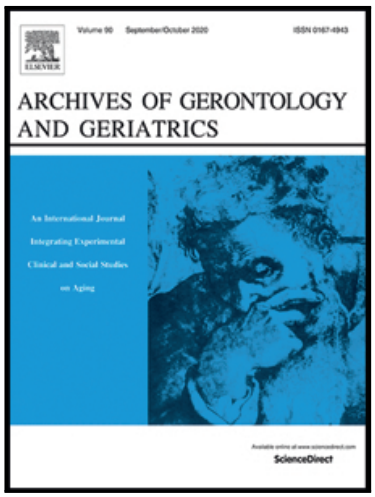

Analysis of behavioral change techniques used in exercise and nutritional interventions targeting adults around retirement age with sarcopenic obesity in a systematic review

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Highlights

- Lifestyle interventions for sarcopenic obese adults lack a psychological foundation
- BCTs are often omitted in interventional studies on sarcopenic obesity in adults
- An interdisciplinary approach is advised when aiming for effective interventions
- Implementing BCTs can foster adherence to interventions in sarcopenic obese adults

Analysis of behavioral change techniques used in exercise and nutritional interventions targeting adults around retirement age with sarcopenic obesity in a systematic review

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Declaration of Interests

The authors declare that they have no competing interests

Abstract

Background. Sarcopenic obesity significantly burdens health and autonomy. Strategies to intervene in or prevent sarcopenic obesity generally focus on losing body fat and building or maintaining muscle mass and function. For a lifestyle intervention, it is important to consider psychological aspects such as behavioral change techniques (BCTs) to elicit a long-lasting behavioral change. **Purpose.** The study was carried out to analyze BCTs used in exercise and nutritional interventions targeting community-dwelling adults around retirement age with sarcopenic obesity. **Methods.** We conducted an analysis of articles cited in an existing systematic review on the effectiveness of exercise and nutritional interventions on physiological outcomes in community-dwelling adults around retirement age with sarcopenic obesity. We identified BCTs used in these studies by applying a standardized taxonomy. **Results.** Only nine BCTs were identified. Most BCTs were not used intentionally (82%), and those used derived from the implementation of lifestyle components, such as exercise classes ("instructions on how to perform a behavior," "demonstration of the behavior," "behavioral practice/rehearsal," and "body changes"). Only two studies used BCTs intentionally to reinforce adherence in their interventions. **Conclusions.** Few studies integrated BCTs in lifestyle interventions for community-dwelling persons around retirement age with sarcopenic obesity. Future studies on interventions to counteract sarcopenic obesity should include well-established BCTs to foster adherence and, therefore, their effectiveness.

Keywords. Behavioral Change Techniques, lifestyle interventions, sarcopenic obesity, exercise, nutrition

1. Introduction

Sarcopenic obesity is defined as the simultaneous occurrence of obesity and sarcopenia. Thus, it is characterized as the co-occurrence of adiposity and low muscle mass and function, both which are related to older age [1]. On the basis of a meta-analysis, the global prevalence of sarcopenic obesity has recently been estimated to be 11% [2]. However, it must be noted that high amounts of fat mass are known to disguise the lack of muscle mass; therefore, causing sarcopenic obesity to be overlooked [3].

Sarcopenia and obesity can enhance each other, increasing the risk of sarcopenic obesity as well as the consequential negative impact of both conditions on a person's health. Research has shown that adults with sarcopenic obesity have a higher risk of disability, institutionalization, comorbidity, and metabolic disorders than those with sarcopenia or obesity alone [4, 5]. A prospective study with an eight-year follow-up showed that the disability risk in older adults with sarcopenic obesity increased by 2.5-fold, whereas no significant increase was observed for persons affected by obesity or sarcopenia alone [6]. Furthermore, the British Regional Heart Study including 4107 men showed that, over a follow-up period of six years, men between the ages of 60 and 79 with sarcopenic obesity had 55% higher mortality risk than men without sarcopenia or obesity [7].

These alarming numbers indicate an urgent need for effective lifestyle interventions to prevent and treat sarcopenic obesity. In general, the objectives of applying interventions are to help people lose body fat and build up muscle mass and function. Changing a lifestyle, requires both effective (nutrition and/or exercise) interventions and effective and last-longing behavioral changes, which can present a challenge. Therefore, to effectively implement a lifestyle intervention, such as regular resistance training or a healthy diet, and to ensure that these changes are sustained over a longer period of time, it is beneficial to apply specific behavior change techniques (BCTs) [8–10]. BCTs have been defined as "an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behavior; that is, a technique is proposed to be an "active ingredient" (e.g., feedback, self-monitoring, and reinforcement)" [11]. Different BCTs are described in the literature [11] and have been studied extensively with regard to exercise and

nutritional interventions. For example, in adults with obesity, BCTs have been shown to improve the effectiveness of interventions [12–14]. Implementing BCTs has also been shown to improve adherence to lifestyle interventions [15, 16], and they have been described as important tools health professionals can use to improve the effectiveness of interventions [17].

Retirement opens up a window of opportunity to improve the lifestyle of older adults, as people in this life phase already need to restructure their daily activities and are often motivated to do so [18]. Thus, retirement age (between the ages of 49 and 67 years in OECD countries [19]) is an ideal time to implement long-lasting lifestyle changes to contribute to healthy ageing. Without intervention, however, researchers have shown that retirement increases the risk of negative changes in body composition, such as an increase in body fat and loss of muscle mass, which are also key features of sarcopenic obesity [20–22]. Researchers have also shown that exercise interventions, such as resistance training, and nutrition interventions, (e.g., hypocaloric diets), are promising for adults with sarcopenic obesity [4]. Lara et al. [14] found that using BCTs such as barrier identification and problem-solving, plan for social support, use of follow-up prompts, and goals setting are essential to increase the effectiveness of lifestyle (nutrition) interventions in older adults near retirement age [14]. However, it is unknown which BCTs in lifestyle interventions can specifically support people with sarcopenic obesity around retirement age. This information is essential to find and design optimal interventions for people with sarcopenic obesity, as these techniques could be used to elicit sustainable lifestyle changes and increase the number of healthy life years in retirement. Due to BCT's positive impact on effectiveness and adherence to interventions, this study was conducted to identify BCTs used in randomized controlled trials (RCTs) implementing nutritional and/or exercise interventions for community-dwelling adults around retirement age with sarcopenic obesity.

2. Methods

We previously conducted a meta-analysis to assess the effectiveness of different exercises and nutritional interventions on physiological outcomes in community-dwelling adults around retirement age with sarcopenic obesity. These findings have been recently published [23], and the review was

prospectively registered in the PROSPERO database (CRD42021276461). The present study was carried out to analyze BCTs used in the primary studies identified by the systematic review and meta-analysis that was published in 2023.

We included randomized controlled trials investigating nutrition and/or exercise interventions in community-dwelling adults around retirement with sarcopenic obesity. The review's inclusion criteria were based on the PICO question (Table 1). As retirement age varies across countries (approximately between 49 and 67 years old [19]), a range of 50 to 70 years old was established in order to be exhaustive. For a study to be included, its mean age should either be within these limits or fall within them when considering the standard deviation.

The systematic literature review was conducted by searching the following databases: PubMed (MEDLINE), EMBASE via OVID, CINAHL via EBSCO Host, and the Cochrane Central Register of Controlled Trails (CENTRAL) in the Cochrane Library from the inception of each database up to and including September 16th, 2021. Additionally, we searched two trial registers (ClinicalTrials.gov and the WHO International Clinical Trials Registry Platform), the web search engine Google Scholar, and the reference lists of the eligible studies. We also conducted two updated searches, once in September and December 2022, using the same search strategy with adjusted time frames. The search strings used are provided in Supplementary Table 1. Two independent reviewers (D.E. and L.R.) performed the study selection and data extraction. A third reviewer was consulted if consensus was not met by the two reviewers through discussion.

In addition, for this study and purpose, the data extraction process included the identification of psychological techniques (i.e., BCTs). In order to obtain replicable and reliable results, from a deductive approach, we followed a standardized behavior change technique taxonomy (v1) [11]. This taxonomy was developed by coding different psychological treatments, identifying irreducible active ingredients, and reaching intercoder agreement. A total of 93 BCTs were included in the taxonomy (for more information, see Supplementary Table 2). This taxonomy has been widely used for the same purpose in previous studies and serves as a standard nomenclature for describing psychological components used in lifestyle interventions. For an operational description of each BCT, consult

Michie et al. [11]. The presence or absence of BCTs (identified based on this taxonomy) was assessed by two clinical psychologists independently who were familiar with the taxonomy (M.S.I. and P.C.C). Mentions of BCTs were sought in the descriptions of the interventions found in the published papers for the included studies. However, if available, additional articles, protocols, or materials that provided a more detailed explanation of the interventions were used. In the case of a disagreement, a consensus was achieved through a discussion between the two reviewers.

Two independent reviewers (P.C.C. and L.J.R.) assessed the risk of bias using the RoB 2 [24]. This assessment tool consists of five domains (bias arising from the randomization process, deviations from the intended intervention, missing outcome data, measurement of the outcome, and selection of the reported result) as well as a total score; both domains and the total score were rated as low, high, or some concerns, regarding the risk of bias. If at least one domain presented some concerns, the overall ratio was established as 'some concerns', if at least one domain presented a high risk of bias or several domains presented some concerns, a total score for the high risk of bias was obtained.

Regarding the data analysis and synthesis, the initial intention had been to conduct a meta-regression to study the influence of BCTs as moderators on effect sizes (the intervention's overall effect sizes were reported in the previously published meta-analysis). However, as recommended in the Cochrane Handbook [25], there were not enough studies nor BCTs to perform a meta-regression. Therefore, a qualitative synthesis of the data was performed. First, studies were grouped depending on the behavior the intervention targeted (exercise, diet, or both). For these studies, we synthesized study characteristics (i.e., inclusion and exclusion criteria, type of intervention and control, and number of BCTS) and results (effectiveness and adherence to the intervention), which can be seen in Table 2. Second, the uses of BCTs in each study, depending on the target behavior, were synthesized in Supplementary Table 3; these are also qualitatively described in the results section. Furthermore, the total use frequency for each BCT was calculated, and these are displayed in Supplementary Table 2. Additionally, the risk of bias was assessed: This is presented in a forest plot created with Robvis in Supplementary Figure 1 [26]. This review was reported following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA; Supplementary Table 4) [27].

3. Results

The systematic literature review conducted in September 2021 yielded a total of 176 studies, which were screened according to predefined inclusion criteria after duplicates had been removed. After the titles and abstracts were screened, 61 full texts were assessed for eligibility. The reasons for excluding full texts were recorded and are shown in Figure 1. Eleven different RCTs were deemed eligible according to the inclusion criteria. One additional RCT was identified through the updated search conducted in September 2022 [28]; however, the authors of this study defined sarcopenic obesity only by BMI and did not measure muscle parameters, and it was therefore excluded. The updated search conducted in December 2022 did not yield further RCTs that were eligible for inclusion. Ultimately, this review resulted in a total of eleven included RCTs.

Six studies focused only on exercise interventions [29–34], and two only on nutritional interventions [35, 36]. The remaining three RCTs studied a combination of exercise and dietary interventions [37–39]. The duration of interventions ranged from 8 to 16 weeks, with sample sizes ranging from 18 [35] to 104 participants [38]. Most of the included RCTs were two-armed, except one three-armed [37], and one four-armed study [33]. One study recruited both male and female participants [33], and one study recruited only male participants [37]. The remaining nine studies included only female participants. In these studies, body composition was measured using either DXA or BIA. The mean age of the participants ranged from 55 to 74 years. Six studies reported adherence to the interventions, ranging from 85 to 97.6%. Detailed study characteristics are published in the initial systematic review and meta-analysis (blinded for review). An overview of the number of BCTs used in the studies, as well as their results on effectiveness, are shown in Tables 2 and 3. The specific BCTs used according to the taxonomy of Michie et al. [11], as well as the frequency of the used BCTs in each study, can be found in Supplementary Tables 2 and 3, respectively.

a. BCTs targeting physical activity

All eight interventions (reported in six studies; Table 2) that targeted physical activity were carried out in classes or with a trainer who taught participants how to perform the exercises. Identified BCTs that were present in all eight active interventions were: “Instructions on how to perform a behavior”

(advise on how to perform a behavior), "demonstration of the behavior" (demonstrate the behavior so the person can imitate it), "behavioral practice/rehearsal" (ask the person to rehearse the target behavior), and "body changes" (alter body function or structure to facilitate behavioral change, for example, by encouraging the person to conduct strength training). These techniques were presented in exercise classes, where the trainer instructed participants how to perform the exercises, demonstrated the exercises, encouraged the practice of exercises, and thus induced body function or structure changes.

The interventions that targeted resistance training (n = 7) included an extra BCT: "graded tasks". "Graded tasks" refers to the progressive establishment of tasks according to their difficulty. The progressive use of elastic bands could be interpreted as an approximation of this technique.

Among all the physical activity interventions, one used other kinds of techniques that were not automatically derived from the exercise intervention: Banitalebi et al. [29] used "goal setting (behavior)" (set a behavioral goal to be achieved; in this case the performance of different exercises) and "review behavioral goal(s)" (review the current behavioral goals and consider changing them according to progress and achievements. This led to either increase, reduce, maintain, or change their prior goal and, in this case, to set the goal higher based on their individual achievements.

b. **BCTs targeting nutrition with or without physical activity**

Regarding the studies targeting nutrition (either accompanied by physical activity for all participants or alone), the characteristics, effectiveness, and number of BCTs are presented in Table 3. Among the three studies implementing both nutrition and exercise training, two of them [37, 39] implemented the mentioned BCTs usually used in exercise classes: "Instructions on how to perform a behavior," "demonstration of the behavior," "behavioral practice/rehearsal," and "body changes". The BCTs used in each study are found in Supplementary Table 3. Also, both studies used resistance training; however, unlike in Maltais et al. [37], only Nabuco et al. [39] described the progressive use of elastic bands. For this reason, "graded tasks" was identified as a BCT only in the latter study.

The third study [38] did not implement physical activity classes; therefore, the usual BCTs associated with these were absent. The BCTs included in this study were: 1) "goal setting (behavior)" – establishing behavioral goals to achieve a protein-rich diet and to do physical activities, and 2) "instructions on how to perform a behavior" – providing instructions for the type, frequency, and amount of physical activity to be performed.

Of the two studies targeting only nutrition [35, 36], one of these did not contain BCTs [35]. The second study [36] is the only one implementing BCTs that are not derived inherently from the lifestyle component intervention. To enhance adherence to the dietetic intervention, these researchers used: 1) "goal setting (behavior)" by establishing dietetic goals, 2) "social support (unspecified)" by providing counseling, and 3) "monitoring of behavior by others without feedback" by monitoring the partipants' adherence to the diet.

4. Risk of bias

The overall RoB2 ratings of the included studies were low risk of bias in four studies [30–32, 39], some concerns toward the risk of bias in five studies [29, 34–37], and high risk of bias in two studies [33, 38]. For the assessment of all domains for each study, see Supplementary Figure 1.

5. Discussion

This study aimed to identify the BCTs used in lifestyle interventions targeting physical activity and/or nutrition in community-dwelling older adults around retirement age with sarcopenic obesity. Unfortunately, the number of BCTs identified in the included studies was very limited. Although the objective of the included trials was not to implement BCTs or incorporate psychological components, these are an essential part of behavior change interventions [8–10], and, therefore, the inclusion of BCTs in lifestyle interventions is essential to reach effective and sustainable results.

The findings of this study suggest that the intentional use of techniques that facilitate a behavior change –i.e., BCTs– is mostly absent and, if they are implemented, their use is not based on a theoretical background. Indeed, most of the identified BCTs are those automatically present when

conducting a lifestyle intervention, such as the techniques generally used in an exercise class. For example, “graded tasks” was only identified due to the progressive use of elastic bands in resistance training, which is a standard procedure for this form of exercise [39, 40]. This hindered us from relating the use of BCTs with effectiveness or adherence in the selected studies. Regarding nutritional interventions, the intentional use of BCTs was only noted in the study of Sammarco et al. [36] reinforcing adherence to the dietetic intervention. However, except for the study by Maltais et al. [37], compliance was not specified in any nutritional interventions, so it was impossible to determine if implementing the BCTs resulted in a higher adherence rate.

Maintenance of and adherence to the target behaviors as well as to the interventions, are some of the main challenges that lifestyle interventions face [41, 42]. Several studies have reported that including behavioral components is critical to successfully changing behaviors and facilitating their maintenance [8–10]. Although several studies have pointed out the importance of following a multidisciplinary approach and including psychological aspects in lifestyle interventions [43, 44], the results of this review show the poor level of implementation and integration of lifestyle interventions with psychological components for community-dwelling older adults with sarcopenic obesity.

Lifestyle interventions promoting healthy behaviors should be implemented as early as possible to ensure that individuals enter retirement with established healthy habits to prevent functional loss and sarcopenic obesity. Nevertheless, this transition period presents an opportune moment to introduce these interventions to adults who have not followed such practices prior to retirement. As previously mentioned, research indicates that, without intervention, retirees tend to gain weight and fat mass while losing muscle [20–22]. Nevertheless, retirees appear to be receptive to health recommendations and can be motivated to engage in healthy behaviors such as physical activity [45–47]. Therefore, the retirement transition can either worsen health behaviors and anthropometrics or serve as a pivotal period to cultivate new healthy habits, mitigating the risk of diseases like obesity, sarcopenia, and sarcopenic obesity.

Focusing on the treatment of (sarcopenic) obesity, it is essential to consider that overweight and obese people usually have a personal history of failed attempts to lose weight [48]. One of the predictors for

failure and lack of maintenance is low self-efficacy [49], which is prevalent among people who struggle to maintain weight loss and suffer relapses [50]. This creates a vicious cycle in which each failed attempt can diminish self-efficacy, hindering the possibility of a future successful attempt [51]. In fact, low self-efficacy has been identified as the main predictor of relapses in both: nutrition and exercise [50] and is one of the main characteristics present in sedentary adults [52]. Thus, implementing appropriate BCTs (e.g., "graded tasks," "feedback on behavior," or "review behavioral goal/s") in lifestyle interventions may act on these variables and prevent future failures and weight regain; for a meta-analysis, see Awoke et al. [12].

Regarding the challenge of adhering to interventions, our results show that the adherence rate was only reported in six out of eleven studies and ranged from 85 to 97.6%. The studies reporting adherence usually have conducted in-person interventions. Therefore, the studies monitor attendance rather than true adherence to the prescribed exercises or diet on their own. In particular, in nutritional interventions, compliance is hardly reported. This result is highly concerning, since these studies assessed effectiveness without knowing whether the participants followed the instructions for their diet or prescribed supplements. Thus, if the effectiveness of nutritional interventions in RCTs is low, this may not reflect the intervention's low efficacy; it may result from participants' lack of adherence. This point is of special importance, because adherence and effectiveness are closely associated. For example, an RCT assessing the effectiveness of four different weight loss diets revealed that the amount of weight loss depended on the dietary adherence level but not the diet type [53]. Furthermore, a lack of adherence to the intervention was identified as one of the most frequent methodological threats to randomized trials [54], in addition to significantly high attrition rates [41]. Studies usually address this problem by using different statistical methods with assumptions that are generally not realistic (e.g., data missing at random [54, 55]) or explanatory variables that are insufficient (e.g., sociodemographic variables [56, 57]). Thus, efforts should be made to increase adherence to the study and intervention design. To do so, the systematic inclusion of behavioral strategies such as BCTs is fundamentally important, as their implementation significantly increases adherence [15, 16, 41].

An important aspect to consider is the relationship between BCTs and cognitive status or impairment. Previous research has indicated that the effectiveness of BCTs that rely on cognitive processes may be compromised in adults with cognitive impairments, such as those with dementia, due to their diminished cognitive functioning [58, 59]. This highlights the potential necessity for strategies that are not dependent on cognitive processes, particularly for older individuals facing cognitive challenges. Strategies like goal setting, providing social support (unspecified), and leveraging credible sources may be more applicable and effective for this demographic [59].

The study results do not enable us to make recommendations for which BCTs and behavioral theories should be used in future studies investigating nutrition and exercise interventions or in clinical practice. However, it remains essential to acknowledge that null results must be reported and gaps and actual limitations in the conduct of studies and interventions must be identified [60]. Thus, the absence of results (i.e., identified BCTs in this context) calls out for a need to comprehensively include appropriate BCTs in lifestyle interventions. As a guide for which BCTs to implement, another systematic review, which identified interventions targeting the improvement of adherence to dietary advice, also concluded that recommending the optimal combination of BCTs to improve adherence proves challenging [61]. These authors, however, identified potentially beneficial BCTs that could be used in practice, including behavioral contract and feedback [61]. Although evidence is too limited to provide specific recommendations on particular BCTs for this population, some basic techniques have proved successful across different intervention types and populations, including “goal setting” and “self-monitoring” [62, 63]. These techniques are commonly implemented in lifestyle interventions and should routinely be incorporated to increase adherence rates successfully [15]. Furthermore, other approaches could prove useful in promoting healthy behavior and adherence to interventions, and these can be implemented through policies and context cues, such as nudging. Overall, the evidence suggests that making small changes in the environment can enhance and promote healthier choices [64]. However, further research is needed to develop specific guidelines for designing nutrition and exercise interventions, including psychological components. With this, it needs to be acknowledged that the use of BCTs and behavioral theories in research and practice should depend on the

intervention's characteristics, the target population, the preferences and values of the target groups, as well as on the organizational context and other relevant variables (e.g., personality, history of failed attempts, self-efficacy). Thus, as mentioned it is important that primary studies targeting sarcopenic obese adults start using these techniques. In this regard, it is also worth mentioning the importance of defining precisely this population as, despite the recent publication of the European Society for Clinical Nutrition and Metabolism (ESPEN) and European Association for the Study of Obesity (EASO), consensus on the definition and diagnosis of sarcopenic obesity is still under debate [1], leading to limited comparability of primary studies within this research field. However, the consensus statement does identify specific cutoffs for various parameters that can be applied when diagnosing sarcopenic obesity, depending on the characteristics of the studied population, such as sex, age group, and ethnicity, which can be helpful in future studies [1]. When examining the parameter of body fat %, for example, the cutoff for Caucasian females aged 60–79 years is 41%, while for Caucasian males, it is 31% [65]. Therefore, cutoff points and diagnosis criteria used in future studies targeting sarcopenic obesity should be set according to the studied population instead of universally [1]. This would enhance the comparability of research, increasing our understanding of lifestyle interventions for older adults with sarcopenic obesity and their adherence to these interventions.

In summary, considering the challenging profile of lifestyle intervention's target population, their history of failed attempts, and the usual lack of adherence, it would be appropriate to consider these aspects when designing and implementing studies using any lifestyle intervention. Although these aspects can be considered in different ways, a multimodal approach in which psychological aspects can be comprehensively integrated remains fundamental to (1) facilitate and maintain behavioral change, (2) carry out a lifestyle intervention without undermining participants' self-efficacy, and (3) increase adherence to the intervention. This approach may yield more reliable results in studies addressing lifestyle interventions such as nutrition and exercise interventions.

This study has certain limitations worth considering. First, this study examined a narrow population of adults, which might have contributed to the low number of identified RCTs. However, as retirement can be seen as a time of transition and change, setting this specific age cutoff in this research provided the possibility to search for targeted recommendations that may not be appropriate for adults outside the studied age range. Furthermore, considering the varying age of

retirement and its potential impact on cognitive status, this aspect should be considered when designing and implementing lifestyle interventions for this population, adapting the BCTs accordingly to the target population. In this regard, it is also pertinent to mention that only a subset of the studies included in our systematic review explicitly considered cognitive status as an inclusion or exclusion criterion. Thus, this critical aspect is not always being considered in the studies and interventions' design, limiting the generalization of our findings. Second, these results cannot be generalized, in part because of the specific population studied, but also because the included studies do not represent the overall lifestyle interventions nor the general inclusion of psychological aspects. Furthermore, additional psychological techniques might have been included in these studies but not sufficiently described and, therefore, are not being considered. This is a common problem encountered in descriptions of interventions [66]. Third, few BCTs were used in these studies, thus, it was not possible to statistically analyze an association between the use of BCTs and the effectiveness or adherence of interventions.

Conclusion

By analyzing BCTs in studies included in a systematic review, we found that few BCTs are used in randomized controlled trials implementing nutritional and/or exercise interventions for community-dwelling adults around retirement age with sarcopenic obesity. If BCTs were used, they were mainly used unintentionally from a psychological perspective, for example, BCTs included when conducting an exercise class (e.g., instructions on how to perform a behavior, demonstration). These findings indicate a need for interdisciplinary collaboration with psychology professionals who can comprehensively integrate BCTs into lifestyle interventions. BCTs can be successfully used to improve adherence to lifestyle interventions, which is particularly important for people with chronic conditions like sarcopenic obesity. Therefore, integrating psychological components in lifestyle interventions, and especially interventions for this target group, would help to ensure that they make sustainable changes in their nutrition and exercise habits. Future studies investigating the effectiveness of interventions counteracting sarcopenic obesity should include BCTs to foster their effectiveness.

References

1. Donini, L. M., Busetto, L., Bischoff, S. C., Cederholm, T., Ballesteros-Pomar, M. D., Batsis, J. A., … Barazzoni, R. (2022). Definition and Diagnostic Criteria for Sarcopenic Obesity: ESPEN and EASO Consensus Statement. *Obesity Facts*, *15*(3), 321–335. https://doi.org/10.1159/000521241
2. Gao, Q., Mei, F., Shang, Y., Hu, K., Chen, F., Zhao, L., & Ma, B. (2021). Global prevalence of sarcopenic obesity in older adults: A systematic review and meta-analysis. *Clinical Nutrition*, *40*(7), 4633–4641. https://doi.org/10.1016/j.clnu.2021.06.009
3. Donini, L. M., Busetto, L., Bauer, J. M., Bischoff, S., Boirie, Y., Cederholm, T., … Barazzoni, R. (2020). Critical appraisal of definitions and diagnostic criteria for sarcopenic obesity based on a systematic review. *Clinical Nutrition*, *39*(8), 2368–2388. https://doi.org/10.1016/j.clnu.2019.11.024
4. Batsis, J. A., & Villareal, D. T. (2018). Sarcopenic obesity in older adults: aetiology, epidemiology and treatment strategies. *Nature reviews. Endocrinology*, *14*(9), 513–537. https://doi.org/10.1038/s41574-018-0062-9
5. Roh, E., & Choi, K. M. (2020). Health Consequences of Sarcopenic Obesity: A Narrative Review. *Frontiers in Endocrinology*, *11*, 332. https://doi.org/10.3389/fendo.2020.00332
6. Baumgartner, R. N., Wayne, S. J., Waters, D. L., Janssen, I., Gallagher, D., & Morley, J. E. (2004). Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly, *12*(12), 1995–2004. https://doi.org/10.1038/oby.2004.250
7. Wannamethee, S. G., Shaper, A. G., Lennon, L., & Whincup, P. H. (2007). Decreased muscle mass and increased central adiposity are independently related to mortality in older men. *The American Journal of Clinical Nutrition*, *86*(5), 1339–46. https://doi.org/10.1093/ajcn/86.5.1339
8. Castelnuovo, G., Pietrabissa, G., Manzoni, G. M., Cattivelli, R., Rossi, A., Novelli, M., … Molinari, E. (2017). Cognitive behavioral therapy to aid weight loss in obese patients: Current perspectives. *Psychology Research and Behavior Management*, *10*. https://doi.org/10.2147/PRBM.S113278
9. Kheniser, K., Saxon, D. R., & Kashyap, S. R. (2021). Long-Term Weight Loss Strategies for Obesity. *The Journal of Clinical Endocrinology and Metabolism*, *106*(7), 1854–1866. https://doi.org/10.1210/clinem/dgab091
10. Turk, M. W., Yang, K., Hravnak, M., Sereika, S. M., Ewing, L. J., & Burke, L. E. (2009). Randomized Clinical Trials of Weight-Loss Maintenance: A Review. *The Journal of cardiovascular nursing*, *24*(1), 58–80. https://doi.org/10.1097/01.JCN.0000317471.58048.32
11. Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., … Wood, C. E. (2013). The Behavior Change Technique Taxonomy (v1) of 93 Hierarchically Clustered Techniques: Building an International Consensus for the Reporting of Behavior Change Interventions. *Annals of Behavioral Medicine*, *46*(1), 81–95. https://doi.org/10.1007/s12160-013-9486-6
12. Awoke, M. A., Harrison, C. L., Martin, J., Misso, M. L., Lim, S., & Moran, L. J. (2022). Behaviour Change Techniques in Weight Gain Prevention Interventions in Adults of Reproductive Age: Meta-Analysis and Meta-Regression. *Nutrients*, *14*(1), 209. https://doi.org/10.3390/nu14010209
13. Samdal, G., Meland, E., Eide, G., Berntsen, S., Abildsnes, E., Stea, T., & Mildestvedt, T. (2019). The Norwegian Healthy Life Centre Study: A pragmatic RCT of physical activity in primary care. *Scandinavian Journal of Public Health*, *47*(1), 18–27. https://doi.org/10.1177/1403494818785260
14. Lara, J., Hobbs, N., Moynihan, P. J., Meyer, T. D., Adamson, A. J., Errington, L., … Mathers, J. C. (2014). Effectiveness of dietary interventions among adults of retirement age: a systematic review and meta-analysis of randomized controlled trials. *BMC Med*, *12*, 60. https://doi.org/10.1186/1741-7015-12-60
15. Burgess, E., Hassmén, P., Welvaert, M., & Pumpa, K. l. (2017). Behavioural treatment strategies improve adherence to lifestyle intervention programmes in adults with obesity: a systematic review and meta-analysis. *Clinical Obesity*, *7*(2), 105–114. https://doi.org/10.1111/cob.12180
16. Pirotta, S., Joham, A., Hochberg, L., Moran, L., Lim, S., Hindle, A., & Brennan, L. (2019).

Strategies to reduce attrition in weight loss interventions: A systematic review and meta-analysis. *Obesity Reviews*, *20*(10), 1400–1412. https://doi.org/10.1111/obr.12914
17. Bossen, D., Bak, M., Braam, K., Wentink, M., Holla, J., Visser, B., & Dallinga, J. (2022). Online and Offline Behavior Change Techniques to Promote a Healthy Lifestyle: A Qualitative Study. *International Journal of Environmental Research and Public Health*, *19*(1), 521. https://doi.org/10.3390/ijerph19010521
18. Schoufour, J. D., Tieland, M., Barazzoni, R., Ben Allouch, S., van der Bie, J., Boirie, Y., … Weijs, P. J. M. (2021). The Relevance of Diet, Physical Activity, Exercise, and Persuasive Technology in the Prevention and Treatment of Sarcopenic Obesity in Older Adults. *Frontiers in Nutrition*, *8*, 661449. https://doi.org/10.3389/fnut.2021.661449
19. OECD. (2023). *Pensions at a Glance 2023: OECD and G20 Indicators*. OECD. https://doi.org/10.1787/678055dd-en
20. Patrick, J. M., Bassey, E. J., & Fentem, P. H. (1982). Changes in body fat and muscle in manual workers at and after retirement. *European Journal of Applied Physiology and Occupational Physiology*, *49*(2), 187–196. https://doi.org/10.1007/BF02334067
21. Stenholm, S., Solovieva, S., Viikari-Juntura, E., Aalto, V., Kivimäki, M., & Vahtera, J. (2017). Change in body mass index during transition to statutory retirement: an occupational cohort study. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 85. https://doi.org/10.1186/s12966-017-0539-2
22. Tam, A. C. T., Steck, V. A., Janjua, S., Liu, T. Y., Murphy, R. A., Zhang, W., & Conklin, A. I. (2022). A systematic review of evidence on employment transitions and weight change by gender in ageing populations. *PLOS ONE*, *17*(8), e0273218. https://doi.org/10.1371/journal.pone.0273218
23. Eglseer, D., Traxler, M., Schoufour, J. D., Weijs, P. J. M., Voortman, T., Boirie, Y., … SO-NUTS Consortium. (2023). Nutritional and exercise interventions in individuals with sarcopenic obesity around retirement age: a systematic review and meta-analysis. *Nutrition Reviews*, *81*(9), 1077–1090. https://doi.org/10.1093/nutrit/nuad007
24. Sterne, J. A. C., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., … Higgins, J. P. T. (2019). RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*, *366*, l4898. https://doi.org/10.1136/bmj.l4898
25. Deeks, J., Higgins, J., & Altman, D. (2023). Chapter 10: Analysing data and undertaking meta-analyses. In J. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. Page, & V. Welch (Eds.), *Cochrane Handbook for Systematic Reviews of Interventions*. Cochrane. Retrieved from https://training.cochrane.org/handbook/current
26. McGuinness, L. A., & Higgins, J. P. T. (2020). Risk-of-bias VISualization (robvis): An R package and Shiny web app for visualizing risk-of-bias assessments. *Research Synthesis Methods*, *n/a*(n/a). https://doi.org/10.1002/jrsm.1411
27. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71
28. El-Hak, M. G. E. H. I. G., El-Badry, S. M., El-Mekawy, H. E. S., & Moustafa, M. H. (2021). Efficacy of aerobic and core exercise training on improving muscle mass and physical performance in postmenopausal women with sarcopenic obesity. *Journal of Cardiovascular Disease Research*, *12*(5), 802–813.
29. Banitalebi, E., Ghahfarrokhi, M. M., & Dehghan, M. (2021). Effect of 12-weeks elastic band resistance training on MyomiRs and osteoporosis markers in elderly women with Osteosarcopenic obesity: a randomized controlled trial. *BMC geriatrics*, *21*(1), 433. https://doi.org/10.1186/s12877-021-02374-9
30. Huang, S. W., Ku, J. W., Lin, L. F., Liao, C. D., Chou, L. C., & Liou, T. H. (2017). Body composition influenced by progressive elastic band resistance exercise of sarcopenic obesity elderly women: a pilot randomized controlled trial. *European Journal of Physical and Rehabilitation Medicine*, *53*(4), 556–563. https://doi.org/10.23736/s1973-9087.17.04443-4
31. Liao, C. D., Tsauo, J. Y., Huang, S. W., Ku, J. W., Hsiao, D. J., & Liou, T. H. (2018). Effects of elastic band exercise on lean mass and physical capacity in older women with sarcopenic obesity: A randomized controlled trial. *Scientific reports*, *8*(1), 2317. https://doi.org/10.1038/s41598-018-20677-7

32. Vasconcelos, K. S., Dias, J. M., Ara, uacute;jo, M. C., Pinheiro, A. C., Moreira, B. S., & Dias, R. C. (2016). Effects of a progressive resistance exercise program with high-speed component on the physical function of older women with sarcopenic obesity: a randomized controlled trial. *Brazilian journal of physical therapy*, *20*(5), 432–440. https://doi.org/10.1590/bjpt-rbf.2014.0174
33. Chen, H. T., Chung, Y. C., Chen, Y. J., Ho, S. Y., & Wu, H. J. (2017). Effects of Different Types of Exercise on Body Composition, Muscle Strength, and IGF-1 in the Elderly with Sarcopenic Obesity. *Journal of the American*, *65*(4), 827–832. https://doi.org/10.1111/jgs.14722
34. Park, J., Kwon, Y., & Park, H. (2017). Effects of 24-Week Aerobic and Resistance Training on Carotid Artery Intima-Media Thickness and Flow Velocity in Elderly Women with Sarcopenic Obesity. *Journal of Atherosclerosis and Thrombosis*, *24*(11), 1117–1124. https://doi.org/10.5551/jat.39065
35. Aubertin-Leheudre, M., Lord, C., Khalil, A., & Dionne, I. J. (2007). Six months of isoflavone supplement increases fat-free mass in obese-sarcopenic postmenopausal women: a randomized double-blind controlled trial. *European Journal of clinical Nutrition*, *61*(12), 1442–1444. https://doi.org/10.1038/sj.ejcn.1602695
36. Sammarco, R., Marra, M., Di Guglielmo, M. L., Naccarato, M., Contaldo, F., Poggiogalle, E., … Pasanisi, F. (2017). Evaluation of Hypocaloric Diet With Protein Supplementation in Middle-Aged Sarcopenic Obese Women: A Pilot Study. *Obesity Facts*, *10*(3), 160–167. https://doi.org/10.1159/000468153
37. Maltais, M. L., Perreault, K., Courchesne-Loyer, A., Lagace, J. C., Barsalani, R., & Dionne, I. J. (2016). Effect of resistance training and various sources of protein supplementation on body fat mass and metabolic profile in sarcopenic overweight older adult men: A pilot study. *International Journal of Sport Nutrition and Exercise Metabolism*, *26*(1), 71–77. https://doi.org/10.1123/ijsnem.2015-0160
38. Muscariello, E., Nasti, G., Siervo, M., Di Maro, M., Lapi, D., D'Addio, G., & Colantuoni, A. (2016). Dietary protein intake in sarcopenic obese older women. *Clinical Interventions in Aging*, *11*, 133–40. https://doi.org/10.2147/cia.S96017
39. Nabuco, H. C. G., Tomeleri, C. M., Fernandes, R. R., Sugihara Junior, P., Cavalcante, E. F., Cunha, P. M., … Cyrino, E. S. (2019). 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. *Clinical Nutrition ESPEN*, *32*, 88–95. https://doi.org/10.1016/j.clnesp.2019.04.007
40. Lee, Y.-H., Lee, P.-H., Lin, L.-F., Liao, C.-D., Liou, T.-H., & Huang, S.-W. (2021). Effects of progressive elastic band resistance exercise for aged osteosarcopenic adiposity women. *Experimental Gerontology*, *147*, 111272. https://doi.org/10.1016/j.exger.2021.111272
41. Lemstra, M., Bird, Y., Nwankwo, C., Rogers, M., & Moraros, J. (2016). Weight loss intervention adherence and factors promoting adherence: a meta-analysis. *Patient Preference and Adherence*, *10*, 1547–1559. https://doi.org/10.2147/PPA.S103649
42. Magkos, F., Hjorth, M. F., & Astrup, A. (2020). Diet and exercise in the prevention and treatment of type 2 diabetes mellitus. *Nature Reviews Endocrinology*, *16*(10), 545–555. https://doi.org/10.1038/s41574-020-0381-5
43. Montesi, L., El Ghoch, M., Brodosi, L., Calugi, S., Marchesini, G., & Dalle Grave, R. (2016). Long-term weight loss maintenance for obesity: a multidisciplinary approach. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, *9*, 37–46. https://doi.org/10.2147/DMSO.S89836
44. Tapsell, L. C., & Neale, E. P. (2016). The Effect of Interdisciplinary Interventions on Risk Factors for Lifestyle Disease: A Literature Review. *Health Education & Behavior*, *43*(3), 271–285. https://doi.org/10.1177/1090198115601092
45. Zantinge, E. M., van den Berg, M., Smit, H. A., & Picavet, H. S. J. (2014). Retirement and a healthy lifestyle: opportunity or pitfall? A narrative review of the literature. *European Journal of Public Health*, *24*(3), 433–439. https://doi.org/10.1093/eurpub/ckt157
46. King, D. E., & Xiang, J. (2017). Retirement and Healthy Lifestyle: A National Health and Nutrition Examination Survey (NHANES) Data Report. *Journal of the American Board of Family Medicine*, *30*(2), 213–219. https://doi.org/10.3122/jabfm.2017.02.160244
47. Vigezzi, G. P., Gaetti, G., Gianfredi, V., Frascella, B., Gentile, L., d'Errico, A., … Odone, A.

(2021). Transition to retirement impact on health and lifestyle habits: analysis from a nationwide Italian cohort. *BMC Public Health*, *21*(1), 1670. https://doi.org/10.1186/s12889-021-11670-3
48. Sainsbury, K., Evans, E. H., Pedersen, S., Marques, M. M., Teixeira, P. J., Lähteenmäki, L., … Sniehotta, F. F. (2019). Attribution of weight regain to emotional reasons amongst European adults with overweight and obesity who regained weight following a weight loss attempt. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*, *24*(2), 351–361. https://doi.org/10.1007/s40519-018-0487-0
49. Roordink, E. M., Steenhuis, I. H. M., Kroeze, W., Chinapaw, M. J. M., & van Stralen, M. M. (2022). Perspectives of health practitioners and adults who regained weight on predictors of relapse in weight loss maintenance behaviors: a concept mapping study. *Health Psychology and Behavioral Medicine*, *10*(1), 22–40. https://doi.org/10.1080/21642850.2021.2014332
50. Roordink, E. M., Steenhuis, I. H. M., Kroeze, W., Schoonmade, L. J., Sniehotta, F. F., & van Stralen, M. M. (2021). Predictors of lapse and relapse in physical activity and dietary behaviour: a systematic search and review on prospective studies. *Psychology & Health*, *38*(5), 1–24. https://doi.org/10.1080/08870446.2021.1981900
51. Palmeira, A. L., Sánchez-Oliva, D., Encantado, J., Marques, M. M., Santos, I., Duarte, C., … Stubbs, R. J. (2022). Motivational and self-efficacy reciprocal effects during a 12-month' weight regain prevention program. *British Journal of Health Psychology*, *28*(2), 467–481. https://doi.org/10.1111/bjhp.12635
52. Szczuka, Z., Banik, A., Abraham, C., Kulis, E., & Luszczynska, A. (2021). Associations between self-efficacy and sedentary behaviour: a meta-analysis. *Psychology & Health*, *36*(3), 271–289. https://doi.org/10.1080/08870446.2020.1784419
53. Dansinger, M. L., Gleason, J. A., Griffith, J. L., Selker, H. P., & Schaefer, E. J. (2005). Comparison of the Atkins, Ornish, Weight Watchers, and Zone diets for weight loss and heart disease risk reduction: a randomized trial. *Jama*, *293*(1), 43–53. https://doi.org/10.1001/jama.293.1.43
54. Steeger, C. M., Buckley, P. R., Pampel, F. C., Gust, C. J., & Hill, K. G. (2021). Common Methodological Problems in Randomized Controlled Trials of Preventive Interventions. *Prevention Science: The Official Journal of the Society for Prevention Research*, *22*(8), 1159–1172. https://doi.org/10.1007/s11121-021-01263-2
55. Nicholson, J. S., Deboeck, P. R., & Howard, W. (2017). Attrition in developmental psychology: A review of modern missing data reporting and practices. *International Journal of Behavioral Development*, *41*(1), 143–153. https://doi.org/10.1177/0165025415618275
56. Davis, M. J., & Addis, M. E. (1999). Predictors of attrition from behavioral medicine treatments. *Annals of Behavioral Medicine*, *21*(4), 339–349. https://doi.org/10.1007/BF02895967
57. Satherley, N., Milojev, P., Greaves, L. M., Huang, Y., Osborne, D., Bulbulia, J., & Sibley, C. G. (2015). Demographic and Psychological Predictors of Panel Attrition: Evidence from the New Zealand Attitudes and Values Study. *PLOS ONE*, *10*(3), e0121950. https://doi.org/10.1371/journal.pone.0121950
58. Nyman, S. R. (2019). Which Behavior Change Techniques Are Effective in Promoting Physical Activity Among Older People With Dementia? A Call for Research Into Three Underexplored Avenues. *Journal of Aging and Physical Activity*, *27*(4), 441–445. https://doi.org/10.1123/japa.2018-0301
59. Nyman, S. R., Adamczewska, N., & Howlett, N. (2018). Systematic review of behaviour change techniques to promote participation in physical activity among people with dementia. *British Journal of Health Psychology*, *23*(1), 148–170. https://doi.org/10.1111/bjhp.12279
60. Miller-Halegoua, S. M. (2017). Why null results do not mean no results: negative findings have implications for policy, practice, and research. *Translational Behavioral Medicine*, *7*(2), 137. https://doi.org/10.1007/s13142-017-0500-6
61. Desroches, S., Lapointe, A., Ratté, S., Gravel, K., Légaré, F., & Turcotte, S. (2013). Interventions to enhance adherence to dietary advice for preventing and managing chronic diseases in adults. *The Cochrane Database of Systematic Reviews*, (2), CD008722. https://doi.org/10.1002/14651858.CD008722.pub2
62. Carraça, E., Encantado, J., Battista, F., Beaulieu, K., Blundell, J., Busetto, L., … Oppert, J.-M. (2021). Effective behavior change techniques to promote physical activity in adults with overweight or obesity: A systematic review and meta-analysis. *Obesity Reviews: An Official Journal*

of the International Association for the Study of Obesity, *22 Suppl 4*(Suppl 4), e13258. https://doi.org/10.1111/obr.13258
63. Samdal, G. B., Eide, G. E., Barth, T., Williams, G., & Meland, E. (2017). Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults; systematic review and meta-regression analyses. *The International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 42. https://doi.org/10.1186/s12966-017-0494-y
64. Marteau, T. M., Ogilvie, D., Roland, M., Suhrcke, M., & Kelly, M. P. (2011). Judging nudging: can nudging improve population health? *BMJ*, *342*, d228. https://doi.org/10.1136/bmj.d228
65. Gallagher, D., Heymsfield, S. B., Heo, M., Jebb, S. A., Murgatroyd, P. R., & Sakamoto, Y. (2000). Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. *The American Journal of Clinical Nutrition*, *72*(3), 694–701. https://doi.org/10.1093/ajcn/72.3.694
66. Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., … Michie, S. (2014). Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *BMJ*, *348*, g1687. https://doi.org/10.1136/bmj.g1687

Table 1. Inclusion criteria based on the PICO question.

Participants	• Community dwellers with sarcopenic obesity diagnosed according to sarcopenia (i.e., SMMI, FFM) and obesity parameters (i.e., BMI, BF%) • Mean age ± SD between 50 and 70 years at baseline
Intervention	• Duration of interventions ≥ 8 weeks • Any nutrition and/or exercise intervention
Control	• Usual care or other nutrition or exercise intervention
Outcomes	• Body composition (fat mass, muscle mass, and lean mass), muscle strength (grip strength), and physical functioning (gait speed)
Study design	• RCTs

Legend: SMMI = Skeletal muscle mass index, FFM = Fat Free Mass, BMI = Body Mass Index, RCT = Randomized Control Trial

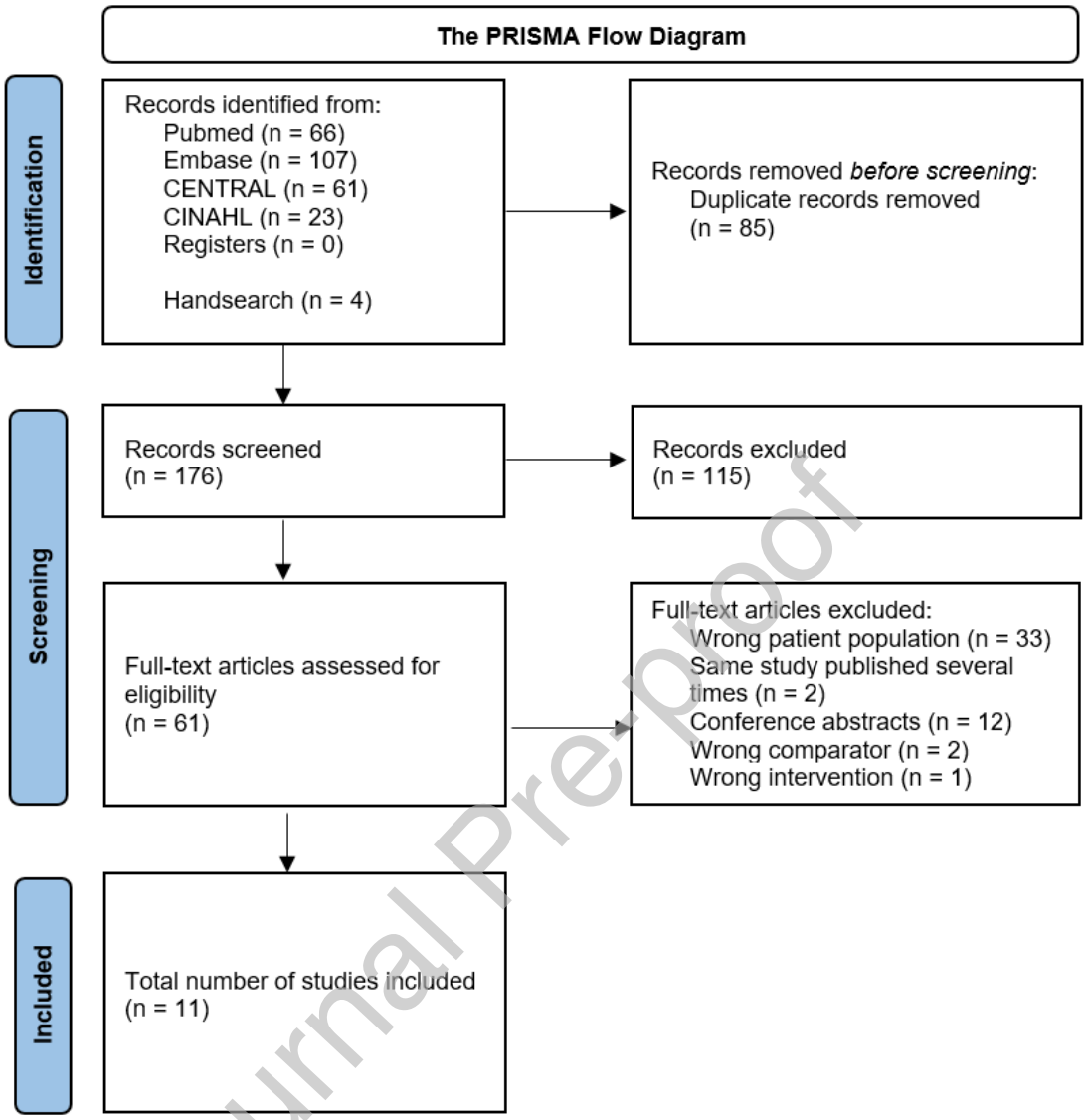

Figure 1. Flow-chart of the identification and screening process of eligible studies

Table 2. Overview of the number of BCTs used and the effectiveness of the intervention(s) targeting exercise used in the studies.

Study; country	Inclusion/Exclusion criteria	Intervention/Control	BCTs	Effectiveness [a]	Adherence
	Exercise interventions				
Banitalebi et al. 2021 (22); Iran	**Inclusion criteria** women aged between 65-80, body fat % > 32%, BMI > 30kg/m^2, − 2.5 ≤ T-score ≤ − 1.0 of L1-L4 and/or total femur or femoral neck, 10m gait speed ≤ 1 (m/s), SMMI ≤ 28% or ≤ 7.76 kg/m^2, no regular exercise training > 30 min once a week over the last 6 months, Montreal Cognitive Assessment (MoCA) cutoff score ≥ 21 **Exclusion criteria** hormonal replacement therapy, resting blood pressure ≥ 160/100 mmHg, fasting triglyceride ≥ 5.7 mmol/L, cardiovascular disease, thyroid problems, cancer, endocrine disorders such as diabetes, kidney or liver diseases, surgeries, smoking, or use of recreational drugs or alcohol.	1) IG: RT – elastic band training 3x/wk 2) CG: typical diet and activity habits	7	**Significant outcomes:** None	85%
Chen et al. 2017 (26); Taiwan	**Inclusion criteria** age between 65-75 years, sarcopenic obesity, willing to participate **Exclusion criteria** immediate disease, current infection, vaccination within last 4 weeks, alcohol or drug abuse, cancer long period of medicated chronic illness Medication that influences the immune system	1) RT: 60-70% of 1 RM 2x/wk for 60 minutes per session 2) AT: 2x/wk for 60 minutes per session 3) CT:1x/wk AT after 48h RT 4) CG: day-to-day lifestyle	5	**Significant outcomes** • RT: body fat %, SMMI, muscle mass % • AT: body fat %, SMMI, BMI • CT: body fat %, SMMI, BMI	Not specified
Huang et al. 2017 (23); Taiwan	**Inclusion criteria** postmenopausal women age between 60-90, ability to independently perform daily	1)IG: RT – elastic band training 3x/wk, 55 minutes per session	5	**Significant outcomes:** None	Not specified

	activities, sarcopenic obese **Exclusion criteria** neurological impairments, severe musculoskeletal disorders or artificial implants, diabetes mellitus, unstable chronic disease	2) CG: health education			
Liao et al. 2018 (24); Liao	**Inclusion criteria** women aged 60-80 years with sarcopenia or obesity **Exclusion criteria** uncontrolled hypertension, joint contraction or internal metal implants, cardiovascular or pulmonary disease, neurological impairment	1)IG: RT – elastic band training, 3x/wk for 55 minutes per session 2) CG: no intervention	5	**Significant outcomes:** body fat %, muscle mass %, upper extremity strength	97.6%
Park et al. 2017 (27); Korea	**Inclusion criteria** sarcopenic obesity, women over the age of 65, exclusion criteria, history of chronic vascular disease, medicated hypertension, diabetes, osteoporosis, arthritis, physical activity: ≥20min/day and ≥3 times/wk	1) IG: RT – elastic band exercise 20-30 min per session 3x/wk + AT 30-50 min per session 5x/wk 2) CG: usual physical activity	5	**Significant outcomes:** Upper extremity strength, gait speed	92%
Vasconcelos et al. 2016 (25); Brazil	**Inclusion criteria** women aged 65 – 80 yrs, sarcopenic obesity **Exclusion criteria** physical, sensory or cognitive disability that affects measurements or exercise, unstable or acute cardiovascular, articular or metabolic disease	1) IG: RT – high speed intervention 2x/wk for 1 hour per session 2) CG: monitored by therapists once a week by phone	5	**Significant outcomes:** Lower extremity strength	85%

[a] Significant outcomes refer to significant differences between intervention and control groups (or different intervention groups)

[b] Results are based on before/after measurements within the intervention/control group

Legend: RT = resistance training, AT = aerobic training, BMI = body mass index, BW = body weight, CT = combined training, CG = control group, WP = whey protein, NPI = normal protein intake, HPI = high protein intake, IG = intervention group, DXA = dual energy X-ray absorptiometry, wk = week, SO = sarcopenic obesity monitored.

Table 3. Overview of the number of BCTs used and the effectiveness of the intervention(s) in the studies targeting nutrition with or without exercise for all participants.

Study; country	Inclusion/Exclusion criteria	Intervention/Control	BCTs	Effectiveness [a]	Adherence
Nutrition Interventions					
Aubertin-Leheudre et al. (2007); Canada	**Inclusion criteria** postmenopausal women between 50-70 years, no major physical incapacity sedentary, stable weight (+/- 2 kg) in 6 months, non-smoker, moderate drinker, no menses in past 12 months **Exclusion criteria** no hormone replacement therapy, medication intake that influences glucose or lipometabolism	1) IG: 4 capsules daily: 70 mg/d isoflavones 2) CG: Placebo	0	**Significant outcomes:** Leg FFM, appendicular FFM, MMI	Not specified
Sammarco et al. (2017); Italy	**Inclusion criteria** women aged 41-74 years with sarcopenic obesity who underwent clinical evaluation at the obesity unit (University Hospital, Naples Italy) **Exclusion criteria** None mentioned	1. IG: Hypocaloric + high protein 2. CG: Hypocaloric + placebo	3	**Significant outcomes[b]** • Hypocaloric diet + high protein intake: Body weight, total body fat mass in kg, body fat % • Hypocaloric diet + placebo: body weight, total body fat mass in kg, body fat %, LBM, muscle strength	Not specified
Nutrition Interventions with Exercise					
Maltais et al. (2016); Canada	**Inclusion criteria** men aged between 60-75yrs, non-smoker, sedentary for at least 5yrs, BMI< 30 kg/m^2, no major physical disabilities, light drinker, stable weight (+/- 2 kg in 6 months), no resistance training in last 3 years	1) IG1: milk powder= 14 g protein + RT 3x/wk for 1 hour per session 2) IG2: commerical EAA powder = 12 g protein + RT 3x/wk for 1 hour per session 3) CG: RT 3x/wk for 1 hour per session	4	**Significant outcomes** • Milk powder protein + RT: gat mass, lean mass • EAA protein + RT: body weight, lean mass	> 90%

	Exclusion criteria kidney disease uncontrolled blood pressure, medication that influences metabolism				
Muscariello et al. (2016); Italy	**Inclusion criteria** women >65 years of age, BMI > 30 kg/m^2 **Exclusion criteria** kidney failure, systemic inflammatory disorders, cancer, neurodegenerative disorders, pharmacological treatment with steroids, antiretroviral drugs, weight-loss medications or insulin, and endocrine disorders	1)IG: Hypocaloric diet and NPI: 0.8 g protein/kg DBW/d +AT: 5x/wk for 30 minutes 2) CG: Hypocaloric diet and HPI: 1.2 g protein/kg DBW/d +AT: 5x/wk for 30 minutes	2	**Significant outcomes**[b] • High protein + AT: body fat in kg, BMI, waist circumference • Normal protein + AT: body fat in kg, BMI	Not specified
Nabuco et al. (2019); Brazil	**Inclusion criteria** women ≥ 60 years with sarcopenic obesity, physically independent, no hormone replacement therapy **Exclusion criteria** completed 8-week-long RT program, cardiac or orthopedic illness, metallic implant, or artificial pacemaker, unable to perform training sessions, failed medical examination	1) IG: WP+ RT (3x/wk) 2) CG: RT 3x/wk + Maltodextrin	5	**Significant outcomes:** None	Not specified

[a] Significant outcomes refer to significant differences between intervention and control groups (or different intervention groups)

[b] Results are based on before/after measurements within the intervention/control group

Legend: RT = resistance training, AT = aerobic training, BMI = body mass index, BW = body weight, CT = combined training, CG = control group, WP = whey protein, NPI = normal protein intake, HPI = high protein intake, IG = intervention group, DXA = dual energy X-ray absorptiometry, wk = week, SO = sarcopenic obesity

Declaration of interests

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

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: