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Review paper
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Sarcopenic obesity in older people

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Abstract

Senility is strongly associated with changes in body composition. Sarcopenic obesity (SO) consists of symptoms such as increased body fat mass and a reduction in muscle strength and/or mass. Material and methods: The review covered treatment methods and diagnostic criteria used in SO patients. Moreover, the impact of SO on the health of older people was reviewed. Papers from the Science Direct and PubMed databases were analysed. The following keywords were used: "sarcopenic obesity", "diagnostic", "treatment", "elderly", and "physical therapy". The inclusion criteria encompassed research studies on SO in older people. To be precise, the review included papers from January 2015 to March 2020, and the review itself was carried out from March to April 2020. Results: Out of over 1,200 SO articles, 18 met all inclusion and exclusion criteria. All of the chosen papers were divided into two main groups. The first group contained papers about SO's impact on the health of older people. The second comprised works about SO treatment methods. The most commonly used SO diagnostic indicators were: BMI ($25kg/m^2$–$30kg/m^2$), BF% (27%–42%), SMI ($x < 24\%$–27%; SMI 0.789), and ALST ($x < 15.02$ kg). SO was also assessed via the use of algorithms. Conclusions: Sarcopenic obesity is a common syndrome related to body composition in older people. Currently, SO patients can be effectively treated with aerobic and resistance training, whole-body electromyostimulations (WB-EMS), supplements, and psychological interventions. Due to the great impact of SO on people's health, future studies should concentrate on systematising the diagnostic criteria for SO.

Keywords: ageing, muscles, geriatrics, adiposity

Introduction

It is quite evident that our society as a whole is ageing. The percentage of older people has been gradually increasing over the years [1]. It's well-known that old age brings with it many changes in body composition such as dynapenia, sarcopenia, and excessive weight [2,3]. These changes force medical staff to take action to prevent sarcopenia, obesity, and their consequences.

In recent years, increased interest in conditions connected to body mass composition has been observed [4]. Generally, sarcopenic obesity (SO) was first defined in 1996 by Heber et al. SO has been described as reduced lean body mass with increased fat mass [5]. Currently, there is no SO definition agreed upon by the majority of authors. Presented SO definitions usually focus on the high level of fat tissue with low muscle strength or mass [6,7].

Sarcopenia and obesity co-occurring constitute the definition of sarcopenic obesity. In 2018, The European Working Group on Sarcopenia (EWGSOP2) defined sarcopenia as an age-related decline in muscle strength, muscle mass, and physical performance [8–10]. In addition, obesity is a condition characterised by increased adiposity (fat tissue) [4]. Statistics show that more than three hundred million people around the world are obese [11]. The results of many papers present a dependence between obesity, muscle mass and strength, though the authors do not strictly relate the analysed parameters to the SO definition [12].

Interest in sarcopenic obesity among medical professionals is growing. Some authors believe that disability is more common in SO individuals [4,13]. From this it follows that sarcopenic obesity affects health, especially in older people. Unfortunately, the definition of SO is limited by the lack of any standardised diagnostic criteria [14]. The purpose of this study was to review the treatment methods applied when presented with sarcopenic obesity. Which indicators were most commonly used to define SO? Additionally, SO's impact on the state of health of older people was analysed.

Material and methods

The review covered various treatment methods and diagnostic criteria used in SO patients. Additionally, the impact of SO on the health of older people was reviewed. Articles from the Science Direct and PubMed databases were analysed. Moreover, the review included papers from January 2015 to March 2020, and the review itself was carried out from March to April 2020.

It included works that met the following criteria:

- The article covered SO in older people only.
- The article detailed various aspects relating to the diagnostics, treatment or the effects of SO.
- The papers had to be of a research nature, not reviews.
- The article contained results from January 2015 to March 2020.

The exclusion criteria were:

- Papers of a review nature.
- If the aim of the study, or the results, covered changes in body mass composition similar to SO, but did not directly use the term "sarcopenic obesity".
- If the article turned out to be a research project that had just been started. Despite the material and research methodology, there were no results as yet and the conclusions were only assumptions.
- If the article was a pilot study, which was later published with expanded results.
- If the article was repeated in both databases.

After entering the keyword "sarcopenic obesity", 1,672 articles from Science Direct and over 684 from PubMed were obtained. After adding: "diagnostic", "treatment", "elderly", and "physical therapy" with the operator 'OR', the number of papers was narrowed to just over 200. The appropriate inclusion and exclusion criteria were introduced, leaving 70 articles. After a detailed analysis of abstracts, only 18 papers met all the requirements needed to objectively present the above topic. All the analysed publications were of a research nature and detailed SO's impact on the health of older people. They also encompassed various methods for intervening in sarcopenic obesity. To make the topic of sarcopenic obesity clearer, the articles were divided into two basic groups. The first group contained 6 papers about the impact of SO on the state of health of older people in order to justify taking up this topic. The second group contained 12 articles about various SO therapies that can be implemented in the treatment of SO. More information about the review process can be found in figure 1.

Results

In the first group, the six articles were analysed according to: the purpose of the study, diagnostic criteria, the characteristics of patients, and SO's impact on the health of older people. This group contained articles about SO's impact on: the risk of falling, the level of physical activity and performance, the health of patients from a bariatric centre, respiratory diseases, individuals with end-stage knee osteoarthritis, and patients undergoing cardiovascular surgery. These results can be found in Table 1.

The second group of articles was made up of twelve publications regarding the impact of SO on health in various fields of medicine. These articles were analysed according to such things as: the purpose of the study, diagnostic criteria, the characteristics of the patients, and the results of various therapies used to treat SO. This group was further divided into three subgroups. The first subgroup, focusing on exercise intervention, comprised: two articles about resistance exercise and aerobic training, two about elastic band resistance training, and two about progressive resistance training. These results can be found in Table 2.

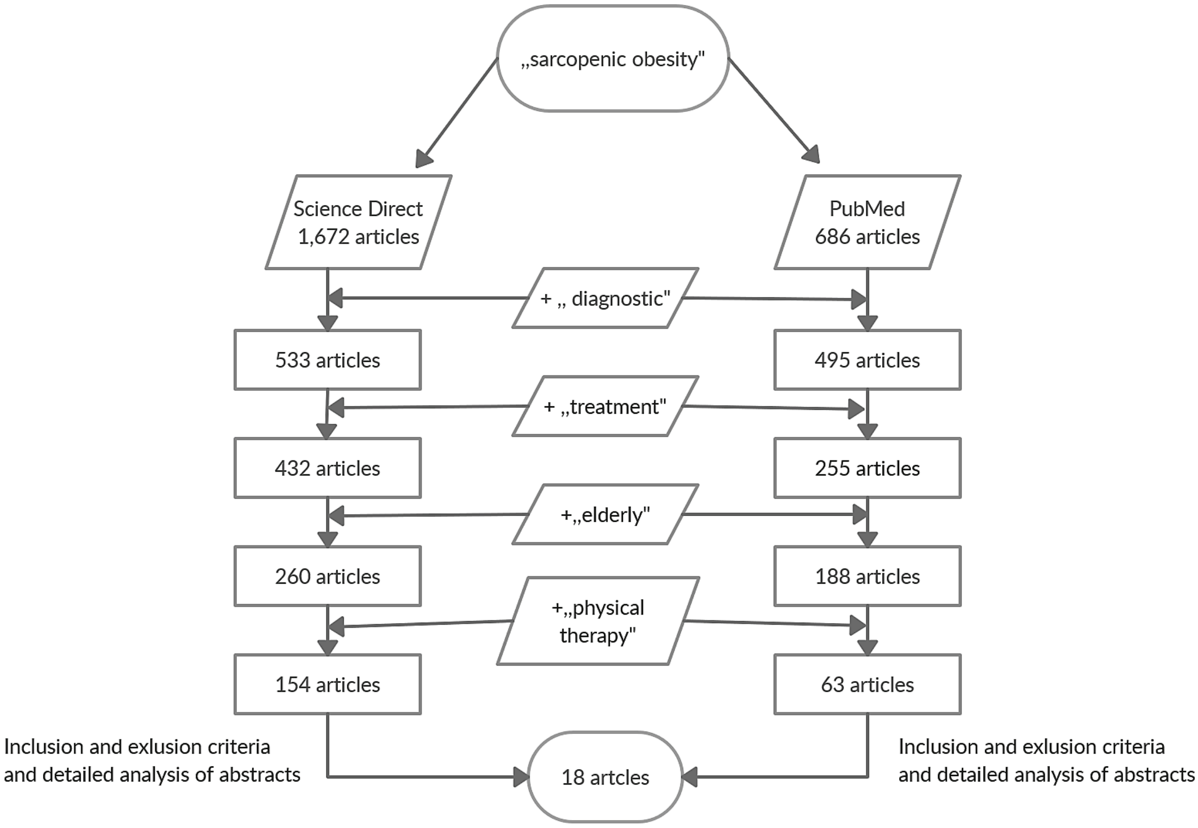

Fig. 1. Flowchart of the literature review process

Tab. 1. Sarcopenic obesity's impact on health in older people

Authors	The aim of the study was…	Results
Follis et al. 2018 [15]	to examine associations between sarcopenia, obesity, SO and falls in healthy postmenopausal women. **SO criteria:** the lowest 20th percentile of ALM BF% > 42%	SO is associated with greater FR in the younger women ((RR) =1.35, 95% (CI) = 1.17–1.56) than older ↑ FR is in Hispanic (RR = 2.40, 95% CI = 1.56–3.67) and non-Hispanic white (RR = 1.24, 95% CI = 1.11–1.39) women with SO. ↑ BF% and ↓ level of physical activity in Fallers
Pajek et al. 2018 [16]	to quantify deficits in physical abilities, exam and analyse associations of LM and FM content with test results. **SO criteria:** lean tissue index in the lower tertile x < 12.2 kg/m^2 fat tissue index in the highest tertile x > 13.9 kg/m^2	↑ BMI, age, and fat tissue index in SO/SOV individuals (P < 0.001) ↓ lean tissue index in SO/SOV individuals (P < 0.001) ↓ HGS (P = 0.07) and physical performance in SO/SOV individuals ↑ deficits in lower extremity tests is SO/SOV individuals
Xiao et al. 2018 [17]	to investigate the SO association with health outcomes in individuals seeking weight loss treatment in a bariatric centre. **SO criteria:** FMI/FFMI ratio> 95 percentile of sex, BMI > 30kg/m^2 FMI – fat mass/height^2 FFMI – fat free mass/height^2	↑ BF%, BMI, FMI/FFMI ratio FMI, and WC in SO compared to non – SO (P < 0.001) ↑ risk of high cholesterol, asthma, hernia, alcoholism in SO patients (p < 0.05)

Tab. 1. Cont.

Authors	The aim of the study was…	Results
Petermann-Rocha et al. 2020 [18]	to examine the association of SO, O, and S with incidence of respiratory disease and mortality. **SO criteria:** Female: HGS < 20kg; SMI < 6.42 kg/m^2 One of the obesity criteria: BMI > 30kg/m^2, WC > 88cm BF% > 38.6% Male: HGS < 30kg; SMI < 8.87kgm2 One of the obesity criteria: BMI > 30kg/m^2, WC > 102cm BF% > 26.9%	↑ risk of respiratory disease incidence in SO patients (HR: 1.51 [95% CI: 1.30; 1.77]) No associations between SO and respiratory mortality (HR: 1.12 [95% CI: 0.76; 1.63]). ↑ sedentary behaviour in SO patients ↓ levels of HGS in S (19.3 ± 6.6) and SO (22.1 ± 9.0) patients ↓ levels of physical activity S (9.2 ± 2.5) and SO (7.4 ± 2.1) patients
Godziuk et al. 2020 [7]	to examine the prevalence of SO in adults with end-stage knee osteoarthritis (OA). **SO criteria:** BMI > 30kg/m2 Female: ASM/$height^2$ < 5.45kg/m^2 ASM/weight < 19.43% ASM/BMI < 0.512kg Male: ASM/$height^2$, x < 7.26 kg ASM/weight < 25.72% ASM/BMI < 0.789 kg/m^2	↓ walking speed, endurance, MS, and self-care activities reported by patients ↓ walking speed, climbing stairs ↑ age in SO group (mean difference of 5.5 years, 95% CI 1.0–9.9) Prevalence of SO depends on diagnostic criteria.
Yamashita et al. 2020 [19]	to examine whether SO identified by preoperative computed tomography is an useful predicting tool of postoperative mortality in individuals with cardiovascular surgery. **SO criteria:** VAT > 103.0 cm^2 for males VAT > 69.0 cm^2 for females MA – below median	↓ HGS, quadriceps strength, gait speed, and 6MV compared with the CG ($p < 0.05$) ↑ risk of mortality (EuroSCORE) (CI = 1.25–7.40) and all-cause mortality in individuals undergoing cardiovascular surgery

ALM – appendicular lean mass; ASMM/ASM – Appendicular Skeletal Muscle Mass; BF% – body fat percentage; BMI – Body Mass Index; FBM – Fat Body Mass; FFM – Fat Free Mass; FM – fat mass; FR – falls risk; HGS – handgrip strength; LM – lean mass; MA – psoas muscle attenuation; MS – muscle strength; non-SO – non-sarcopenic obese; O – obese individuals; S – sarcopenic individuals; SMI – Skeletal Muscle Mass Index; SO – sarcopenic obesity; SOV – sarcopenic overweight; TBF – total body fat; VAT – visceral adipose tissue; WC – waist circumference; ↑ – improvement; ↓ – deterioration.

The second subgroup consisted of articles concerning dietary interventions. It contained: two articles about exercise and nutrition (tea, protein), one paper about nutrition and diet only, and one about psychological impact on individuals living with sarcopenic obesity. The results of the above analyses are presented in Table 3.

The last subgroup included papers which used whole body electromyostimulation therapy in patients with SO. It contained three papers about the effect of whole-body electromyostimulation and protein nutrition. These results can be found in Table 4.

In all of the above papers, obesity was assessed based on the following indicators: BMI (25–30kg/m^2), BF% (27%–42%,) VAT (x >103.0cm^2 male, x > 69.0cm^2 female), WC (x > 88cm female, x > 103 male), a fat tissue index in the highest tertile (x > 13.9 kg/m^2), and appendicular FFM as a sum of upper and lower limb FFM.

Sarcopenia was assessed based on the following indicators: SMI (x < 24–27%; SMI < 5.67kg–8.87kg/m^2;

Tab. 2. Exercise interventions' effects in sarcopenic obesity patients

Authors	The aim of the study was…	Material characteristics	Results after interventions
Huang et al. 2017 [20]	to investigate body composition changes after 12-week elastic band RT in people with SO. **SO criteria:** SMI < 27.6% BF% > 30%	Female SG = 18 CG = 17 age: 60–90 CG had a 40-min lesson about SO	In SG: ↓ TBF ($P = 0.035$) and BF% ($P = 0.02$) ↑ BMD ($P = 0.026$) ↑ T-score ($P = 0.028$) and Z-score ($P = 0.021$) Differences between SG and CG: ↓ BF% ($P = 0.011$) and TBF ($P = 0.023$)
Dieli-Conwright et al. 2018 [21]	to examine the clinical efficacy of 16-week exercise intervention on metabolic syndrome in breast cancer posttreatment survivors with SO. **SO criteria:** ASMM < 5.45kg/m^2 BMI > 30.0kg/m^2	Female SG = 50 age: 52.8 ± 10.6 CG = 50 age: 53.6 ± 10.1	↓ BMI body weight, all fat indicators, and SO biomarkers in the SG compared with baseline ($P < 0.01$) and the CG ($P < 0.01$) ↑ LBM, ASMM in the SG compared with baseline ($P < 0.01$) and the CG ($P < 0.01$) ↓ all metabolic syndrome variables ($P < 0.001$) ↑ insulin, HOMA-IR, leptin, and IL-8 ($P < 0.01$) in the CG
Liao et al. 2017 [22]	to investigate the effects of 12-week elastic RT in individuals with SO. **SO criteria:** SMI < 7.15kg/m^2 BF% > 30%	Female SG = 25 age: 66.39 ± 4.49 CG = 21 age: 68.42 ± 5.86	↑ FFM ($P < 0.05$) and leg LM ($P < 0.001$) in the SG, ↓ TBF ($P < 0.01$) and BF% ($P < 0.001$) in the SG Differences between the SG and the CG: ↑ gait speed ($P < 0.01$) ↑ TUG, TCR, SLS ($P < 0.001$) Significant correlation between leg LM and TUG ($r = –0.37$), TCR ($r = 0.42$), gait speed ($r = 0.36$), MQ of the upper ($r = 0.48$), and MQ of lower extremity ($r = 0.45$) ↓ patients satisfying SO's criteria
Park et al. 2017 [23]	to examine the effects of a 24-week aerobic and RT on carotid parameters in patients with SO. **SO criteria:** BMI ≥ 25.0kg/m^2; ASM/weight > 25.1%	Female SG = 25 CG = 25 age:74.1 ± 6.1	In the SG: ↑ CIMT ($p < 0.01$) ↓ carotid artery intima-media thickness ($p < 0.01$) ↑ wall shear rate ($p < 0.05$) and peak systolic flow velocity ($p < 0.01$), diastolic flow velocity ($p < 0.001$).
Gadelha et al. 2016 [24]	to identify the effects of RT on SO in older people. **SO criteria:** BMI ≥ 30 kg/m^2 appendicular FFM – FFM of lower and upper limbs;	Female SG = 69 age: 67.0 ± 5.2 CG = 64	↑ FFM, AFFM and Peak Torque ($P < 0.01$) ↑ muscle strength (assessed with isokinetic dynamometer) ($P < 0.01$)

AFFM – Appendicular Fat Free Mass; ALM – appendicular lean mass; ALST – appendicular lean soft tissue; ASM/ASMM – appendicular skeletal muscle mass; BF% – body fat percentage; BMD – bone mineral density; BMI – body mass index; CG – control group; CIMT – carotid artery intima-media thickness; FBM – fat body mass; FFM – fat free mass; LBM – lean body mass; MQ – muscle quality (ratio of muscular strength to muscle mass); RT – resistance training; SG – study group; SMI – skeletal muscle mass index (total skeletal muscle mass/total body mass); SO – Sarcopenic obesity; TBF – total body fat; TCR – timed chair rise; TUG – Timed up and Go test; WHR – waist-hip ratio; ↑ – improvement, ↓ – deterioration.

SMI > 0.789), ALST ($x < 15.02$ kg), LBM (as <90% of the subject's ideal fat free mass), ALM (the lowest 20th percentile), and lean tissue index (in the lower tertile, $x < 12.2$ kg/m^2)

In addition, sarcopenia was assessed according to the following algorithms: ASM/height2 ($x < 5.45$ kg/m^2 female; $x < 7.26$ kg male), ASM/weight ($x < 19.43\%$

Tab. 3. Dietary interventions in SO patients

Authors	The aim of the study was…	Material characteristics	Results after interventions
Kim et al. 2016 [25]	to examine the effects of exercise, tea catechin and amino acid supplementation on blood components, body composition, and physical function in older individuals with SO. **SO criteria:** SMI < 5.67kg/m^2 BF% ≥ 32% HGS < 17kg Or BF% ≥ 32% Walking speed < 1.0m/s	Female Ex + N = 36 age: 80.9 ± 4.2 Ex= 35 age: 81.2 ± 4.3 N= 34 age: 81.2 ± 4.9 HE= 34 age: 81.1 ± 5.1 Health education classes	↓ TBF in Ex + N greater than in HE (P = 0.036) ↓ TFM the greatest in Ex (P = 0.014) ↑ stride in Ex+N and Ex compared to the N and HE groups ↑ step length in Ex greater than in HE (P = 0.007). ↓ AFM by 4.9% in the Ex + N, 3.4% in Ex, 2.5% in N ↑ knee extension strength increased in the Ex + N by 17.8%, in Ex by 12.8%, and in N by 9.0% ↑ walking speed in Ex + N by 5.7% ↓ leptin in Ex + N by 13.5%, in Ex by 11.9%, and in N by 7.6%
Ponti et al. 2018 [26]	to identify changes in body composition by DXA in obese individuals enrolled into two weight loss medical programs. **SO criteria:** BMI > 30kg/m^2 SMI < 24.9%	Female CBT = 27 age: 56 ± 11 NCP = 21 age: 59 ± 9	CBT and NCP: ↓ BMI, total and regional FM ↓ VAT (P < 0.05) ↓ FM-to-LM in CBT (P < 0.01) and NCP (P < 0.05)
Nabuco et al. 2019 [27]	to examine the effects of 12-week RT associated with whey protein supplementation in individuals with SO. **SO criteria:** ALST < 15.02 kg BF% > 35%	Female SG = 13 age: 68.0 ± 4.2 protein + RT CG = 13 age: 70.1 ± 3.9 training only	↑ LST, ALST in SG compared with the CG (P < 0.001) ↓ TFM, FM in SG compared with the CG (P < 0.05) ↓ WHR, WC in both groups (P < 0.05) ↓ frequency of sarcopenia in SG (13 to 6). ↑ muscular strength in both groups (P < 0.05) ↓ SO in SG group (61.5%, P < 0.05) ↑ functional capacity, and plasma metabolism biomarkers (P < 0.05) ↑ chest press, knee extension, total MS and preacher curl (P < 0.05)
Sammarco et al. 2017 [28]	to investigate the efficacy of a low-calorie and high-protein nutrition program in people with SO. **SO criteria:** FBM% > 34.8% LBM < 90% of the subject's ideal FFM	Female SG = 9 age: 55.0 ± 9.6 Low-calorie, high-protein diet CG = 9 low-calorie diet, placebo	↓ weight, FAT (kg) in SG (P = 0.01) ↓ FFM, FAT (%) in SG (P = 0.05) ↑ general health in SF-36 test in SG (P = 0.03) ↑ HGS in SG (P = 0.01) ↓ weight, FAT (%) in CG (P = 0.05) ↓ FAT (kg) in CG (P = 0.03) ↓ LBM greater in SG (P < 0.05)

AFM – appendicular fat mass; ALM – appendicular lean mass; ALST – appendicular lean soft tissue; BF% – body fat percentage; BMI – body mass index; CBT – cognitive-behavioral therapy; CG – control group; Ex – exercises groups; Ex+N and Ex – exercises for 3 months; Ex+N and N – supplementation for 3 months; Ex+N – exercise and nutrition group; FBM – fat body mass; FFM – free fat mass; HE – health educated; HGS – handgrip strength; LBM – lean body mass; LST – lean soft tissue; N – nutrition group; NCP – nutritional counseling plan; RT – resistance training; SG – study group, SMI – skeletal muscle mass index (total skeletal muscle mass/total body mass); SO – sarcopenic obesity; TBF – total body fat; TFM – trunk fat mass; WC – waist circumference; WHR – waist-hip ratio; ↑ – improvement, ↓ – deterioration.

Tab. 4. Whole-body electromyostimulation effects (WB-EMS) in patients with sarcopenic obesity

Authors	The aim of the study was…	Material characteristics	Results after interventions
Kemmler et al. 2017 [29]	to examine the effect of 16-weeks WB-EMS protocol on SO and sarcopenia in older men. **SO criteria:** SMI < 0.789; BF% > 27%;	Male WB-EMS&P = 33 age: 77.1 ± 4.3 Protein group = 33 age: 78.1 ± 5.1 CG = 34 age: 76.9 ± 5.1	↑ SMI in WB-EMS&P (P=0.001) and Protein group (P = 0.043) ↓ SMI in CG (P = 0.033) ↓ TBF in WB-EMS and Protein groups (p < 0.001) ↑ Z-Score in WB-EMS&P (P < 0.001) and Protein group (P = 0.007) ↑ HGS in the WB-EMS group (P < 0.001)
Kemmler et al. 2016 [30]	to identify the effect 26-weeks WB-EMS protocol in individuals with SO. **SO criteria:** SMI < 5.75kg/m^2; BF% > 35%	Female WB-EMS&P = 25 age: 76.4 ± 2.9 WB-EMS = 25 age: 77.3 ± 4.9 CG = 25 Age:77.4 ± 4.9	↑ Z-Score in the WB-EMS&P and the WB-EMS groups (p ≤ 0.046) ↑ SMI in both WB-EMS groups (p ≤ 0.003) ↑ gait speed in WB-EMS (p = 0.026) ↓ HGS in CG group (P = 0.03) CG parameters significantly deteriorate.
Wittmann et al. 2016 [31]	to determine the effect of 6-months WB-EMS protocol on the metabolic syndrome in individuals with SO. **SO criteria:** SMI < 5.75kg/m^2; BF% > 35%	Female WB-EMS&P = 25 age: 76.4 ± 2.9 WB-EMS = 25 age: 77.3 ± 4.9 CG = 25 age: 77.4 ± 4.9	↓ MetS Z-score in WB-EMS&P group compared with the CG (P = 0.001) ↓ MAP in both WB-EMS groups (P = 0.038) ↓ WC in WB-EMS group compared with CG (P = 0.036) ↓ HDL-C in the WB-EMS&P compared with CG (P = 0.006) ↓ HDL-C in CG (P = 0.007)

BF% – body fat percentage; CG – control group; HDL-C – high-density lipoprotein cholesterol; HGS – handgrip strength; MAP – mean arterial pressure; SG – study group; SMI – Skeletal Muscle Mass Index (total skeletal muscle mass/total body mass); SO – sarcopenic obesity; WB-EMS – whole body electromyostimulation; WB-EMS&P – whole body electromyostimulation and protein supplementation; WC – waist circumference; ↑ – improvement, ↓ – deterioration.

female; x < 25.72% male), and ASM/BMI (x < 0.512 kg/m^2 female; x < 0.789 kg/m^2 male).

The studies were conducted in groups of females only (12 articles), males only (2 articles), and mixed gender groups (5 articles). The analysed groups from the above papers differed in the number of participants (18–170.083).

Discussion

Generally, sarcopenic obesity is characterised as a condition typified by a reduction in lean body mass and muscle strength, but with increased fat mass [32]. It is therefore a combination of obesity and sarcopenia. To objectively present the above topic, it should be noted that sarcopenic obesity has a significant impact on health in older people. This explains the necessity to tackle the topic of SO and act to prevent this state of affairs. The purpose of this study was to review the treatment methods administered in patients with sarcopenic obesity.

The basic assumptions for SO therapy are to increase muscle strength and mass, and reduce adiposity. Resistance training is one of the most commonly used methods to do this in SO individuals. After employing resistance training, there were significantly fewer patients who met the SO criteria regarding muscle mass and physical difficulties [22]. Moreover, combined exercises decreased the risk of cardiovascular diseases in this group of patients [23]. Combined resistance and aerobic exercises effectively improved metabolic syndrome and SO in survivors of breast cancer [21]. Huang et al. conclude that if exercises are conducted for a long period, muscle mass increases significantly [20]. Stover et al. show that older SO individuals can also make substantial improvements due to resistance training. These improvements in muscle function can help older people to lead a life with functional independence. Moreover, they can reduce the risk of disability and falling [6].

Dietary patterns also play a crucial role in SO treatment [33]. Studies show that just three months of training improves physical performance in older people [34].

WB-EMS (whole-body electromyostimulation) is one therapeutic intervention often applied in SO patients. It allows for the simultaneous stimulation of, for example: the thighs, hip/bottom, abdomen, and upper extremities. It is worth mentioning that, during the stimulation period, low-intensity exercises were simultaneously conducted [29]. The application of WB-EMS is regarded as a safe and popular method for increasing muscle mass and functional capacity [30]. Furthermore, Wittmann et al. confirmed the efficacy of this application on metabolic syndrome in a group of SO patients [31].

Some authors combined exercises or electromyostimulation with supplements [25,27,29–31]. Kim et al. checked the impact of amino acid and tea catechin supplementation with exercises on the SO parameters [25]. They concluded that it effectively improved adiposity, blood composition, and increased physical activity. Nabuco et al. recorded an ALST increase, and a decreased total of trunk fat mass due to ingestion of whey protein paired with resistant training [28]. Similar results were obtained by Kemmler and co-authors. They showed that WB-EMS and/or whey protein supplements reduced sarcopenia and SO [29,30]. An important conclusion is therefore that the eating habits of people undergoing SO treatment should most definitely be modified [26].

The definition of SO is limited by the lack of consensus regarding diagnostic criteria [14]. However, the results of many papers examine the relationship between adiposity, muscle mass, and muscle strength [12]. SO is often described as a coexistence of low muscle mass, and high Body Mass Index (BMI), total body fat (TBF), or body fat percentage (BF%). These parameters are assessed via bioelectrical impedance analysis or dual-energy X-ray absorptiometry (DEXA). On the other hand, Hamer et al. define SO as a combination of a BMI of over 30kg/m^2 and HGS [35]. In some studies, authors use Appendicular Lean Mass (ALM) to assess muscle mass [36].

In all of the analysed publications, indicators from DEXA scans were taken into account. DEXA also allows changes in body composition to be monitored [14]. It is widely known that weight gain and weight loss are associated with changes in body composition [26]. The most commonly used adiposity indicators are BF% and BMI. Most of the authors surveyed used BF% to assess body fat content [20,22,25,27,29,30]. The differences in the BF% in the papers is large (from 27% to 42%). Huang et al. as well as Lia et al. define obesity as BF% >30% [20,22]. On the other hand, Follis et al. define obesity as BF% >42% [15]. Importantly, the wide range of BF% has no relation to the sex of the participants. Moreover, BMI has been used in six works [7,17,18,21,24,26]. Attention should be paid to the wide range in BMI values, which in individual authors ranged from 25kg/m^2 to 30kg/m^2 [23]. From this it follows that some subjects were overweight, not obese. Such huge discrepancies in BMI and BF values can lead to inaccurate results and conclusions.

The most often used muscle mass indicator in the above articles was the Skeletal Muscle Mass Index (SMI). SMI was used in nine articles. In addition, some authors used other indicators: LBM, ASMM, and ALST. However, it should be noted that obese individuals tend to have a relatively high LBM, which may not indicate the presence of SO in these patients. It follows from this that more reliable parameters (SMI) for assessing muscle mass should be taken into account during SO assessment [36].

In some papers, SO was assessed according to various algorithms. Park et al. used the following algorithm: ASM/weight > 25.1% [23]. In turn, Godziuk et al. used: ASM/height^2, ASM/weight, and ASM/BMI indexes. Similar algorithms were used in many of the articles, for example: (ALM/weight) × 100% [7]. It is worth mentioning that the FNIH Sarcopenia Project recommends cut-off points for appendicular lean mass adjusted for ALM/BMI [37].

Generally, some authors included low muscle strength and low levels of physical performance in the definition of sarcopenic obesity [34]. It should be noted that these are sarcopenia's diagnostic criteria [6]. Physical performance parameters are important in a physiotherapist's work. They could help them to identify patients at risk of SO. Functional indicators such as HGS, knee extension strength, gait speed, SF-36 tests, EuroSCORE, or Timed Up and Go tests (TUG) were used in seven articles. It should be mentioned that a low level of physical performance and activity are more strongly associated with obesity, not with sarcopenia [36].

To explain why the topic of SO was tackled, attention should be paid to the impact of sarcopenic obesity on overall health. Having sarcopenic obesity is associated with a risk of falling. Follis et al. prove that people who fall have a lower level of physical performance and higher BF% value. Moreover, the risk of suffering a fall while having SO is associated with age and race/ethnicity [15]. They conclude that SO creates the highest risk of falling in Hispanic, older women.

It worth to mentioning that SO individuals had a higher risk of respiratory disease incidence. Despite that, there was no association between SO and respiratory mortality. Petermann-Rocha et al. also conclude that one must take into account the lack of unequivocal definition of SO-related cut-off points [18]. The studies showed that SO was the strongest predictor of high cholesterol and asthma. Moreover, patients with SO were more likely to suffer from alcoholism or hernia [17]. They also presented a lower level of physical activity and had deficits in functional tests of lower extremities [16,19]. This condition could be associated with low knee flexors and extensor strength. SO patients had lower values of HGS, slower gait speed, and lower 6-minute walking distance [19]. Additionally, both SO and knee osteoarthritis individuals had difficulties with climbing stairs. They also presented slower walking speed [7]. It should be noted that increases in physical activity contribute to an improvement in the health of SO patients.

Conclusions

Currently, SO patients can be effectively treated with aerobic and resistance training, whole-body electromyostimulation (WB-EMS), supplements, and psychological interventions. The most commonly used indicators to assess sarcopenic obesity were BMI, PB%, SMI, ALST, and LBM. Moreover, SO also can be assessed according to various algorithms. Unfortunately, diagnostic criteria for sarcopenic obesity vary considerably. Future studies should concentrate on determining the correct cut-off points for diagnosing SO, something which could help in identifying patients at high risk in various fields of medicine. An interdisciplinary holistic approach, training, and body composition monitoring of older patients all predispose to better functioning in daily life. Due to the great impact of SO on health, future studies should focus on attempting to evaluate SO using functional assessment.

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Conflicts of interest
The authors declare no conflict of interest.

References

1. Fauziana R, Jeyagurunathan A, Abdin E, Vaingankar J, Sagayadevan V, Shafie S, et al. Body mass index, waist-hip ratio and risk of chronic medical condition in the elderly population: results from the Well-being of the Singapore Elderly (WiSE) Study. BMC Geriatr. 2016; 16: 125.
2. Biolo G, Cederholm T, Muscaritoli M. Muscle contractile and metabolic dysfunction is a common feature of sarcopenia of aging and chronic diseases: from sarcopenic obesity to cachexia. Clin Nutr. 2014 Oct; 33(5): 737-48.
3. Bell KE, von Allmen MT, Devries MC, Phillips SM. Muscle Disuse as a Pivotal Problem in Sarcopenia-related Muscle Loss and Dysfunction. J Frailty Aging. 2016; 5(1): 33-41.
4. Barazzoni R, Bischoff S, Boirie Y, Busetto L, Cederholm T, Dicker D, et al. Sarcopenic Obesity: Time to Meet the Challenge. Obes Facts. 2018 Sep;11(4): 294-305.
5. Heber D, Ingles S, Ashley JM, Maxwell MH, Lyons RF, Elashoff RM. Clinical detection of sarcopenic obesity by bioelectrical impedance analysis. Am J Clin Nutr. 1996; 64: S472-S477
6. Hardy R, Cooper R, Aihie Sayer A, Ben – Shlomo Y, Cooper C, Deary IJ, et al. Body Mass Index, Muscle Strength and Physical Performance in Older Adults from Eight Cohort Studies: The HALCyon Programme. PLoS One. 2013; 8(2): e56483.
7. Godziuk K, Prado CM, Woodhouse LJ, Forhan M. Prevalence of sarcopenic obesity in adults with end-stage knee osteoarthritis. Osteoarthritis Cartilage. 2019; 27(12): 1735-45.
8. Krzymińska-Siemaszko R, Fryzowicz A, Czepulis N, Kaluźniak-Szymanowska A, Dworak LB, Wieczorowska-Tobis K. The impact of the age range of young healthy reference population on the cut-off points for low muscle mass necessary forthe diagnosis of sarcopenia. Eur Rev Med Pharmacol Sci. 2019 May; 23(10): 4321-32.
9. Stöver K, Heber AH, Eichberg S, Brixius K. Influences of Resistance Training on Physical Function in Older, Obese Men and Women With Sarcopenia. J Geriatr Phys Ther. 2018 Jan/Mar; 41(1): 20-7.
10. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019 Jan 1; 48(1): 16-31.
11. Ercan S, Baskurt Z, Baskurt F, Cetin C. Balance disorder, falling risks and fear of falling in obese individuals: cross-sectional clinical research in Isparta. J Pak Med Assoc. 2020 Jan; 70(1): 17-23.
12. Grillot J, D'Engremont C, Parmentier AL, Lakkis Z, Piton G, Cazaux D, et al. Sarcopenia and visceral obesity assessed by computed tomography are associated with adverse outcomes in patients with Crohn's disease [published online ahead of print, 2020 Jan 11]. Clin Nutr. 2020; S0261-5614(20)30001-7.
13. de Souza Vasconcelos KS, Dias JMD, de Araújo MC, Pinheiro AC, Maia MM, Dias RC. Land-based

versus aquatic resistance therapeutic exercises for older women with sarcopenic obesity: study protocol for a randomised controlled trial. Trials. 2013; 14: 296.
14. Zamboni M, Rubele S, Rossi AP. Sarcopenia and obesity. Curr Opin Clin Nutr Metab Care. 2019 Jan; 22(1):13-9.
15. Follis S, Cook A, Bea JW, Going SB, Laddu D, Cauley JA, et al. The Association between Sarcopenic Obesity and Falls in a Multiethnic Cohort of Postmenopausal Women. J Am Geriatr Soc. 2018 Dec; 66(12): 2314-20.
16. Pajek MB, Pajek J. Characterization of Deficits Across the Spectrum of Motor Abilities in Dialysis Patients and the Impact of Sarcopenic Overweight and Obesity. Clin Nutr. 2018; 37(3): 870-7.
17. Xiao J, Cain A, Purcell SA, Ormsbee MJ, Contreras RJ, Kim JS, et al. Sarcopenic Obesity and Health Outcomes in Patients Seeking Weight Loss Treatment. Clin Nutr ESPEN. 2018; 23: 79-83.
18. Petermann-Rocha F, Yang S, Gray SR, Pell JP, Celis-Morales C, Ho FK. Sarcopenic obesity and its association with respiratory disease incidence and mortality. Clin Nutr. 2020; S0261-5614(20)30109-6.
19. Yamashita M, Kamiya K, Matsunaga A, Masuda T, Ako J, Miyaji K, et al. Prognostic value of sarcopenic obesity estimated by computed tomography in patients with cardiovascular disease and undergoing surgery. J Cardiol. 2019; 74(3): 273–8.
20. Huang S, Ku J, Lin L, Liao Ch, Chou L, Liou T. Body Composition Influenced by Progressive Elastic Band Resistance Exercise of Sarcopenic Obesity Elderly Women: A Pilot Randomized Controlled Trial. Eur J Phys Rehabil Med. 2017 Aug; 53(4): 556-63.
21. Dieli-Conwright CM, Courneya KS, Demark-Wahnefried W, Sami N, Lee K, Buchanan TA, et al. Effects of Aerobic and Resistance Exercise on Metabolic Syndrome, Sarcopenic Obesity, and Circulating Biomarkers in Overweight or Obese Survivors of Breast Cancer: A Randomized Controlled Trial. J Clin Oncol. 2018 Mar 20; 36(9): 875–83.
22. Liao CD, Tsauo JY, Lin LF, Huang SW, Ku JW, Chou LC, et al. Effects of elastic resistance exercise on body composition and physical capacity in older women with sarcopenic obesity. A CONSORT-compliant prospective randomized controlled trial. Medicine (Baltimore). 2017 Jun; 96(23): e7115.
23. Park J, Kwon Y, Park H. Effects of 24-Week Aerobic and Resistance Training on Carotid Artery Intima-Media Thickness and Flow Velocity in Elderly Women with Sarcopenic Obesity. J Atheroscler Thromb. 2017 Nov 1; 24(11): 1117–24.
24. Gadelha AB, Paiva FM, Gauche R, de Oliveira RJ, Lima RM. Effects of resistance training on sarcopenic obesity index in older women: A randomized controlled trial. Arch Gerontol Geriatr. Mar 2016; 65: 168-73.
25. Kim H, Kim M, Kojima N, Fujino K, Hosoi E, Kobayashi H, et al. Exercise and Nutritional Supplementation on Community-Dwelling Elderly Japanese Women With Sarcopenic Obesity: A Randomized Controlled Trial. J Am Med Dir Assoc. 2016; 17(11): 1011-9.
26. Ponti F, Soverini V, Plazzi A, Aparisi Gómez MP, Mercatelli D, Guglielmi G, et al. DXA-assessed changes in body composition in obese women following two different weight loss programs. Nutrition. 2018; 46: 13-9.
27. Nabuco HCG, Tomeleri CM, Fernandes RR, Sugihara Junior P, Cavalcante EF, Cunha PM, et al. Effect of whey protein supplementation combined with resistance training on body composition, muscular strength, functional capacity, and plasma-metabolism biomarkers in older women with sarcopenic obesity: A randomized, double-blind, placebo-controlled trial. Clin Nutr ESPEN. 2019; 32: 88-95.
28. Sammarco R, Marra M, Di Guglielmo ML, Naccarato M, Contaldo F, Poggiogalle E, et al. Evaluation of Hypocaloric Diet With Protein Supplementation in Middle-Aged Sarcopenic Obese Women: A Pilot Study. Obes Facts. 2017; 10(3): 160-7.
29. Kemmler W, Weissenfels A, Teschler M, Willert S, Bebenek M, Shojaa M, et al. Whole-body Electromyostimulation and Protein Supplementation Favorably Affect Sarcopenic Obesity in Community-Dwelling Older Men at Risk: The Randomized Controlled FranSO Study. Clin Interv Aging. 2017; 12: 1503-13.
30. Kemmler W, Teschler M, Weissenfels A, Bebenek M, von Stengel S, Kohl M, et al. Whole-body Electromyostimulation to Fight Sarcopenic Obesity in Community-Dwelling Older Women at Risk. Resultsof the Randomized Controlled FORMOsA-sarcopenic Obesity Study. Osteoporos Int. 2016; 27(11): 3261-70.
31. Wittmann K, Sieber C, von Stengel S, Kohl M, Freiberger E, Jakob F, et al. Impact of whole body electromyostimulation on cardiometabolic risk factors in older women with sarcopenic obesity: the randomized controlled FORMOsA-sarcopenic obesity study. Clin Interv Aging. 2016; 11: 1697–706.
32. Kreidieh D, Itani L, El Masri D, Tannir H, El Ghoch M. Association Between Reduced Daily Steps and Sarcopenic Obesity in Treatment-Seeking Adults With Obesity. Front Endocrinol (Lausanne). 2020; 11: 22.
33. Rasaei N, Kashavarz SA, Yekaninejad MS, Mirzaei K. The association between sarcopenic obesity (SO) and major dietary patterns in overweight and obese adult

women. Diabetes & Metabolic Syndrome. 2019 Jul-Aug; 13(4): 2519-24.
34. Magiera A, Kaczmarczyk K, Wiszomirska I, Olszewska E. Physical capacity in elderly women. Adv Rehab. 2012; 26(2): 29-36.
35. Hamer M, O'Donovan G. Sarcopenic obesity, weight loss, and mortality: the English Longitudinal Study of Ageing. Am J Clin Nutr. 2017 Jul; 106(1): 125-9.
36. El Ghoch M, Calugi S, Dalle Grave R. Sarcopenic obesity: definition, health consequences and clinical management. Open Nutr J. 2018; 12: 70-3.
37. Studenski SA, Peters KW, Alley DE, Cawthon PM, McLean RR, Harris TB, et al. The FNIH sarcopenia project: Rationale, study description, conference recommendations, and final estimates. J Gerontol A Biol Sci Med Sci. 2014; 69: 547-58.