

Review

# How Exercise and Dietary Intervention Affect the Outcome of Osteosarcopenic Obesity Syndrome?

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Received: 30 April 2018; Accepted: 25 May 2018; Published: 28 May 2018



**Abstract:** Osteosarcopenic obesity (OSO) is described as the simultaneous presence of osteopenia/osteoporosis, sarcopenia, and increased adiposity. Over time, older adults with OSO syndrome might be at greater risk for loss of physical function and bone fractures. Furthermore, a sedentary lifestyle, inadequate nutrition, pharmaceutical drugs, and chronic conditions encompass the multifactorial nature of OSO syndrome. Physical activity and a healthy diet play a crucial role in management and treatment of OSO syndrome. Research has shown that even low-intensity physical activity or daily habitual activity can maintain bone mineral density, muscle strength, and improve muscle quality, and reduce adiposity. However, older adults with high risk of fall and injuries require tailored exercise intensity. Also, balanced daily intake of vitamin D, calcium, and protein is important in prevention and treatment of OSO syndrome in postmenopausal women. Effective measurement of bone mass, muscle mass, and strength is required when detecting OSO syndrome and to evaluate the balance, strength and endurance of elder individuals and severity of the condition.

**Keywords:** osteosarcopenic obesity; exercise; diet; aging; fall

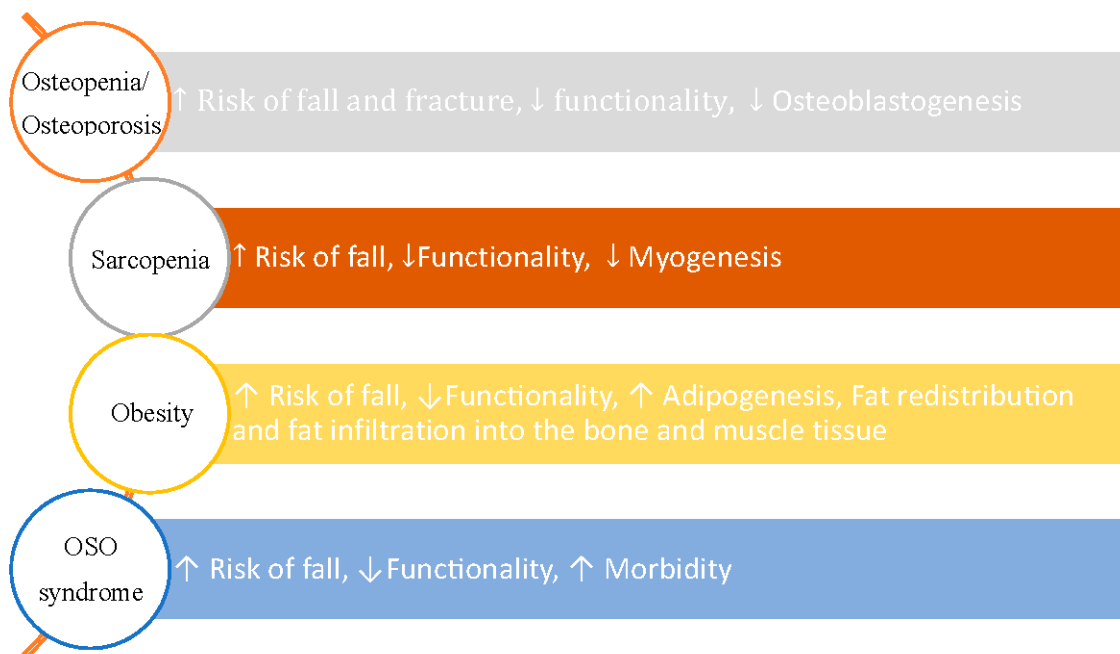
## 1. Introduction

Osteosarcopenic obesity (OSO) syndrome is accompanied by changes in body composition, including deterioration of bone mass (manifested as osteopenia/osteoporosis), decline in muscle strength and muscle mass (sarcopenia), and increased presence of adipose tissue or fat redistribution in the abdominal region and its infiltration into bone and muscle (Figure 1) [1,2]. Although OSO syndrome has been previously diagnosed among younger individuals [3], the older adults (specifically, postmenopausal women over the age of 65) and patients with chronic conditions have a particular higher risk for OSO syndrome [2,4,5]. Specifically, in older women, there is an age-related loss of bone, lean mass and muscle strength, and gain in adiposity [4]. It is important to take into consideration that young obese individuals with decreased lean body mass have a higher chance of developing OSO syndrome and frailty earlier than healthy lean individuals [3]. Refer to Table 1 for risk factors involved in etiology of OSO syndrome.

Given the severe consequences of OSO syndrome on general health status and quality of life in the elderly population, early prevention measures are required to evaluate its progression and halt its advancement. Therefore, the purpose of this document is to give an overview of the literature regarding the precise pathophysiologic processes, diagnostic criteria, and effective physical measurements to evaluate the severity of OSO syndrome. The current review will look into the management of OSO syndrome through diet and exercise, as well as its relationship with fall risk.

Aging is not only associated with increased adiposity, but also with fat redistribution and infiltration into the bone and muscle tissues [1,4]. Skeletal muscle, bone, and fat masses are all derived from shared mesenchymal stem cells [6]. When the body is affected by systemic low-grade inflammation, it will result in exacerbated adipogenesis and suppressed osteoblastogenesis and

myogenesis in adults [7–10]. Visceral adiposity has a negative impact on bone and muscle health by promoting low-grade chronic inflammation [11,12]. Adipose tissue is involved in secreting pro-inflammatory cytokines, such as tumor necrosis factor-alpha, interleukin 1 and 6, and C-reactive protein [7,13–16]. Therefore, excess adiposity, which itself is associated with increased secretion of inflammatory mediators, may decrease osteogenesis and myogenesis [7,9].



**Figure 1.** Osteosarcopenic obesity consequences. ↑: increased; ↓: decreased

**Table 1.** Factors associated with development of osteosarcopenic obesity syndrome.

Intrinsic Factors [4,5,17,18]	Extrinsic Factors [2,18–21]
Age	Medication
Gender	Diet
Chronic diseases	Exercise
Muscular strength	
Skeletal muscle mass	
Percentage of body fat	
Bone mineral density	

## 2. Diagnostic Criteria

The criteria for the diagnosis of OSO syndrome is based on the combination of diagnostic criteria reflecting bone, muscle, and fat impairment. Ilich et al., [2] used a combination of several criteria for diagnosing OSO syndrome, which include (a) *T*-scores  $\leq -1.0$  standard deviation (SD) of the lumbar spine (L<sub>1</sub>–L<sub>4</sub>) and/or femoral neck [22], (b) the 20th percentile of the residual distribution for appendicular lean mass (ALM) with cut-off point  $\leq -1.43$  for diagnosing sarcopenia [23], and (c) body fat  $\geq 32\%$  dual-energy X-ray absorptiometry (DXA) [23]. The current diagnostic criteria are based on several recent studies [24–28]. Refer to Table 2 for detailed diagnostic criteria of OSO syndrome based on *T*-score and body composition.

**Table 2.** Diagnostic criteria of OSO syndrome based on bone density and body composition.

Condition	T-Score $\leq -1.0$ SD at the Femoral Neck, or Lumbar Spine	<20th Percentile of ALM for Women	Fat Mass $\geq 32\%$ for Women
Osteopenia/osteoporosis	Yes	No	No
Sarcopenia	No	Yes	No
Obesity	No	No	Yes
OSO	Yes	Yes	Yes

ALM: appendicular lean mass; OSO: osteosarcopenic obesity; SD: standard deviation; ALM =  $-17.4 + 18.3 \times \text{height (m)} + 0.16 \times \text{body fat (kg)}$ .

### 3. Diet and Exercise in OSO Population

The elderly population face a challenge in following a healthy diet, due to diminished appetite, changes in taste and smell, poor dentition, and chronic diseases [29]. Moreover, absorption of many nutrients decreases with aging [4,29]. Diet plays a vital role in maintaining bone health and body composition. A recent study showed women with OSO syndrome have a lower daily intake of vitamin D and calcium (diet and supplements) in comparison to those who were osteopenic obese, only osteopenic, sarcopenic, or obese [25], suggesting potential health benefits of maintaining an adequate intake of vitamin D and calcium. Moreover, low serum vitamin D concentrations have been observed in the population with OSO syndrome [30]. Insufficient protein intake can increase muscle wasting in aging adults [31,32]. Based on a recent recommendation for OSO population, high protein diet (1.4–1.6 g/kg/day) is required to maintain muscle quality and muscle mass [18]. Also, a recent study on postmenopausal women showed a significant positive correlation between the total amount of protein intake, and right femoral neck bone mineral density and T-score [25]. However, it is important to balance high protein diets with calcium and vitamin D, as an extensive high protein diet is associated with increased urinary calcium excretion, which may affect bone mineral density [33,34]. Aside from energy imbalance and lower protein intakes, it has been revealed that high levels of simple carbohydrates and low omega-3 polyunsaturated fatty acids may also contribute to OSO syndrome [18,20]. It is also worth noting that the elderly, including frail women living in an assisted living facility or living alone, tend to rely on someone else for food preparation. This lifestyle may result in reduced protein and total energy intake [20,35]. Finally, several studies have shown that the nutrient composition of the Western diet may not promote healthy aging, and may contribute to the development of OSO syndrome [7,19,20,36,37].

Considerable evidence exists regarding the fact that low physical activity combined with inadequate nutrient intake may further aggravate the decline in muscle protein synthesis and contribute to muscle loss in older adults [19,20,38]. Resistance training may reduce fat mass [39] while improving bone mineral density [40,41]. A recent study by Cunha et al., showed that 12 week resistance training is effective in improving the risk factors of OSO syndrome among older women ( $\geq 60$  years old) [5]. In another study with a longer duration of intervention (12 month exercise program combining aerobic step, flexibility/postural control training, and resistance training) on postmenopausal Caucasian women revealed an increase in skeletal muscle mass [42]. It is clear that resistance and aerobic exercises require at least some level of functionality in the elderly population. However, aging is often associated with comorbidities, in addition to the physical changes to bone, and body composition [4,17]. There are many barriers to exercise for frail populations due to their physical limitations [43]. Therefore, conventional resistance and aerobic exercises may not be the best viable option for OSO population as the first line of treatment. Unconventional activities (tai chi, yoga, Pilates, etc.) might be more suitable for older population [18,21]. The results of several studies on the effects of tai chi in sedentary obese women suggest that it could result in fat mass loss [44,45]. Moreover, tai chi may help in maintaining bone mineral density and improving body composition [21]. Similarly, a 6 month study with yoga exercise intervention showed a significant improvement in balance (timed one-legged stand and forward flexibility) in the elderly population (65–85 years) [46]. In addition, an 8 week Pilates exercise program on postmenopausal women (>60 years old) revealed a significant decrease in percent body

fat and increase in lean body mass [47]. The effect of tai chi, yoga, and Pilates on OSO population has not been widely studied. Regardless, there is enough evidence to suggest that these activities have the potential to be used for treatment or prevention of OSO [21,48]. Nevertheless, more research is needed in this area.

On a different note, in the past few years, research has looked into the effects of whole body vibration on bone mineral density and body composition. Whole body vibration seems to be an alternative treatment option for older population who are not able to perform conventional exercise due to chronic conditions, such as chronic obstructive pulmonary disease [49], chronic heart failure [50], etc. Three whole body vibration sessions per week for 12 weeks may increase leg power and bone formation in older individuals [51]. Moreover, the results of several meta-analyses suggest that whole body vibration may improve bone mineral density in postmenopausal women and reduce the risk of fall and fracture [52,53]. Therefore, whole body vibration seems to be a promising intervention for treatment of OSO syndrome.

Prescribing exercise (even in the form of low intensity or habitual activity) is needed to maintain or improve bone mineral density [21,54–57], maintain muscle strength and muscle quality, reduce adiposity, and improve balance [21,48,58]. A significant negative correlation has been reported between total hours of unconventional physical activity/week and waist circumference in postmenopausal women. In addition, total hours of habitual physical activity (gardening, housework, etc.) and the average number of steps climbed were negatively correlated with total body fat percentage, body mass index (BMI), and hip and abdominal circumference [25]. Thus, even low-intensity exercise or habitual activities may maintain the bone mineral density and muscle mass, and reduce the risk of obesity for OSO syndrome. A recent recommendation for OSO population has emphasized the importance of comprehensive exercise program matched with the balance and strength of each individual [18,21]. The goal is to improve functionality, quality of life, and most importantly, prevent falls.

#### 4. Physical and Functional Performance Tests to Evaluate OSO Syndrome

Decreased physical function by aging can indicate an increased risk for morbidity and long-term disability [38,59]. Specific measurements are required to evaluate balance, strength, and endurance in the older population. Handgrip strength, knee isometric strength, sit-to-stand test (to measure lower body strength, balance, and range of motion), 4 m timed normal and brisk walk tests (to measure locomotion), 2 min walk test (to measure endurance), and timed one leg stance (to measure balance) are all parts of the recommended measurements for OSO syndrome [2,60–62]. These tests are valuable measurements to assess fall risk and evaluate changes or deficits in body composition preceding OSO syndrome.

Handgrip strength has been used as a powerful predictor of functional abilities in older adults [63,64]. Several studies reported that loss of handgrip strength is associated with lower bone mineral density [65,66]. Moreover, poorer handgrip strength is associated with increased risk of falls [63,64]. Women identified with OSO syndrome have a poorer handgrip score in comparison to only obese population [27]. Furthermore, lower handgrip strength is reported to be associated with malnutrition, which exacerbates the loss of bone and lean mass [67,68].

Some researchers view muscle quality as a more reliable measurement of functional status than strength alone [69]. Muscle quality can be measured as maximal force production per unit of muscle mass [69]. A one-repetition max from the knee extension divided by leg lean mass (kg) has been used as a measurement of muscle quality [70]. Results of a recent study revealed that older adults with OSO syndrome had significantly lower knee extension scores than the individuals identified by only obese or osteopenic obese, which may further reinforce the association between the combined impact of bone loss, sarcopenia, and obesity, with the overall loss of fitness [24]. Although aging, myosteatosis, and chronic diseases affect the muscle quality, strength training can improve the condition [4,69,71].

Also, the sit-to-stand test has been used to measure balance and range of motion in the lower extremities [72–74]. Based on Center for Disease Control and Prevention (CDC) recommendations

a cut-off point of ten sit-to-stands in 30 s was used to determine the risk of fall [75]. Women ages 75–79 years who performed less than ten sit-to-stands were classified as “below average strength” for lower body evaluation. Poorer sit-to-stand test scores have been associated with slower walking pace [66,76]. Drey et al. [77] found a statistically significant decline in sit-to-stand score in osteosarcopenic population in comparison to only osteopenic or only obese individuals. The sit-to-stand test has also been used to evaluate OSO population; lower sit-to-stand scores in older adults with OSO were reported in comparison to osteopenic obese, only osteopenic, and only sarcopenic [24].

Walking speed is another predictor of functional status and frailty in older populations [78–80]. Higher fat accumulation in the lower extremities is correlated with slower walking speeds [66]. In addition, higher femoral neck bone mineral density is associated with faster walking speed [65]. In a study conducted on postmenopausal women (age of  $61.6 \pm 7.4$  years), the OSO population presented the slowest normal and brisk walking speed in comparison to sarcopenic obese and osteopenic obese population [38].

In addition, the one-leg stance is a reliable assessment of balance in older adults [65,66]. The scores for this test decrease with age [2,81]. Balance impairment is associated with reduced gait speed [82]. A study conducted by Shin et al., [66] revealed a 21% decrease in ability to stand with each leg (30 s) as total body and gynoid region fat increase by 1% in the older population.

Overall, the physical and functional test results of several studies reinforce the concept that older women with OSO syndrome are more prone to greater functional decline than those who have each aspect of this syndrome separately. A significant weakening in the OSO population in regard to sit-to-stand and knee extension scores and slower walking speed indicate a greater loss of strength in the quadriceps muscles.

## 5. Fall Prevention in OSO Syndrome

The increased risk of falls and hip fractures is probably of the greatest concern for the OSO population [38,48]. Fall-related injuries are one of the major causes of mortality and disability among the older individuals [83]. The intensity of exercise should never surpass the physical ability of older adults and it should not increase the risk of fall, as according to CDC, falls are leading cause of injury and death in older American adults [84], and the second leading cause of accidental or unintentional injury deaths globally [85]. In addition, each year, an estimated 646,000 individuals die from falls worldwide [85]. One out of every five falls causes serious injury, such as head injury or bone fracture [84]. Moreover, one out of three fall-related deaths were attributable to low bone mineral density [83]. Bone fractures, especially in the elderly, can lead to long-term disability, institutionalization, and even mortality [86,87].

A number of risk factors related to falls have been identified. Being female, independent living, previous history of falls, physical disability, use of a walking aid, fear of falling, Parkinson’s disease, vertigo, and visual/sensory deficits were associated with higher risk of fall in community-dwelling older adults [88]. Moreover, a study on Mexican older adults (>60 years old) has shown obesity, depressive symptoms, and urinary incontinence were significant factors associated with falls [89]. Fall risk factors can be classified as extrinsic factors which reflect medication and home hazards, or intrinsic factors which include overall functional status [48]. The previous history of falls, muscle strength, postural instability, and fear of falling are independent predictors of fall in the older population [90–92]. It has also been reported that obesity, concurrent with low muscle strength, is associated with higher fall risk score among older adults [93]. Furthermore, persistent vitamin D deficiency in the elderly is associated with increased risk of falls and fractures [94]. The association of osteoporosis and sarcopenia with fall risk factors has been reported previously [95].

As OSO syndrome is a fundamental health challenge, a multifactorial approach should be considered to reduce the risk of fall and fracture. OSO individuals may benefit from comprehensive physical activity program, nutritional intervention, and pharmacological treatment for preventing

fall [18,48]. Since extensive diet-induced weight loss in older obese adults can lead to further impaired physical function by accelerating bone loss [96] and fat-free mass loss [97], a proper nutritional intake is principal in preventing fall and fracture. It is of paramount importance for the management of osteoporosis and the prevention of falls to achieve an adequate intake of calcium and vitamin D and also engage with healthy lifestyle habits. Active lifestyle and avoidance of tobacco, alcohol, and drug consumption, such as long-term use of corticosteroids (unless there is an indication) all have an important role in reducing the risk of fall and fracture [18,48,89]. It has also been described that vitamin D supplement may improve muscle strength, and reduce the risk of falls and mortality in postmenopausal women [98,99]. Moreover, active vitamin D treatment may prevent and treat both osteoporosis and sarcopenia [100].

Although physical activity alone has been described to have beneficial effects on reducing the risk of fall [101], combining exercise with other strategies, including education, has been shown to be even more effective [102]. The long-term balance training program and tai chi, as an alternative, have shown to be effective in improving functional balance and reducing the risk of fall in elderly women [103,104]. Furthermore, it has been described that whole body vibration intervention reduces fall risk factors [105].

Also, a dramatic increase in the number of falls and fractures at the beginning of menopause has been linked to the decrease in estradiol serum concentrations [106]. Initiation of hormone replacement therapy soon after menopause has shown positive effects on balance, leading to a decrease in the risk of falls [107,108]. However, the results are still controversial [106], therefore, more clinical trials are needed to approve the use of hormone replacement therapy to improve body composition and reduce the risk of fall.

As has been previously discussed in the literature, increased body fat promotes damage to bone and muscle tissues simultaneously, weakening the bone structure and changing the muscle quality [1,4,17,109,110]. Compared to those who are only obese or sarcopenic, older adults with sarcopenic obesity have less physical strength and functional capacity, and are at greater risk of falls and consequently, long-term disability [111–113]. Finally, considering the complex nature of OSO syndrome, a multifactorial approach is recommended to reduce the risk of fall among elderly individuals.

## 6. Discussion and Summary

Aging causes numerous physiological changes in body composition, including a decrease in both muscle and bone mass, and a gradual increase in fat mass [4,17,114]. An ultimate consequence is the development of OSO syndrome [17]. One of the main risks related to changes in body composition is the higher chance of fall and fracture. Physical activity and a healthy diet may slow the progression of OSO syndrome and reduce the risk of fall. It is worth considering that low-intensity exercises, such as tai chi, yoga, Pilates, etc., or whole body vibration, can be used as alternatives for conventional exercise (aerobic and resistance training) in prevention and treatment of OSO syndrome in older adults. It is recommended that practitioners consider the individuals' chronic conditions and limitations, so that exercise could be altered according to the level of fitness and strength. Finally, OSO population should be monitored for daily levels of calcium, vitamin D, and protein intake, to ensure maintaining an optimal diet.

**Conflicts of Interest:** The author declares no conflict of interest.

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