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Effects of exercise in older adults with osteosarcopenic adiposity: a systematic review and meta-analysis of randomized controlled trials

Lei Chen[1†], Wenlu Zhou[2†], Ju Li[1], Taotao Xu[1] and Zhenyu Shi[1*]

Abstract

Aim To evaluate the effects of exercise training on patients with osteosarcopenic adiposity (OSA).

Methods A comprehensive search was conducted in PubMed, Embase, Cochrane Library, Web of Science, CNKI, Wanfang, and VIP databases for randomized controlled trials (RCTs) on exercise treatment for OSA patients. The search included both Chinese and English literature up to April 2024. Reference lists and grey literature were also reviewed. Two researchers independently screened the literature, extracted data, and assessed the quality of included studies. Meta-analysis was performed using RevMan 5.4 software.

Results A total of 7 studies were included in this meta-analysis. Exercise interventions significantly improved bone mineral density (BMD) (MD = 0.0195, 95% CI: 0 to 0.02, $P = 0.03$), body fat (BF) (MD = -4.0, 95% CI: -5.46 to -2.54, $P < 0.01$), and hand grip strength (HGS) (MD = 3.13, 95% CI: 0.72 to 5.54, $P = 0.01$) in patients with OSA. However, no significant differences were observed in skeletal muscle mass index (SMI) (MD = 0.12, 95% CI: -0.26 to 0.50, $P = 0.55$), gait speed (GS) (SMD = 0.75, 95% CI: -1.26 to 2.76, $P = 0.47$), or C-reactive protein (CRP) (MD = -0.23, 95% CI: -0.90 to 0.44, $P = 0.50$).Conclusion: Exercise interventions can effectively improve clinical symptoms and signs in OSA patients to varying degrees, highlighting the importance of exercise in the management of OSA.

Keywords Osteosacopenia, Adiposity, Osteoporosis, Sarcopenia, Exercise, Randomized controlled trial

Aging leads to changes in body composition, such as the loss of bone and muscle mass and an increase in fat. As the global population ages, the risks of osteoporosis, sarcopenia, and obesity gradually increase, becoming common chronic diseases that threaten the health of the elderly. This population faces significant health challenges [1, 2]. A study with an average follow-up time of 10.7 years suggested that [3] obese patients with concomitant sarcopenia had lower lumbar spine bone mineral density (BMD) and total body bone mineral density compared to those with simple obesity and also had a higher incidence of non-vertebral fractures. Osteoporosis, sarcopenia, and

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obesity are interrelated conditions. Compared to having any one of these conditions alone, the simultaneous presence of osteoporosis, sarcopenia, and obesity poses a greater threat to health. In 2014, Ilic et al. [4] introduced the concept of Osteosarcopenic Adiposity (OSA) syndrome, defined as a syndrome characterized by the concurrent presence of reduced bone mass, decreased muscle mass and function, and increased adipose tissue. The prevalence of OSA syndrome has been reported to range from 6 to 19% [5–7], but due to the rapid development of an aging society and the lack of standardized diagnostic criteria, the actual prevalence may be much higher than currently reported [8, 9]. As a condition that severely impacts the health and quality of life of the elderly, OSA syndrome presents higher health risks compared to its individual components. Patients with OSA are more likely to experience functional impairment, increasing the risks of falls, fractures, disability, and even death [4, 10]. OSA often coexists with other conditions such as diabetes [11] and respiratory diseases [12] further increasing the burden on healthcare systems and imposing significant economic costs on individuals, families, and society.

Currently, the treatment methods for OSA syndrome primarily include exercise and nutritional therapy [1, 13]. Exercise therapy is considered a practical, safe, and effective method. It primarily works by stimulating osteogenic responses, maintaining bone density, and reducing muscle mass decline and lower limb muscle strength loss associated with aging [4, 14]. It also helps overcome anabolic resistance and mild chronic inflammation related to aging. Through these mechanisms, exercise can significantly increase muscle mass and bone density, reduce fat mass, and alleviate the disease burden on patients [15]. Studies by Huang et al. [16] and Liao et al. [17] have found that exercise training significantly improves patients' bone density, muscle mass, and physical function. However, systematic reviews and evaluations have yet to be conducted. In recent years, research evaluating the effects of exercise on patients with OSA syndrome has gradually increased. Meta-analyses by Liu et al. [18] and Yang et al. [19] have been conducted, but they showed differences in outcome measures such as skeletal muscle mass index and gait speed.

For instance, Liu et al. [18]focused solely on elderly female patients, which may limit the generalizability of their findings to the broader elderly population. Furthermore, while OSA is an emerging concept that has gained increasing attention, the body of research remains in its early stages, with relevant literature still scarce. Notably, there has been insufficient exploration of how exercise interventions influence the varied clinical manifestations of OSA in patients [19]. This study aims to address these gaps by incorporating a broader range of relevant studies.

Moreover, the diagnostic criteria for OSA remain inconsistent across different studies, which may affect the comparability and consistency of results [20, 21]. Consequently, this study will examine the potential impact of differing diagnostic standards on the evaluation of OSA patients and will further assess the heterogeneity found in existing literature. While current clinical studies have largely focused on the effects of resistance training on OSA patients, there is a lack of research on other types of exercise interventions [18, 19]. This systematic review intends to expand the scope by comprehensively reviewing literature on exercise interventions, evaluating the effectiveness of various exercise types on OSA patients, and providing support for future research in this area.

Additionally, this study will consider individual patient differences, such as age, gender, and coexisting conditions, to provide more personalized and scientifically grounded recommendations for exercise treatment plans. Our goal is to offer robust evidence to clinicians, enabling them to design more precise and effective treatment strategies based on the specific conditions of their patients. Through this systematic review, we not only aim to fill the existing gaps in the literature but also to offer a more comprehensive framework for future research, ultimately advancing the application and development of exercise therapy in OSA patients.

Methods

This review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This study was registered in the International Prospective Register of Systematic Reviews Prospero under number CRD42024532009.

Inclusion and exclusion criteria

Inclusion Criteria: (1) Patients diagnosed with OSA syndrome which diagnosed standard must mentioned in the txt (2) Study type: randomized controlled trials (RCTs). (3) Intervention: Exercise intervention in the experimental group (resistant training, aerobic training, mixed training etc.); control group received conventional treatment, nutritional therapy, or other treatments. (4) Outcomes: Primary outcomes included bone mineral density (BMD), skeletal muscle index(SMI), body fat(BF), and C-reactive protein (CRP); Secondary outcomes included hand grip strength (HGS), gait speed (GS) or other indexes that indicator of the patient's physical function. (5) patients` age ≥ 60.

Exclusion Criteria: (1) Duplicate publications. (2) Studies without full text or with only abstracts available. (3) the comparisons were not performed according to the intervention type. (4) studies containing any complications that affect the measurement of outcome measures in OSA patients will not be included.

Search strategy

The databases Cochrane Library, Web of Science, PubMed, Embase, CBM, CNKI, Wanfang, and VIP were searched from inception to January 2025. supplementary searches will include reference lists of included studies. The search strategy combined subject terms and free words. The specific search strategies in every database are detailed in the Supplementary Document 1.

Literature screening and data extraction

Two researchers independently screened the literature and extracted data according to the inclusion and exclusion criteria. Any disagreements were resolved by a third researcher. Data extraction included authors, sample size, patient age, interventions, control measures, and outcomes.

Quality assessment

The quality of included studies was assessed using the Cochrane Handbook for Systematic Reviews of Interventions 5.1.0 [22]. The assessment included seven items, and each item was judged as having a "low risk," "high risk," or "unclear risk" of bias. Studies were rated as A (fully met criteria), B (partially met criteria), or C (did not meet criteria).

Statistical analysis

Meta-analysis was conducted using RevMan 5.4 software. Continuous outcomes were expressed as mean difference (MD) or standardized mean difference (SMD) with 95% confidence intervals (CI). Heterogeneity among studies was assessed using the chi-square test and I^2 statistic. Fixed-effect models were used if $P > 0.1$ and $I^2 < 50\%$; otherwise, random-effect models were applied. Subgroup analyses, sensitivity analyses, or qualitative descriptions were performed if necessary. $P < 0.05$ was considered statistically significant.

Results

Literature screening process

The initial search yielded a certain number of studies, with 7 studies [15, 16, 23–27] finally included. The literature screening process is shown in Fig. 1. According to our statistics and calculations, the kappa statistic is calculated to be 0.91. This indicates that the consistency between the two screening results is at a very good level. This result indicates that there is a high degree of consistency between different screening steps in the data screening process of this study, and the screening results have strong reliability and stability, providing a solid data foundation for subsequent research analysis based on the screened data.

Study characteristics

A total of 7 articles were included in this study. Among them, there were all RCTs. The basic characteristics of the included literature are presented in Table 1.

Study quality

Seven articles were included, of which four were rated as grade A and the other three were rated as grade B. Four articles described the methods and process of randomization while three articles did not. All articles but one mentioned allocation concealment and used blinding for outcome assessors with explanation of blinding. In seven articles complete data is reported. No reporting bias was observed in all articles. All articles compared the baseline characteristics of the study subjects, such as age, gender, and disease. The quality assessment of the articles is shown in Fig. 2 (Risk of bias graph) and Fig. 3 (Risk of bias summary).

Primary outcomes

Bone mineral density

Five studies evaluated the effect of exercise on BMD in patients with OSA (Fig. 4). No significant heterogeneity was observed among the studies ($P = 0.76$, $I^2 = 0$), indicating a consistent outcome across the studies. Consequently, a fixed-effect model was used for the analysis. The results demonstrated that exercise led to a statistically significant improvement in BMD compared to the control group (MD = 0.0195, 95% CI: 0 to 0.02, $P = 0.03$). These findings suggest that incorporating exercise may be an effective approach to enhance bone health in individuals with OSA.

Skeletal muscle mass index

Two studies assessed the post-intervention SMI in patients (Fig. 5). No significant heterogeneity was detected between the studies ($P = 0.48$, $I^2 = 0$), indicating consistent findings across the studies. Therefore, a fixed-effect model was applied. The analysis revealed no significant difference between the exercise and control groups (MD = 0.12, 95% CI: -0.26 to 0.50, $P = 0.55$). This suggests that exercise did not lead to a measurable change in SMI.

Body fat

Five studies examined the impact of exercise on BF in OSA patients (Fig. 6). No heterogeneity was observed among the studies ($P = 0.99$, $I^2 = 0$), indicating consistent results across the studies. A fixed-effect model was employed for the analysis. The findings demonstrated that exercise significantly reduced BF in OSA patients (MD = -4.0, 95% CI: -5.46 to -2.54, $P < 0.01$), suggesting that exercise is an effective intervention for reducing BF in this patient group.

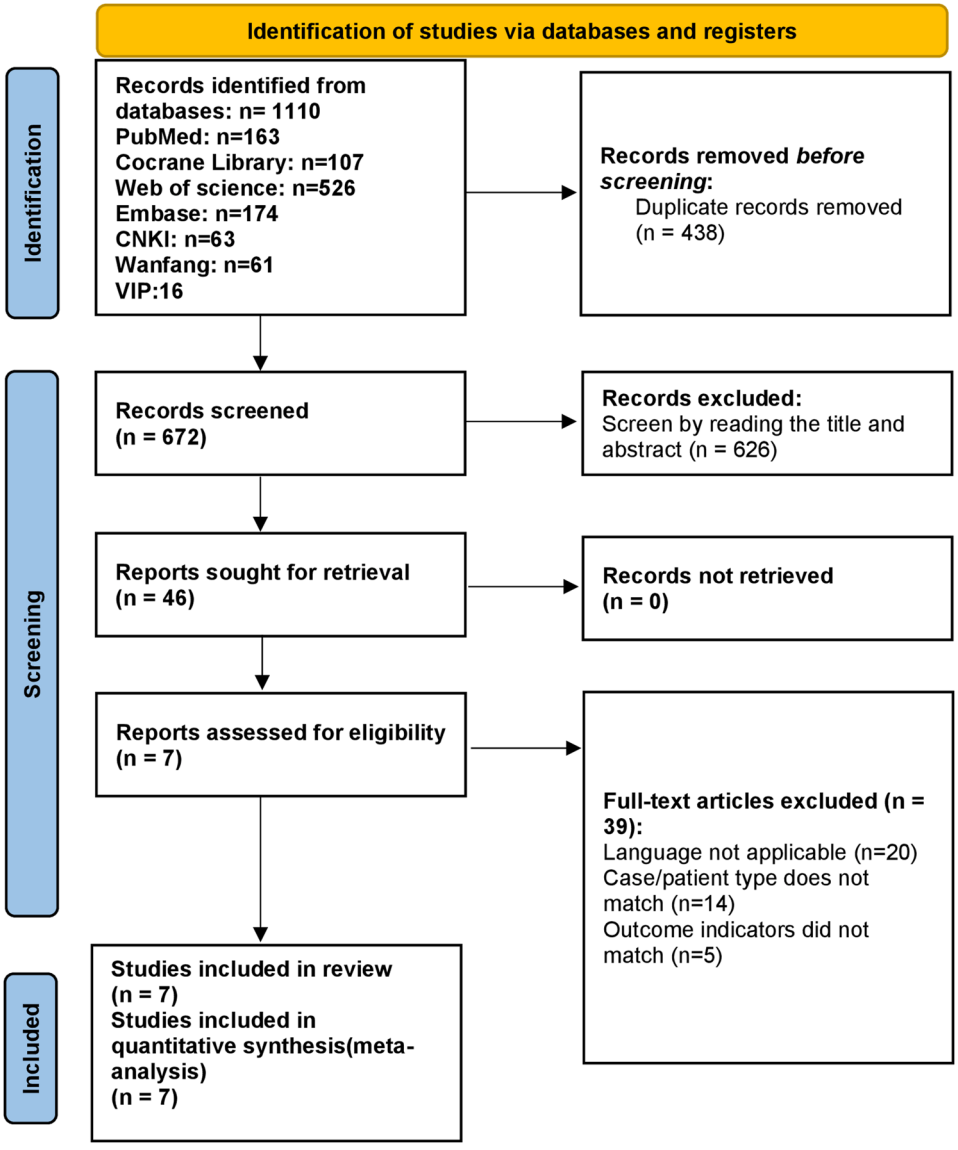

Fig. 1 literature screening process

High-sensitivity C-reactive protein

Two studies assessed changes in CRP levels post-intervention (Fig. 7). No significant heterogeneity was observed between the studies ($P = 0.67$, $I^2 = 0$), indicating that the studies had consistent results. As a result, a fixed-effect model was applied to the data. The pooled analysis revealed no significant difference in CRP levels between the exercise and control groups (MD = -0.23, 95% CI: -0.90 to 0.44, $P = 0.50$). This suggests that exercise did not lead to a meaningful reduction in CRP levels in the studied patient population.

Secondary outcomes

Gait speed

Two studies reported post-intervention GS (Fig. 8). Significant heterogeneity was detected between the studies ($P < 0.01$, $I^2 = 93\%$), indicating substantial variability in the results. Given this high level of heterogeneity, a random-effects model was employed to account for the differences across the studies. Despite the variability, the pooled analysis found no significant difference between the exercise and control groups (SMD = 0.75, 95% CI: -1.26 to 2.76, $P = 0.47$). This suggests that exercise did not lead to a statistically significant change in GS in the studied population.

Hand grip strength

Two studies evaluated the impact of exercise on HGS in OSA patients (Fig. 9). No heterogeneity was observed between the studies ($P = 0.51$, $I^2 = 0$), indicating a consistent effect across the studies. Therefore, a fixed-effect model was applied for the analysis. The pooled data

Table 1 Characteristics of included studies

Study	Published time	Age (Experimental/Control)	Sample Size (Experimental /Control)	Intervention	Diagnosis of OSA	Intervention frequency	Control	Outcome
Huang et al. [16]	2017	68.89 ± 4.91/69.53 ± 5.09	18/17	Progressive elastic band resistance training program	SMI<27.6% Body fat>30%	55 min a time, 3 times a week, 12 weeks	Health education	BMD, SMI, BF, CRP
Liao et al. [20]	2017	66.39 ± 4.49/68.42 ± 5.86	25/21	Progressive resistance exercise training with Theraband	SMI<7.15 kg/m^2 Body fat>30%	45–50 min a time, 3 times a week, 12 weeks	Regular intervention	BF, HGS, GS
Cunha et al. [21]	2017	66.6 ± 5.1/68.3 ± 4.2/67.3 ± 3.6	21/20/21	Progressive resistance exercise training(self-gravity)	Not reported	30 min a time, 3 times a week, 12 weeks 50 min a time, 3 times a week, 12 weeks	Regular intervention	BMD, BF
Kazemipour et al. [22]	2020	64.11 ± 3.81/64.05 ± 3.35	32/31	Progressive elastic band resistance training	DEXA T-score≤ -2.5 (L1-L4) Body fat > 32%, BMI > 30 kg/m2, walking test (MWT) (10) ≤ 1 m/s^2	45–50 min a time, 3 times a week, 12 weeks	Regular intervention	BMD, CRP
Hashemi et al. [23]	2020	64.11 ± 3.81/64.05 ± 3.35	15/15	Progressive elastic band resistance training program	Body fat > 32%, DEXA: -2.5 ≤T-score≤-1 BMI ≥ > 30 kg/m^2 walking test (MWT) (10) ≤ 1 m/s^2	50 ~ 55 min a time, 3 times a week, 12 weeks	Regular intervention	BMD
Li et al. [24]	2020	63.8 ± 3.56/64.93 ± 3.84	15/12	Elastic band resistance training combined with aerobic training	DEXA T-score≤ -1 (L1-L4) Body fat ≥ 25%(Male); ≥30%(Female) SMI ≤ 7 kg/m^2(Male) ≤ 5.4 kg/m^2(Female)	Aerobic training: 30 ~ 45 min a time, 5 times a week, 12 weeks Resistance training: 45 ~ 60 min a time, 3 times a week, 12 weeks	No intervention	BMD, SMI, BF
Lee et al. [15]	2021	70.13 ± 4.41/71.82 ± 5.23	22/24	Elastic band resistance training	SMI<5.67 kg/m grip strength < 20 kg or gait speed < 0.8 m/s DEXA T-score<-1 Body fat >35%	55 min a time, 3 times a week, 12 weeks	Regular intervention	BF, SMI, HGS, GS

BF: Body fat; SMI: skeletal muscle mass index; BMD: bone mineral density; HGS: hand grip strength; GS: gait speed; CRP: C-reactive protein

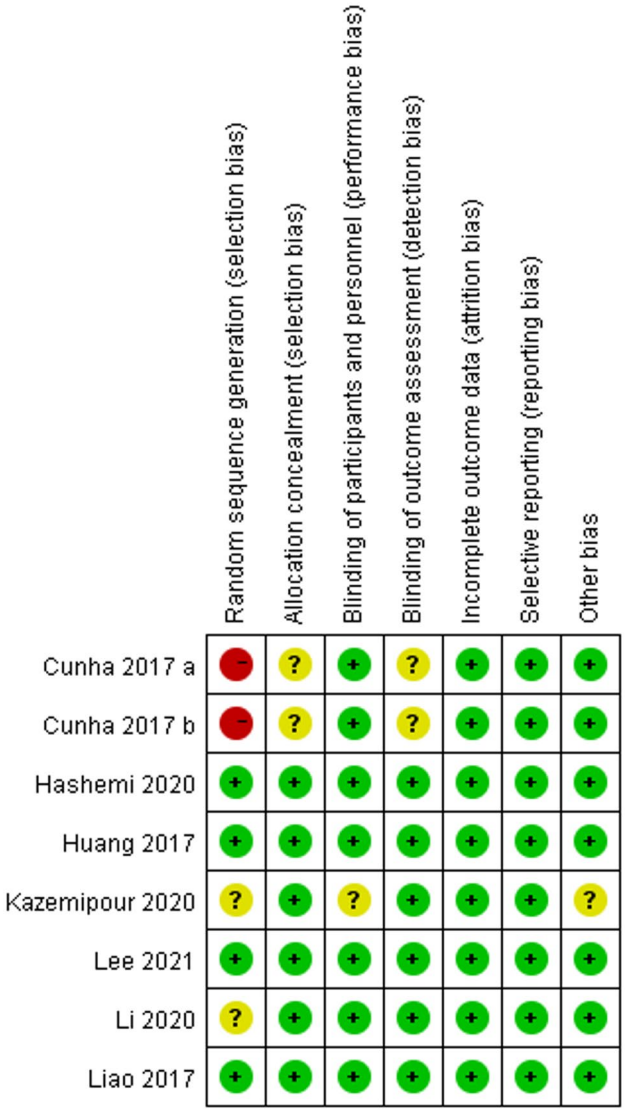

Fig. 2 Risk of bias graph

demonstrated that exercise led to a statistically significant improvement in HGS in the exercise group compared to the control group (MD = 3.13, 95% CI: 0.72 to 5.54, $P = 0.01$). These findings suggest that exercise is an effective intervention to enhance handgrip strength in OSA patients.

Publication bias

Due to the inclusion of only 7 studies, a funnel plot analysis was not performed.

Subgroup analysis

The decision to exclude subgroup analysis from this study was made due to the limited number of studies included in the meta-analysis. Given the heterogeneity among the available studies and the small sample size for certain subgroups, performing a subgroup analysis would not provide reliable results. Furthermore, subgroup analysis often requires larger sample sizes to ensure statistical power and to minimize the risk of overinterpretation of results. Thus, for the accuracy and robustness of our findings, we opted not to perform subgroup analysis in this review.

Discussion

OSA is a newly defined geriatric syndrome that significantly increases the risks of falls, fractures, hospitalization, and death in the elderly due to the overlap of multiple chronic diseases. [4] Currently, no definitive treatment strategy exists for OSA syndrome, but related research indicates that exercise is an effective intervention that can improve clinical symptoms to some extent [18, 19]. This study included 7 articles to analyze the impact of exercise on OSA patients.

Liu [18] and Yang's [19] studies both indicate that exercise can enhance BMD in OSA patients, consistent with our findings. Osteocytes can sense and respond to mechanical load to maintain bone homeostasis [28]. Mechanical load mainly comes from the gravitational

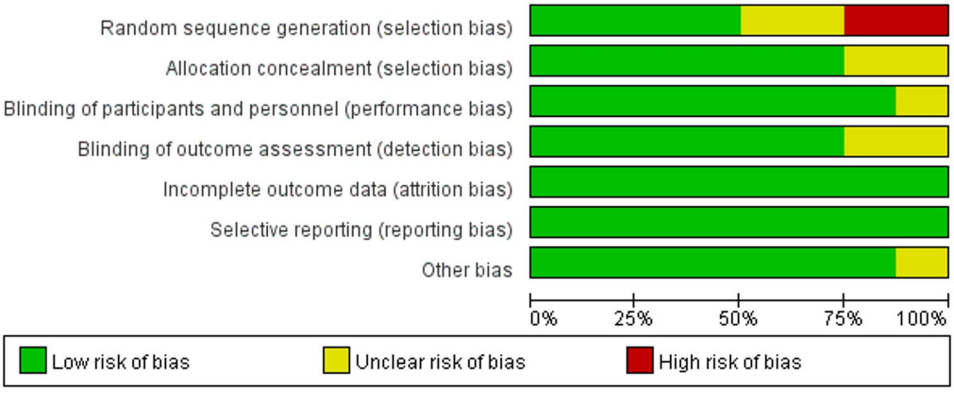

Fig. 3 Risk of bias summary

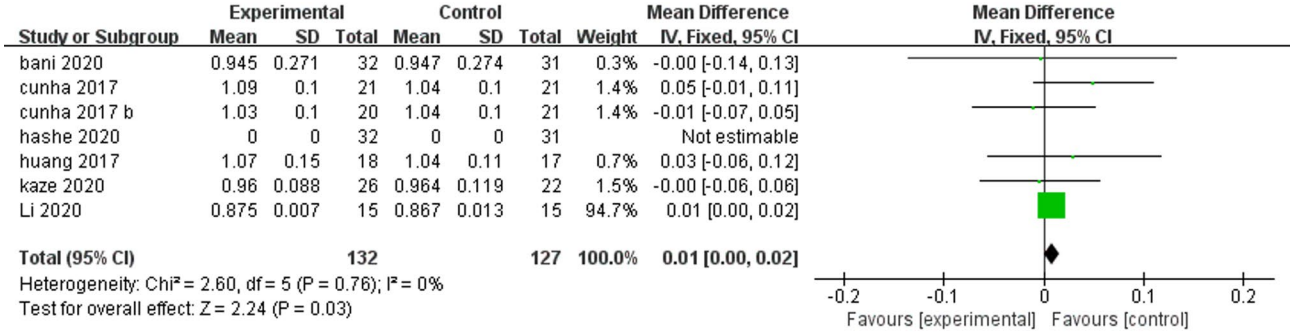

Fig. 4 The effect of exercise on Bone mineral density in OSA patients

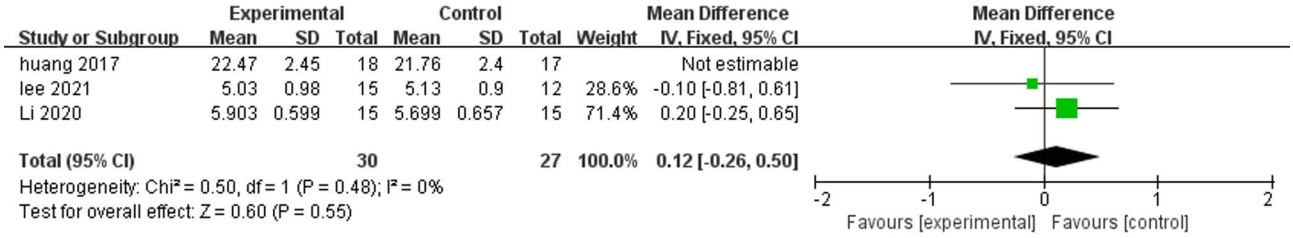

Fig. 5 The effect of exercise on Skeletal muscle mass index in OSA patients

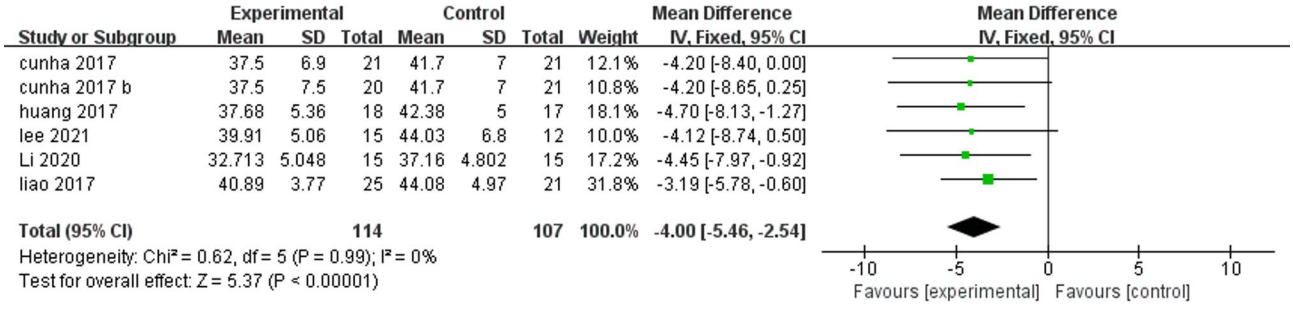

Fig. 6 The effect of exercise on body fat in OSA patients

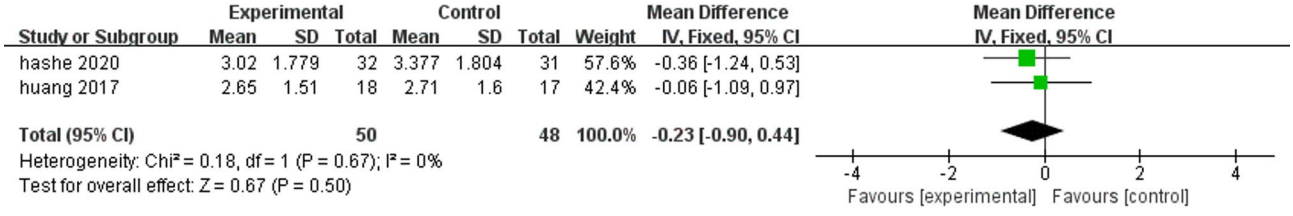

Fig. 7 The effect of exercise on High-sensitivity C-reactive protein in OSA patients

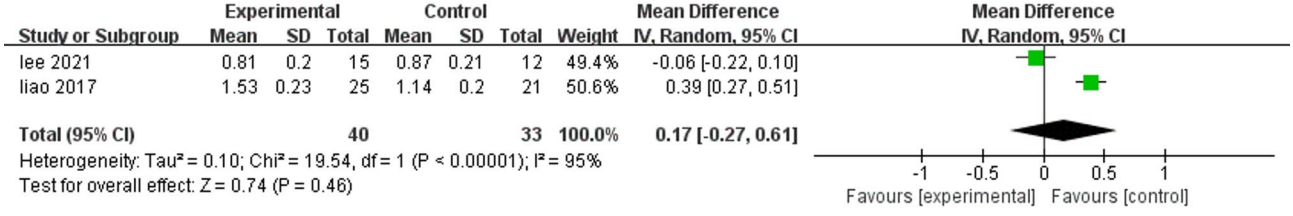

Fig. 8 The effect of exercise on Gait speed in OSA patients

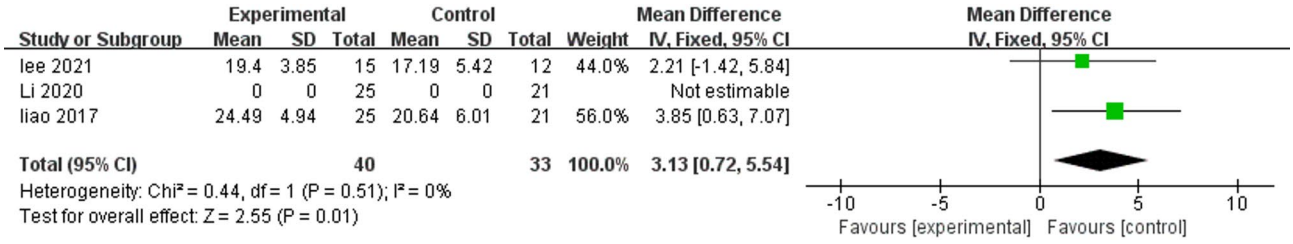

Fig. 9 The effect of exercise on Hand grip strength in OSA patients

transmission during weight-bearing activities and the reactive forces from muscle contractions during exercise. These stimuli can upregulate IGF-1 expression, activate the PI3K/Akt and Wnt/β-catenin signaling pathways [29], promote osteoblast differentiation, and inhibit osteoclast differentiation, thereby promoting bone formation and inhibiting bone resorption, increasing BMD in OSA patients. This is why Kaze et al. found that resistance training with elastic bands promoted IGF-1 expression. Therefore, resistance exercise can significantly increase BMD in patients by activating signaling pathways within osteocytes. Furthermore, exercise may enhance muscle strength, thereby increasing the mechanical stimulation exerted by muscles on bones, promoting bone formation, and improving BMD [30]. During muscle contraction, various beneficial factors, such as myostatin [31] and irisin [32], are secreted. These factors not only regulate osteocyte function but also work synergistically with enhanced mechanical stimulation to further promote bone health, ultimately leading to an increase in BMD.

Moreover, the improvement in grip strength is directly attributable to resistance training, as resistance exercises effectively enhance both upper and lower limb muscle strength, thereby significantly increasing grip strength. However, research on grip strength measurement remains relatively limited, and it is often overlooked in systematic reviews and meta-analyses within this field. For instance, the studies by Liu et al. [18] and Yang et al. [19] did not include grip strength as an outcome measure. Therefore, its role in assessing improvements in muscle function still requires further investigation and validation. Compared to patients with simple sarcopenia or osteoporosis, OSA patients experience gradual infiltration and replacement of normal muscle by adipose tissue. Their BMI and body fat percentage are significantly higher than normal standards, muscle aging accelerates, muscle mass and bone density further decrease, and physical activity gradually diminishes, posing serious health risks. Yarizadeh et al. [33] proposed that growth hormone is a lipolytic hormone that stimulates the breakdown of adipose tissue via hormone-sensitive lipase. Resistance training can induce an acute increase in growth hormone, breaking down subcutaneous and visceral fat in a short period, thereby facilitating fat loss. Typically, there is a proportional relationship between lean muscle mass and body fat content. Resistance exercise, an anaerobic activity, can increase the cross-sectional area of type I and II muscle fibers and lean muscle mass, thereby reducing body fat content [34]. Li et al.'s study also found that resistance training with elastic bands combined with moderate-intensity aerobic exercise yields the best results [35]. Aerobic exercise increases peak oxygen consumption and basal metabolic rate, reduces abdominal and visceral fat, and significantly lowers body fat in OSA patients [36, 37]. However, current research on the effects of aerobic exercise in OSA patients remains limited. To date, there are no studies specifically investigating the impact of aerobic exercise alone on OSA, and the only study included in this review that incorporated aerobic exercise did not demonstrate a unique advantage of aerobic training in managing OSA [27]. This suggests that further research is required to elucidate the role of aerobic exercise in OSA treatment. Future studies should explore different aerobic training modalities, intensities, and durations to determine whether aerobic exercise can provide additional benefits beyond resistance training in improving BMD, SMI or other index in OSA patients.

Our study found that exercise did not significantly affect the SMI or CRP in OSA patients, differing from the findings of Liu et al. [18]. This discrepancy may be due to the short intervention periods in the included studies, all of which were 12 weeks long. Since skeletal muscle adaptation typically requires a longer period, a 12-week intervention may not be sufficient to induce significant changes in SMI and CRP levels. Future research should consider extending the intervention duration to validate the long-term effects of exercise. The excessive inflammatory factors and chronic inflammatory environment in OSA patients further reduce muscle mass and strength, increasing the difficulty of exercise intervention. Longer intervention durations, higher intensity, and frequency may be required to significantly improve skeletal muscle mass and serum inflammatory levels in OSA patients. Additionally, nutritional support also shows beneficial effects on OSA patients [38]. Liao et al. [39]suggested that resistance training combined with protein supplementation is more effective in preventing muscle

mass and strength loss in elderly obese patients. Future research should explore the combined effects of resistance exercise and nutritional support on OSA patients.

Gait speed is considered representative of lower limb muscle function [2].Our study's findings on gait speed are consistent with those of Yang et al. [19], possibly due to the limited number of related studies included (only two), which might lead to false-negative results. The small sample size and lack of comprehensive research on OSA, a relatively newly recognized medical condition, make it difficult to reduce heterogeneity using methods such as subgroup analysis. Given the scarcity of studies on OSA, these limitations are expected. Expanding research efforts and incorporating more studies focused on gait speed assessment in OSA patients could facilitate more accurate evaluations and ultimately enhance patient outcomes. Moreover, studies have shown that [40] gait speed reflects the coordination of limb and joint movements, mainly related to hip extensor strength and trunk control. The interventions by Liao [23]and Lee et al. [15] involved resistance training with elastic bands, primarily designed for muscle contraction and relaxation of various parts of the upper and lower limbs. These exercises were less effective in improving hip extensor strength, possibly affecting the study results. Therefore, clinical healthcare professionals should focus on enhancing hip extensor strength and trunk control when intervening in gait speed for OSA patients to make the intervention more targeted.

Early diagnosis of OSA is crucial for timely and effective intervention. Imaging technologies such as DXA and BIA, along with biochemical markers (e.g., serum creatinine, cystatin C, and inflammatory cytokines), help in the early detection and assessment of bone density, muscle mass, and fat distribution [41, 42]. Early diagnosis facilitates the integration of exercise interventions, nutritional support, and pharmacological treatments, potentially preventing or slowing the progression of OSA [43]. Protein and vitamin D supplementation combined with resistance training can help maintain muscle mass and bone density while reducing fat accumulation [39]. Our study emphasizes the importance of multidisciplinary approaches in managing OSA. By integrating exercise, nutritional support, and early diagnostic strategies, healthcare professionals can better address the multifaceted nature of OSA. Future research should continue to explore the optimal combination of these interventions to improve patient outcomes.

This study systematically evaluated the effects of exercise interventions on OSA patients, providing novel clinical evidence and further elucidating the potential role of exercise in improving bone mineral density (BMD), muscle strength, gait speed, and inflammatory levels. Unlike previous studies, this research not only focuses on the traditional effects of exercise interventions but also incorporates grip strength, gait speed, and muscle function, which have been less systematically reviewed, thereby expanding the scope of OSA intervention research. Additionally, this study emphasizes the importance of individual differences, long-term interventions, and the potential synergy between exercise and nutritional support in managing OSA, offering a more comprehensive perspective for future research.

However, as OSA is still a relatively new medical concept, existing studies exhibit limitations in exercise modality selection, intervention duration, and follow-up periods. Future research should aim to optimize personalized exercise intervention strategies and integrate multidisciplinary treatment approaches, such as nutritional interventions, sleep management, and pharmacological treatments, to enhance the overall health outcomes of OSA patients. Moreover, the long-term adherence and sustained effects of exercise interventions remain underexplored, necessitating further investigations into safe, efficient, and sustainable training protocols. Future studies should also incorporate emerging technologies, such as wearable devices and tele-rehabilitation, to enhance patient engagement and long-term adherence to exercise regimens.

In summary, this study not only provides new evidence supporting exercise interventions for OSA but also lays the foundation for future research optimizations and innovations. High-quality research is needed to bridge the existing knowledge gaps and ultimately improve the health outcomes of OSA patients.

Limitations

Despite providing novel insights into the effects of exercise interventions on OSA, this study has several limitations. First, the number of included studies was relatively small, and some analyses were based on a limited number of trials, potentially reducing the statistical power and generalizability of the findings. Second, most of the included studies had short intervention durations (primarily 12 weeks), which may not be sufficient to induce significant changes in skeletal muscle mass and inflammatory markers. Long-term interventions are required to fully assess the sustained effects of exercise on OSA management. Third, this review primarily included studies focusing on resistance training, while evidence regarding the effects of aerobic exercise or combined training on OSA remains limited. Future studies should explore the comparative effectiveness of different exercise modalities to determine the optimal intervention strategy. Fourth, heterogeneity in study design, diagnostic criteria, and outcome assessments across the included studies posed challenges in drawing consistent conclusions. The lack of standardized OSA diagnostic criteria further complicates

comparisons between studies. Finally, factors such as lifestyle behaviors, sleep disturbances, and dietary intake, which may influence OSA progression, were not comprehensively analyzed in this review. Future research should integrate these factors to provide a more holistic understanding of OSA management through lifestyle modifications.

Conclusions

This study evaluated the effects of exercise interventions on OSA, highlighting their impact on BMD, muscle strength, and functional capacity. Findings suggest that resistance training enhances BMD and grip strength, but its effects on SMI and CRP remain inconclusive, likely due to short intervention durations and study limitations.

As OSA is a newly recognized condition, current research is limited by small sample sizes, heterogeneity, and lack of long-term follow-up. Future studies should explore optimal exercise modalities, integrate multimodal interventions (aerobic training, nutrition, pharmacology), and leverage wearable technologies to enhance adherence and effectiveness. This study underscores the need for long-term, multidisciplinary approaches to improve OSA patient outcomes and guide future research.

Abbreviations

BMD	Bone mineral density
OSA	Osteosarcopenic Adiposity
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomized controlled trials
SMI	Skeletal muscle index
BF	Body fat
CRP	C-reactive protein
HGS	Hand grip strength
GS	Gait speed
MD	Mean difference
SMD	Standardized mean difference
CI	Confidence intervals

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12891-025-08581-4.

Supplementary Material 1

Supplementary Material 2

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Not applicable.

Author contributions

W.Z. and L.C. wrote the main manuscript text and prepared Figs. 1, 2, 3, 4, 5, 6 and 7. J.L. T.X. and Z.S. reviewed the manuscript. T.X. and Z.S. approved the final version of manuscript and provide funding.

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Data availability

This study is a systematic review and a meta-analysis. All the data sourced from the articles listed in the tables within the manuscript.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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