5

RSMI = Relative skeletal muscle mass index.

Table 2. The diagnostic criteria for components of sarcopenia based on values of the young reference population.

Results

In the REFERENCE sample (N=400), the mean age was 30.4 years (SD 6.0). The mean age of the OSTPRE 15 (OSTPRE sample at the 15-year measurements) sample (N=344) was 68.6 (SD 2.9) years, in the OSTPRE 20 (OSTPRE sample at the 20-year measurements) sample (N=267) 73.6 (SD 2.7) years and in the OSTPRE 25 (OSTPRE sample at the 25-year measurement) sample (N=195) 77.3 (2.7) years. Due to inclusion criteria, there were no chronic diseases among the participants of the reference sample. In the OSTPRE sample, the mean number of chronic diseases was 4.6 (SD 3.0) in a 15-year follow-up, 5.4 (3.5) in a 20-year follow-up, and 7.0 (4.3 SD) in a 25-year follow-up. In the REFERENCE, the mean BMI was 23.1 (SD 3.7) kg/m^2, while in OSTPRE 15, OSTPRE 20, and OSTPRE 25, BMI were 29.0 (4.8) kg/m^2, 28.6 (5.2) kg/m^2 and 28.4 (4.9) kg/m^2, respectively. The characteristics of the REFERENCE and OSTPRE populations are presented in Table 1.

The diagnostics cut-off values for sarcopenia were determined by using − 2 SD values of the reference population. The cut-off values for RSMI, GS, and QS were 5.1 kg/m^2, 26.4 kg, and 29.8 kg, respectively (Table 2).

1.8 % of the REFERENCE were under -2 SD of RSMI. In OSTPRE 15/20/25 measurements, 1.2% / 1.9% / 0.5% of women were under -2 SD of REFERENCE RSMI. 1.3 % of the REFERENCE were under -2 SD of grip strength. In the OSTPRE 15/20/25 measurements, 52.2% / 42.3% / 48.8% were under -2 SD of REFERENCE grip strength. 1.3% of the REFERENCE were under -2 SD of QS, whereas in the OSTPRE 15/20 measurements, 47.4% / 55.2% of women were under −2 SD of QS REFERENCE. The comparison of distributions for FMI revealed that almost every woman belonged to the -1 SD group. With regards to FMI, 100 % of the OSTPRE 15 women, 99.6% of the OSTPRE 20, and 99.5% of women were over -1 SD (Figure 2). The change in muscle mass and muscle strength with age is shown in Figure 3.

Chi-squared homogenous test, the standard deviation distributions of RSMI did not differ in REFERENCE compared to any OSTPRE measurement points ($p>0.05$). The standard deviation distributions of GS and QS were significantly different in REFERENCE compared to all OSTPRE measurement points ($p<0.001$).

The standard deviation distributions of RSMI did not differ between the OSTPRE measurement points ($p>0.05$).

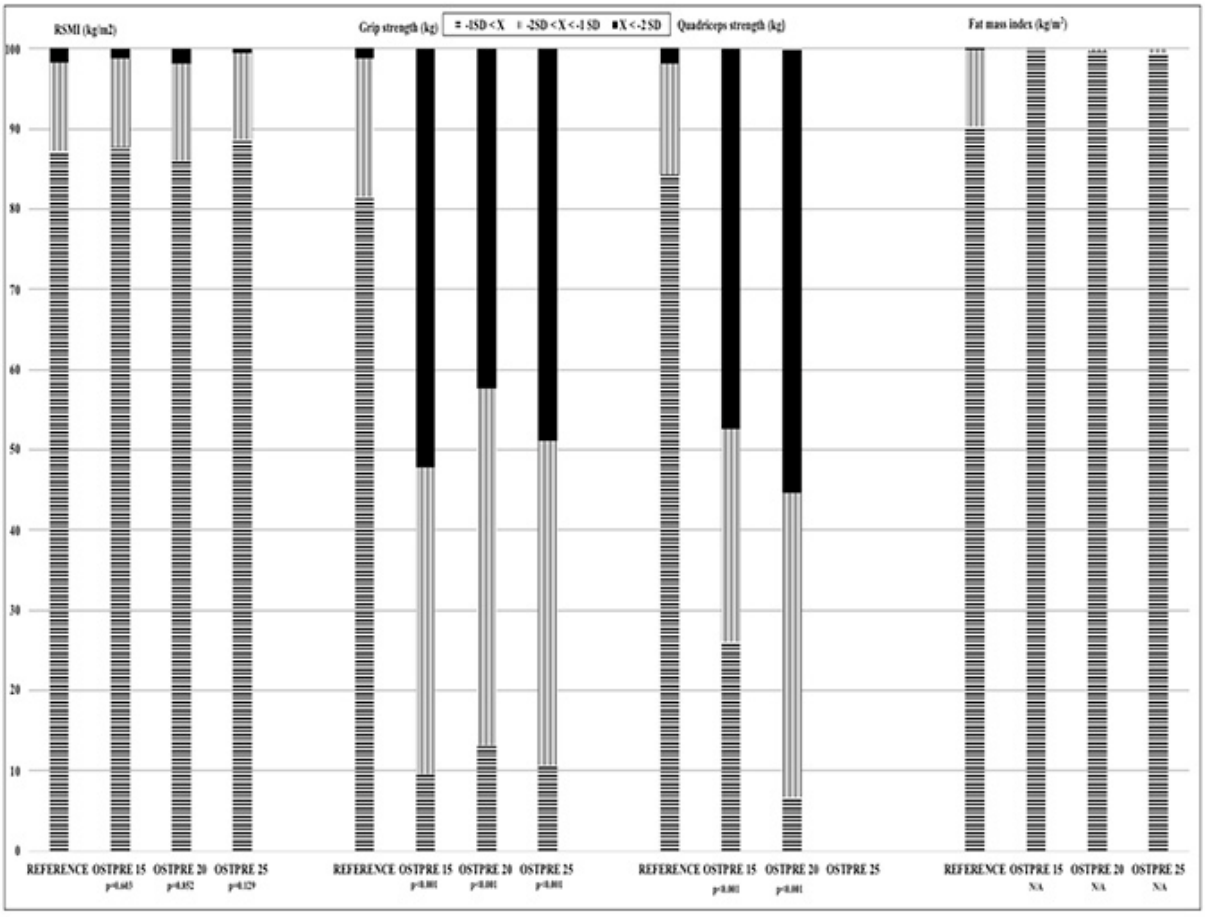

Figure 2 shows the distributions of RSMI (kg/m^2), Grip Strength (kg), Quadriceps Strength (kg) and Fat Mass Index (kg/m^2) in the REFERENCE, OSTPRE 15, OSTPRE 20 and OSTPRE 25 population based on standard deviations of young reference population. The cut-off points were -1 SD ja – 2 SD based on young reference populations. The statistical significance of standard deviations distributions of components for sarcopenia in different study populations were analyzed by Chi-squared homogenous test without the Yates' correction. The distributions of body composition in REFERENCE were compared to the respective distributions in OSTPRE. N/A= Unable to do statistics because of distributions.

Figure 2. The distributions of components of sarcopenia in the different study populations.

The standard deviation distributions of GS were statistically different when compared between OSTPRE 15 and OSTPRE 20. However, the result may be considered ambivalent because the proportions of under – 2SD were higher in OSTPRE 15 than in OSTPRE 20. In GS, the standard deviation distributions did not differ statistically significantly between OSTPRE 15/20 and OSTPRE 25. In QS, the standard deviation distributions were statistically significantly different between OSTPRE 15 and OSTPRE 20. QS was not performed in OSTPRE 25 follow-up. It was unable to do statistics of FMI because of distributions.

Discussion

EWGSOP2 suggests that gender and region-specific cut-off values should be determined for sarcopenia. To date, we are not aware of cut-off values reported for Nordic Countries. Our study aimed to determine these cut-off values from a population of healthy Finnish young women.

Based on the present study, the diagnostic cut-off point for RSMI should be set at 5.1 kg/m^2, for GS 26.4 kg, and for QS 29.8 kg in Finnish Caucasian women. In RSMI, the sarcopenic proportions were similar in older women

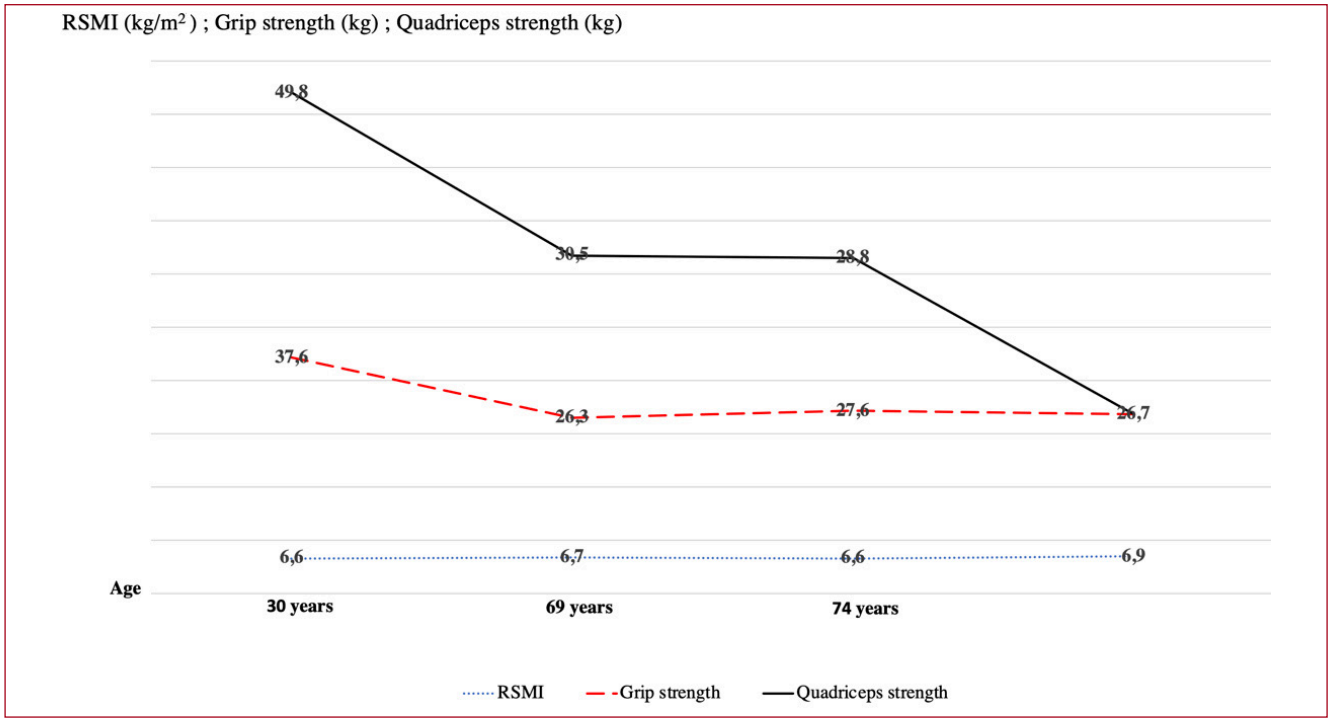

Figure 3. The relationship between age and muscle mass/strength.

and young women, whereas in GS and in QS, sarcopenic portions were significantly higher in older women than in younger women. Our results strongly support the EWGSOP2 recommendation that muscle strength is the most important indicator of presarcopenia and sarcopenia[1].

Sarcopenia is rarely an independent disease but rather a part of frailty syndrome[30]. Liguori et al. described that mental health, physical activity, and nutritional and social status are common factors affecting both of these two diseases[31]. In addition, the etiology, pathogenesis, and risk factors of osteoporosis have been observed to be similar to osteoporosis[32]. Reginster et al. even asked a question that is there one or two diseases? They stated sarcopenia and osteoporosis are two disorders that mainly affect elderly patients and cause financial burdens. They suggested further investigations of common pathology pathways for the developing drugs that can be used against both of these diseases.

In 1994, Osteoporosis was determined by the World Health Organization (WHO) as a bone mineral density is less than 2.5 standard deviation below the sex-specific mean value of young adult bone mineral density (BMD)[33]. In contrast, there are no well-established cut-off standard deviations or values for sarcopenia[34]. Therefore, they recommended exploring geographic differences in components of sarcopenia. In osteoporosis, a BMD has been the golden standard and accepted around the world, whereas in sarcopenia, the most appropriate measure is not as apparent. In addition, the outcome is not as obvious as the fracture in osteoporosis[34].

Investigators have taken an analog model of osteoporosis, overweight, and underweight studies in determining the cut-off values for sarcopenia. There is not a well-established method to choose the best cut-off point but rather disagreement on which would be the best cut-off point. EWGSOP 2 listed gaps in sarcopenia research and suggested some topics which need further investigation[1]. In their opinion, the development of validated cut-off points will depend on normative data and their predictive value for hard-end points, and this has to be a high priority for research studies. In addition, they stated that gender-specific and region-specific threshold values for sarcopenia diagnosis improve the prediction of outcomes. Based on this, the cut-off points of this study will subvert the diagnosing of sarcopenia in Nordic countries and even in Northern Europe.

Several previous studies have reported diagnostic criteria for sarcopenia based on cut-off values of components for sarcopenia in older women. Furthermore, there are only a few studies, including both the young reference and older female populations. In addition, there are no previous studies from Northern Europe. In comparison with previous studies, in our young reference population, RSMI

was similar to previous[35,36] but lower than in Mexico[12] and higher than in the USA[37] and China[38]. In older women, RSMI was higher than in previous studies, but the difference was not large[12,35–37]. Apart from Baumgartner's study RSMI did not decrease much in earlier studies, and this finding is similar to our results[10,12,35,36]. The − 2 SD cut-off point in RSMI of this study (5.1 kg/m^2) was also similar compared to previous studies (5.1 to 5.7 kg/m^2)[8,36,37,39].

GS was higher in this study in the young and older population than in previous studies. In the young population, the GS was 37.6 kg, whereas in previous studies, the GS values have ranged from 28.3 to 32.9 kg[40–42]. In the older population, the GS was 26.3 kg, while in previous studies, the GS has ranged from 19.9 kg to 22.7 kg[9,38,40]. The -2 SD cut-off point of GS was 26.4 kg in this study, whereas it has ranged from 16 to 20 kg in previous studies[8,9,39]. It is still being determined why grip strength was significantly higher than in previous studies. In this study, grip strength was measured with a hand-held dynamometer (JAMAR™ handgrip dynamometer), the most used tool to measure grip strength worldwide[43]. The measurement position and protocol were the same as in the other studies. Study participants with hand or wrist arthritis can squeeze Jamar with less force than other types of dynamometers, thus minimizing pain[44]. In Asia, the mechanical type of dynamometer (Smedley) is widely used[45], and it has been reported to underestimate grip strength compared to Jamar[46]. It has been reported that Jamar hydraulic has the potential to overestimate grip force because of the inertial movement of the needle, which can jump slightly higher than the actual reading[47]. In addition, across studies, the position of the hand during the grip strength measurement may vary. In some devices, grip strength is measured with a balloon, and in others, with a grip handle[48]. These aspects are likely to explain some of the differences in grip strength values in our study in comparison to other studies. This topic requires further research. The proportions of under -2 SD in GS and QS were higher in OSTRPE 15 than in OSTPRE 20. Probably more healthier women survived to later years OSTPRE and were able to complete the OSTPRE 20 measurements. Those who survived only to the 15-year follow-up but not to the 20-year follow-up may have had lower muscle strength and worse general health status.

According to EWGSOP 2, more research is needed to determine the cut-off points of sarcopenia in different regions of the world. Thus, the objective of this study is crucial. This is the first study to define cut-off values for components of sarcopenia for Nordic Women. The study also determines the prevalence of sarcopenia in Nordic countries based on two large study samples collected from the same region. The advantages of the present study included its healthy, relatively large REFERENCE sample, which included 400 young women. Our large REFERENCE sample was composed of the same number of women in every quartile (20–25 years, 25–30 years, 30–35 years, and 35–40 years). The advantages of our OSTPRE sample included its population-based nature and high participation rate. The OSTPRE population included all women born in 1932-1941 and residents in the Kuopio region in 1989. Thus, the study sample may be considered representative of the total female population. The measurement sample was selected randomly from this total sample to minimize selection bias. Both study populations were selected from the same geographic area, and we believe they are comparable to the computation of age differences between these two populations. Trained personnel performed muscle strength and anthropometric measurements, which may increase the precision of measurements. Dual X-ray absorptiometry, a pneumatic hand-held dynamometer (Jamar), and a dynamometer chair are objective, convenient, and commonly used methods for quantifying muscle mass, fat mass, grip strength, and quadriceps strength. Furthermore, the results of body composition are reliable because two different DXA machines were cross-calibrated according to the previous study[24].

There are several potential limitations that need to be considered. Even though the OSTPRE densitometer sample was a random stratified sample and recruiting of the REFERENCE sample was based on distributing conventional paper flyers, the study samples may not fully represent the underlying population. Although these two study populations (REFERENCE and OSTPRE) were collected from the same geographic area, there may be some differences between the study populations. For example, several lifestyle factor differences between the REFERENCE and OSTPRE populations may exist. The young reference population was recruited from the personnel of the Kuopio University Hospital and the University of Eastern Finland. Therefore, it is not a random population sample, and the risk of bias cannot be totally excluded. However, only healthy volunteers were included, which eliminates the bias due to morbidities. The young reference population has been described earlier in detail[19]. Moreover, the REFERENCE sample may include persons who have completed higher levels of education than the average Finnish population. Therefore, the REFERENCE study sample does not fully represent the general population of Finland. Furthermore, it is likely that in the OSTPRE study, the frailest persons did not participate in the measurements. Thus, the cut-off values may be higher than if the whole sample had participated in the measurements. Lastly, it is possible that the members of the OSTPRE sample have done more manual work in their earlier lives than the members of the REFERENCE sample[49]. The physical activity levels and dietary intake were not considered in the comparison of REFERENCE and OSTPRE groups, although they affect muscle strength because inquiry to the REFERENCE did not include dietary intake information and physical activity was asked with a different way in the REFERENCE than OSTPRE[50]. DXA can separate fat, bone mineral, and lean tissue based on X-ray absorption, and it highly correlates with both MRI and

CT measures of skeletal muscle mass[51]. However, Erlandson et al. stated that DXA is unable to assess muscle quality because of the inability to quantify intramuscular adipose tissue (IMAT) distribution within and around muscles. This is considered to be a major limitation of DXA imaging[52].

Conclusion

In conclusion, this population-based study on the Finnish female population determines the diagnostic criteria for components of sarcopenia for Caucasian women. Based on the present study, the diagnostics criteria are RSMI 5.1 kg/m^2, grip strength 26.4 kg, and quadriceps strength 29.8 kg in Finnish Caucasian women. The proportions of sarcopenic values of GS and QS increased in older women, while in RSMI, the sarcopenic values were the same in younger and older women. Thus, we recommend using muscle strength measurements as a primary parameter for the diagnosis of sarcopenia.

Ethics approval

The study was approved by the Ethics Committee of Kuopio University (The previous name of University of Eastern Finland), approval numbers: 1217/13.02.00/2018 and 11/2011. All methods were carried out in accordance with relevant national guidelines and regulations.

Consent to participate

All participants provided written informed consent.

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Authors' contributions

S.S, Ju.S, T.R, R.H and H.K collected the data for the study. S.S and Jo.S conceived and designed the analysis and performed the analysis. Ju.S, T.R, R.H and H.K made suggestions for improvements of writing. S.S and Jo.S prepared the main text, tables and figures. All authors reviewed and approved the final version of the manuscript.

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