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Review

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

Pegah JafariNasabian [1,*]

[1] [1]Department of Nutrition, Food and Exercise Sciences, Florida State University, Tallahassee, Florida; pjafarinasabian@fsu.edu

* Correspondence: pjafarinasabian@fsu.edu; Tel.: +1-850-296-6636

Abstract: Osteosarcopenic obesity (OSO) is described by 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 [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]. 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].

Given the severe consequences of OSO syndrome on general health status and quality of life 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 [1,5]. 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-

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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].

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 ≤ −1.0 SD of the lumbar spine (L_1-L_4) and/or femoral neck [17], b) The 20th percentile of the residual distribution for appendicular lean mass (ALM) with cut-off point ≤ -1.43 for diagnosing sarcopenia [18] and c) body fat ≥32% DXA [18]. The current diagnostic criteria are based on several recent studies [19–23]. Refer to **Table 1** for detailed diagnostic criteria of OSO syndrome based on *T*-score and body composition.

Table 1. Diagnostic criteria of OSO syndrome based on bone density and body composition.

Condition	*T*-score ≤ −1.0 SD at the femoral neck, or lumbar spine	<20th percentile of ALM for women	Fat mass ≥ 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

ALM = −17.4 + 18.3 × height (m) + 0.16 × body fat (kg)

3. Diet and Exercise in OSO Population

Elderly population face a challenge to follow a healthy diet due to diminished appetite, changes in taste and smell, poor dentition and chronic diseases [24]. Moreover, absorption of many nutrients decreases with aging [4,24]. 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 [20], suggesting potential health benefits of maintaining an adequate intake of vitamin D and calcium. Moreover, low serum vitamin D concentration has been observed in population with the OSO syndrome [25]. Insufficient protein intake can increase muscle wasting in aging adults [26,27]. Based on a recent recommendation for OSO population, high protein diet (1.4-1.6g/kg/day) is required to maintain the muscle quality and muscle mass [28]. 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 [20]. However, it is important to balance high protein diet with calcium and vitamin D, as extensive high protein diet is associated with increased urinary calcium excretion, which may affect bone mineral density [29,30]. Aside from energy imbalance and lower protein intakes, it has been revealed that high level of simple carbohydrates and low omega-3 polyunsaturated fatty acids may also contribute to OSO syndrome [28,31]. It is also worth noting that elderly including frail women living in an assisted living facility or living alone tend to rely on someone else for food preparation. This life-style may result in reduced protein and total energy intake [32,31].

Considerable evidence exists regarding the fact that low physical activity combined with inadequate nutrients intake may further aggravate the decline in muscle protein synthesis and contribute to muscle loss in older adults [31,33,34]. Resistance training may reduce fat mass [35] while improving bone mineral density [36,37]. A recent study by Cunha *et al.*, showed that 12-week resistance training is effective to improve the risk factors of OSO syndrome among older women (≥ 60 years old) [38]. In another study with a longer duration of intervention (12-month exercise program combining aerobic step, flexibility/postural control training and resistance training) on

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postmenopausal Caucasian women revealed an increase in skeletal muscle mass [39]. 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 [4,40]. There are many barriers to exercise for frail population due to their physical limitations [41]. 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 [28,42]. The results of several studies on the effects of Tai Chi in sedentary obese women suggest that it could result in fat mass loss [43,44]. Moreover, Tai Chi may help in maintaining bone mineral density and improving body composition [42]. 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) [45]. 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 [46]. 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 [42,47]. 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 [48], chronic heart failure [49], etc. Three whole body vibration sessions per week for 12 weeks may increase leg power and bone formation in older individuals [50]. 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 [51,52]. 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 [42,53–56], maintain muscle strength and muscle quality, reduce adiposity and improve balance [42,57,47]. 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), hip and abdominal circumference [20]. 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 [28,42]. The goal is to improve functionality, quality of life, and most importantly preventing 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 [34,58]. 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-meter timed normal and brisk walk tests (to measure locomotion), 2-minute walk test (to measure endurance), and timed one leg stance (to measure balance) are all parts of the recommended measurements for OSO syndrome [2,59–61]. 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 [62,63]. Several studies reported that loss of handgrip strength is associated with lower bone mineral density [64,65]. Moreover, poorer handgrip strength is associated with increased risk of falls [62,63]. Women identified with OSO syndrome have a poorer handgrip score in comparison to only obese

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population [22]. Furthermore, lower handgrip strength is reported to be associated with malnutrition, which exacerbates the loss of bone and lean mass [66,67].

Some researchers view muscle quality as a more reliable measurement of functional status than strength alone [68]. Muscle quality can be measured as maximal force production per unit of muscle mass [68]. A one-repetition max from the knee extension divided by leg lean mass (kg) has been used as a measurement of muscle quality [69]. 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 [19]. Although aging, myosteatosis and chronic diseases affect the muscle quality, strength training can improve the condition [4,68,70].

Also, the sit-to-stand test has been used to measure balance and range of motion in the lower extremities [71–73]. Based on Center for Disease Control and Prevention (CDC) recommendation cut-off point of ten sit-to-stands in 30 seconds was used to determine the risk of fall [74]. 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 [65,75]. Drey *et al*., [76] 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 [19].

Walking speed is another predictor of functional status and frailty in older populations [77–79]. Higher fat accumulation in the lower extremities is correlated with slower walking speeds [65]. In addition, higher femoral neck bone mineral density is associated with faster walking speed [64]. In a study conducted on postmenopausal women (age of 61.6 ± 7.4 years), the OSO population presented the slowest normal and brisk walking speed in comparison to sarcopenic obese and osteopenic obese population [34].

In addition, the one-leg stance is a reliable assessment of balance in older adults [64,65]. The scores for this test decrease with age [2,80]. Balance impairment is associated with reduced gait speed [81]. A study conducted by Shin *et al*., [65] revealed a 21% decrease in ability to stand with each leg (30 seconds) 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 indicates 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 [34,47]. Fall-related injuries are one of the major causes of mortality and disability among the older individuals [82]. The intensity of exercise should never surpass the physical ability of older adult and it should not increase the risk of fall, as according to CDC falls are leading cause of injury and death in American older adults [83] and the second leading cause of accidental or unintentional injury deaths globally [84]. In addition, each year an estimated 646,000 individuals die from falls worldwide [84]. One out of every five falls causes serious injury such as head injury or bone fracture [83]. Moreover, one out of three fall-related deaths were attributable to low bone mineral density [82]. Bone fractures, especially in the elderly, can lead to long-term disability, institutionalization and even mortality [85,86].

A number of risk factors related to falls have been identified. Being a 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 [87]. Moreover, a study on Mexican older adults (>60 years old) has shown obesity, depressive symptoms and urinary incontinence were significant factors associated with falls [88]. Fall risk factors can be classified as extrinsic factors which reflect medication and home hazards or

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intrinsic factors which include overall functional status [47]. The previous history of falls, muscle strength, postural instability and fear of falling are independent predictors of fall in the older population [89–91]. It has also been reported that obesity concurrent with low muscle strength is associated with higher fall risk score among older adults [92]. Furthermore, persistent vitamin D deficiency in the elderly is associated with increased risk of falls and fractures [93]. The association of osteoporosis and sarcopenia with fall risk factors has been reported previously [94].

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 [28,47]. Since extensive diet-induced weight loss in older obese adults can lead to further impaired physical function by accelerating bone loss [97] and fat-free mass loss [98], 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 life-style habits. Active life-style 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 [28,47,88]. It has also been described that vitamin D supplement may improve muscle strength, and reduce the risk of falls and mortality in postmenopausal women [99,100]. Moreover, active vitamin D treatment may prevent and treat both osteoporosis and sarcopenia [101].

Although physical activity alone has been described to have beneficial effects on reducing the risk of fall [102], combining exercise with other strategies including education has been shown to be even more effective [103]. 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 [104,105]. Furthermore, it has been described that a whole body vibration intervention reduces fall risk factors [106].

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 [107]. Initiation of hormone replacement therapy soon after the menopause, has shown positive effects on balance, leading to a decrease in the risk of falls [108,109]. However, the results are still controversial [107], 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 it 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 [1,4,40,110,111]. 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 [95,112,113]. 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 [4,40,114]. An ultimate consequence is the development of OSO syndrome [40]. 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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Peer-reviewed version available at J. Funct. Morphol. Kinesiol. 2018, 3, 31; doi:10.3390/jfmk3020031

References

1. Ilich, Kelly OJ, Inglis JE, Panton LB, Duque G, Ormsbee MJ. Interrelationship among muscle, fat, and bone: connecting the dots on cellular, hormonal, and whole body levels. Ageing Res. Rev. [Internet]. 2014 [cited 2015 May 27]; 15:51–60. doi:10.1016/j.arr.2014.02.007.
2. Ilich JZ, Kelly OJ, Inglis JE. Osteosarcopenic obesity syndrome: What is it and how can it be identified and diagnosed? Curr. Gerontol. Geriatr. Res. [Internet]. 2016 [cited 2016 Nov 22]; 2016:1–7. doi:10.1155/2016/7325973.
3. Stefanaki C, Peppa M, Boschiero D, Chrousos GP. Healthy overweight/obese youth: early osteosarcopenic obesity features. Eur. J. Clin. Invest. [Internet]. 2016 [cited 2016 Nov 26]; 46(9):767–778. doi:10.1111/eci.12659.
4. JafariNasabian P, Inglis JE, Reilly W, Kelly OJ, Ilich JZ. Aging human body: changes in bone, muscle and body fat with consequent changes in nutrient intake. J. Endocrinol. [Internet]. 2017 [cited 2017 May 4]; :JOE-16-0603. doi:10.1530/JOE-16-0603.
5. JafariNasabian P, Inglis JE, Reilly W, Kelly OJ, Ilich JZ. The aging body: Changes in body composition on tissue and organism levels and nutritional status. J. Endocrinol. (Under Rev.
6. Hao J, Zhang Y, Jing D, Shen Y, Tang G, Huang S, et al. Mechanobiology of mesenchymal stem cells: Perspective into mechanical induction of MSC fate. Acta Biomater. [Internet]. 2015 [cited 2018 Apr 29]; 20:1–9. doi:10.1016/j.actbio.2015.04.008.
7. Ilich JZ, Kelly OJ, Kim Y, Spicer MT. Low-grade chronic inflammation perpetuated by modern diet as a promoter of obesity and osteoporosis. Arh. Hig. Rada Toksikol. 2014; 65(2):139–48. doi:10.2478/10004-1254-65-2014-2541.
8. Deshpande S, James AW, Blough J, Donneys A, Wang SC, Cederna PS, et al. Reconciling the effects of inflammatory cytokines on mesenchymal cell osteogenic differentiation. J. Surg. Res. 2013; 185(1):278–85. doi:10.1016/j.jss.2013.06.063.
9. Gimble JM, Zvonic S, Floyd ZE, Kassem M, Nuttall ME. Playing with bone and fat. J. Cell. Biochem. [Internet]. 2006 [cited 2014 Aug 29]; 98(2):251–66. doi:10.1002/jcb.20777.
10. Rosen CJ, Bouxsein ML. Mechanisms of disease: is osteoporosis the obesity of bone? Nat. Clin. Pract. Rheumatol. [Internet]. 2006 [cited 2014 Aug 29]; 2(1):35–43. doi:10.1038/ncprheum0070.
11. Gilsanz V, Chalfant J, Mo AO, Lee DC, Dorey FJ, Mittelman SD. Reciprocal relations of subcutaneous and visceral fat to bone structure and strength. J. Clin. Endocrinol. Metab. [Internet]. 2009 [cited 2016 Nov 21]; 94(9):3387–3393. doi:10.1210/jc.2008-2422.
12. Zhang P, Peterson M, Su GL, Wang SC. Visceral adiposity is negatively associated with bone density and muscle attenuation. Am. J. Clin. Nutr. [Internet]. 2015 [cited 2016 Nov 21]; 101(2):337–343. doi:10.3945/ajcn.113.081778.
13. Pradhan AD, Manson JE, Rifai N, Buring JE, Ridker PM. C-reactive protein, interleukin 6, and risk of developing type 2 diabetes mellitus. JAMA [Internet]. 2001 [cited 2016 Nov 21]; 286(3):327–34. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11466099.
14. Liu P-Y, Hornbuckle LM, Panton LB, Kim J-S, Ilich JZ. Evidence for the association between abdominal fat and cardiovascular risk factors in overweight and obese African American women. J. Am. Coll. Nutr. [Internet]. 2012 [cited 2016 Jan 22]; 31(2):126–32. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22855918.
15. Anty R, Bekri S, Luciani N, Saint-Paul M-C, Dahman M, Iannelli A, et al. The inflammatory C-reactive protein is increased in both liver and adipose tissue in severely obese patients independently from

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 2 May 2018 doi:10.20944/preprints201805.0014.v1

Peer-reviewed version available at J. Funct. Morphol. Kinesiol. 2018, 3, 31; doi:10.3390/jfmk3020031

metabolic syndrome, type 2 diabetes, and NASH. Am. J. Gastroenterol. [Internet]. 2006 [cited 2017 Feb 13]; 101(8):1824–1833. doi:10.1111/j.1572-0241.2006.00724.x.

16. Saijo Y, Kiyota N, Kawasaki Y, Miyazaki Y, Kashimura J, Fukuda M, et al. Relationship between C-reactive protein and visceral adipose tissue in healthy Japanese subjects. Diabetes, Obes. Metab. [Internet]. 2004 [cited 2017 Feb 13]; 6(4):249–258. doi:10.1111/j.1462-8902.2003.0342.x.
17. Kanis JA, Melton LJ, Christiansen C, Johnston CC, Khaltaev N. The diagnosis of osteoporosis. J. bone Miner. Res. [Internet]. 1994 [cited 2016 Jan 24]; 9(8):1137–41. doi:10.1002/jbmr.5650090802.
18. Obesity Algorithm: Clinical Guidelines for Obesity Treatment [Internet]. Am. Soc. Bariatr. Physicians (ASBP), Obes. Algorithm. 2015 [cited 2017 Jan 26]; Available from: http://obesitymedicine.org/obesity-algorithm/.
19. Inglis JE. Identifying Osteosarcopenic Obesity in a Group of Older Women. 2017;
20. JafariNasabian P. Analyzing Bone, Muscle and Adipose Tissue Biomarkers to Identify Osteosarcopenic Obesity Syndrome in Older Women [Internet]. 2017 [cited 2017 Aug 6]; doi:10257175.
21. Inglis JE, Jafarinasabian P, Hebrock H, Ave M, Goosby K, Beyer E, et al. Older women with osteosarcopenic obesity have lower handgrip strength and knee extension strength than osteopenic or obese-only women. Adv. Nutr. 2017; 8(1):9–9.
22. JafariNasabian P, Inglis JE, Ave MP, Hall KJ, Nieto SE, Kelly OJ, et al. Metabolic profile of osteosarcopenic obesity syndrome: identifying biomarkers for diagnostic criteria. FASEB J. [Internet]. 2017 [cited 2017 Apr 21]; 31(1 Supplement):151.5-151.5. Available from: http://www.fasebj.org/content/31/1_Supplement/151.5.abstract?sid=fa01a742-a6d5-4112-a5c6-f635f2f32df4.
23. Inglis JE, JafariNasabian P, Gilman JC, Kelly OJ, Ilich JZ. Possible nutritional etiology of osteosarcopenic obesity syndrome. FASEB J. [Internet]. 2016; 30:1156.8. Available from: http://www.fasebj.org/content/30/1_Supplement/1156.8.
24. Pray L, Boon C, Ann Miller E, Pillsbury L. Providing healthy and safe foods as we age: Workshop summary. Institude Med. Natl. Acad. [Internet]. 2010 [cited 2016 Oct 16]; Available from: http://www.nap.edu/catalog/12967.html.
25. Kim J, Lee Y, Kye S, Chung Y-S, Lee O. Association of serum vitamin D with osteosarcopenic obesity: Korea National Health and Nutrition Examination Survey 2008-2010. J. Cachexia. Sarcopenia Muscle [Internet]. 2016 [cited 2016 Nov 21]; 8:259–266. doi:10.1002/jcsm.12154.
26. Bales CW, Ritchie CS. Sarcopenia, weight loss, and nutritional frailty in the elderly. Annu. Rev. Nutr. [Internet]. 2002 [cited 2016 Jan 27]; 22:309–23. doi:10.1146/annurev.nutr.22.010402.102715.
27. Morley JE. Anorexia, sarcopenia, and aging. Nutrition. 2001; 17(7–8):660–3.
28. JafariNasabian P, Inglis J, Kelly O, Ilich J. Osteosarcopenic obesity in women: impact, prevalence, and management challenges. Int. J. Womens. Health [Internet]. 2017 [cited 2017 Jan 17]; 9:33–42. doi:10.2147/IJWH.S106107.
29. Heaney RP, Layman DK. Amount and type of protein influences bone health. Am. J. Clin. Nutr. [Internet]. 2008 [cited 2017 Feb 2]; 87(5):1567S–1570S. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18469289.
30. Cuenca-Sánchez M, Navas-Carrillo D, Orenes-Piñero E. Controversies surrounding high-protein diet intake: satiating effect and kidney and bone health. Adv. Nutr. [Internet]. 2015 [cited 2016 Dec 13]; 6(3):260–6. doi:10.3945/an.114.007716.
31. Kelly OJ, Gilman JC, Kim Y, Ilich JZ. Macronutrient intake and distribution in the etiology, prevention

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 2 May 2018 doi:10.20944/preprints201805.0014.v1

Peer-reviewed version available at J. Funct. Morphol. Kinesiol. 2018, 3, 31; doi:10.3390/jfmk3020031

and treatment of osteosarcopenic obesity. Curr. Aging Sci. 2017; 10:83–105.

32. Volpi E, Campbell WW, Dwyer JT, Johnson MA, Jensen GL, Morley JE, et al. Is the optimal level of protein intake for older adults greater than the recommended dietary allowance? J. Gerontol. A. Biol. Sci. Med. Sci. [Internet]. 2013 [cited 2016 Dec 12]; 68(6):677–81. doi:10.1093/gerona/gls229.

33. Kelly OJ, Gilman JC, Kim Y, Ilich JZ. Micronutrient intake in the etiology, prevention and treatment of osteosarcopenic obesity. Curr. Aging Sci. 2016; 9:260–278.

34. Ilich JZ, Inglis JE, Kelly OJ, McGee DL. Osteosarcopenic obesity is associated with reduced handgrip strength, walking abilities, and balance in postmenopausal women. Osteoporos. Int. 2015; 26(11):2587–95. doi:10.1007/s00198-015-3186-y.

35. Donnelly JE, Smith BK. Is exercise effective for weight loss with ad libitum diet? Energy balance, compensation, and gender differences. Exerc. Sport Sci. Rev. [Internet]. 2005 [cited 2018 Apr 29]; 33(4):169–74. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16239833.

36. Marques EA, Mota J, Carvalho J. Exercise effects on bone mineral density in older adults: a meta-analysis of randomized controlled trials. Age (Dordr). [Internet]. 2012 [cited 2018 Apr 29]; 34(6):1493–515. doi:10.1007/s11357-011-9311-8.

37. Turner CH, Robling AG. Exercise as an anabolic stimulus for bone. Curr. Pharm. Des. [Internet]. 2004 [cited 2018 Apr 29]; 10(21):2629–41. Available from: http://www.ncbi.nlm.nih.gov/pubmed/15320750.

38. Cunha PM, Ribeiro AS, Tomeleri CM, Schoenfeld BJ, Silva AM, Souza MF, et al. The effects of resistance training volume on osteosarcopenic obesity in older women. J. Sports Sci. [Internet]. 2018 [cited 2018 Apr 29]; 36(14):1564–1571. doi:10.1080/02640414.2017.1403413.

39. Aragão FR, Abrantes CG, Gabriel RE, Sousa MF, Castelo-Branco C, Moreira MH. Effects of a 12-month multi-component exercise program on the body composition of postmenopausal women. Climacteric [Internet]. 2014 [cited 2018 Apr 29]; 17(2):155–63. doi:10.3109/13697137.2013.819328.

40. Ormsbee MJ, Prado CM, Ilich JZ, Purcell S, Siervo M, Folsom A, et al. Osteosarcopenic obesity: the role of bone, muscle, and fat on health. J. Cachexia. Sarcopenia Muscle. 2014; 5(3):183–92. doi:10.1007/s13539-014-0146-x.

41. Bethancourt HJ, Rosenberg DE, Beatty T, Arterburn DE. Barriers to and facilitators of physical activity program use among older adults. Clin. Med. Res. [Internet]. 2014 [cited 2018 Apr 24]; 12(1–2):10–20. doi:10.3121/cmr.2013.1171.

42. Kelly OJ, Gilman JC. Can unconventional exercise be helpful in the treatment, management and prevention of osteosarcopenic obesity? Curr. Aging Sci. 2016;

43. Dechamps A, Gatta B, Bourdel-Marchasson I, Tabarin A, Roger P. Pilot study of a 10-week multidisciplinary Tai Chi intervention in sedentary obese women. Clin. J. Sport Med. [Internet]. 2009 [cited 2018 Apr 29]; 19(1):49–53. doi:10.1097/JSM.0b013e318193428f.

44. Yu T-Y, Pei Y-C, Lau Y-C, Chen C-K, Hsu H-C, Wong AMK. Comparison of the effects of swimming and Tai Chi Chuan on body fat composition in elderly people. Chang Gung Med. J. [Internet]. [cited 2018 Apr 29]; 30(2):128–34. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17596001.

45. Oken BS, Zajdel D, Kishiyama S, Flegal K, Dehen C, Haas M, et al. Randomized, controlled, six-month trial of yoga in healthy seniors: effects on cognition and quality of life. Altern. Ther. Health Med. [Internet]. [cited 2018 Apr 29]; 12(1):40–7. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16454146.

46. Fourie M, Gildenhuys G, Shaw I, Shaw B, Toriola A, Goon D. Effects of a Mat Pilates Programme on Body Composition in Elderly Women. West Indian Med. J. [Internet]. 2013 [cited 2018 Apr 29]; 62(6).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 2 May 2018 doi:10.20944/preprints201805.0014.v1

Peer-reviewed version available at J. Funct. Morphol. Kinesiol. 2018, 3, 31; doi:10.3390/jfmk3020031

doi:10.7727/wimj.2012.107.

47. Hita-Contreras F, Martínez-Amat A, Cruz-Díaz D, Pérez-López FR. Osteosarcopenic obesity and fall prevention strategies. Maturitas [Internet]. 2015 [cited 2016 Jan 20]; 80(2):126–32. doi:10.1016/j.maturitas.2014.11.009.

48. Gloeckl R, Heinzelmann I, Baeuerle S, Damm E, Schwedhelm A-L, Diril M, et al. Effects of whole body vibration in patients with chronic obstructive pulmonary disease – A randomized controlled trial. Respir. Med. [Internet]. 2012 [cited 2018 Apr 29]; 106(1):75–83. doi:10.1016/J.RMED.2011.10.021.

49. Lai C-L, Chen H-Y, Tseng S-Y, Liao W-C, Liu B-T, Lee M-C, et al. Effect of whole-body vibration for 3 months on arterial stiffness in the middle-aged and elderly. Clin. Interv. Aging [Internet]. 2014 [cited 2018 Apr 29]; 9:821–8. doi:10.2147/CIA.S60029.

50. Corrie H, Brooke-Wavell K, Mansfield NJ, Cowley A, Morris R, Masud T. Effects of vertical and side-alternating vibration training on fall risk factors and bone turnover in older people at risk of falls. Age Ageing [Internet]. 2015 [cited 2018 Apr 27]; 44(1):115–122. doi:10.1093/ageing/afu136.

51. Ma C, Liu A, Sun M, Zhu H, Wu H. Effect of whole-body vibration on reduction of bone loss and fall prevention in postmenopausal women: a meta-analysis and systematic review. J. Orthop. Surg. Res. [Internet]. 2016 [cited 2018 Apr 27]; 11(1):24. doi:10.1186/s13018-016-0357-2.

52. Slatkovska L, Alibhai SMH, Beyene J, Cheung AM. Effect of whole-body vibration on BMD: a systematic review and meta-analysis. Osteoporos. Int. [Internet]. 2010 [cited 2018 Apr 27]; 21(12):1969–1980. doi:10.1007/s00198-010-1228-z.

53. Hughes VA, Frontera WR, Wood M, Evans WJ, Dallal GE, Roubenoff R, et al. Longitudinal muscle strength changes in older adults: influence of muscle mass, physical activity, and health. J. Gerontol. A. Biol. Sci. Med. Sci. 2001; 56(5):B209-17.

54. Ilich JZ, Brownbill RA. Habitual and low-impact activities are associated with better bone outcomes and lower body fat in older women. Calcif. Tissue Int. 2008; 83(4):260–71. doi:10.1007/s00223-008-9171-0.

55. Wolff I, van Croonenborg JJ, Kemper HC, Kostense PJ, Twisk JW. The effect of exercise training programs on bone mass: a meta-analysis of published controlled trials in pre- and postmenopausal women. Osteoporos. Int. 1999; 9(1):1–12. doi:10.1007/s001980050109.

56. Lanyon LE. Functional strain as a determinant for bone remodeling. Calcif. Tissue Int. 1984; 36 Suppl 1:S56-61.

57. Deckx N, Wens I, Nuyts AH, Hens N, De Winter BY, Koppen G, et al. 12 weeks of combined endurance and resistance training reduces innate markers of inflammation in a randomized controlled clinical trial in patients with multiple sclerosis. Mediators Inflamm. 2016; 2016:6789276. doi:10.1155/2016/6789276.

58. Morley JE, Anker SD, von Haehling S. Prevalence, incidence, and clinical impact of sarcopenia: facts, numbers, and epidemiology-update 2014. J. Cachexia. Sarcopenia Muscle [Internet]. 2014 [cited 2016 Aug 22]; 5(4):253–9. doi:10.1007/s13539-014-0161-y.

59. Fong SSM, Choi AWM, Luk WS, Yam TTT, Leung JCY, Chung JWY. Bone Mineral Density, Balance Performance, Balance Self-Efficacy, and Falls in Breast Cancer Survivors With and Without Qigong Training: An Observational Study. Integr. Cancer Ther. [Internet]. 2018 [cited 2018 Apr 25]; 17(1):124–130. doi:10.1177/1534735416686687.

60. Reuben DB, Magasi S, McCreath HE, Bohannon RW, Wang Y-C, Bubela DJ, et al. Motor assessment using the NIH Toolbox. Neurology [Internet]. 2013 [cited 2016 Feb 10]; 80(11 Suppl 3):S65-75. doi:10.1212/WNL.0b013e3182872e01.

61. Kuh D, Karunananthan S, Bergman H, Cooper R. A life-course approach to healthy ageing: maintaining

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 2 May 2018 doi:10.20944/preprints201805.0014.v1

Peer-reviewed version available at J. Funct. Morphol. Kinesiol. 2018, 3, 31; doi:10.3390/jfmk3020031

physical capability. Proc. Nutr. Soc. [Internet]. 2014 [cited 2018 Apr 25]; 73(2):237–248. doi:10.1017/S0029665113003923.

62. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing. 2010; 39(4):412–23. doi:10.1093/ageing/afq034.

63. Savino E, Martini E, Lauretani F, Pioli G, Zagatti AM, Frondini C, et al. Handgrip strength predicts persistent walking recovery after hip fracture surgery. Am. J. Med. [Internet]. 2013 [cited 2018 Apr 24]; 126(12):1068–75.e1. doi:10.1016/j.amjmed.2013.04.017.

64. Lindsey C, Brownbill RA, Bohannon RA, Ilich JZ. Association of Physical Performance Measures With Bone Mineral Density in Postmenopausal Women. Arch. Phys. Med. Rehabil. [Internet]. 2005 [cited 2018 Apr 24]; 86(6):1102–1107. doi:10.1016/j.apmr.2004.09.028.

65. Shin H, Liu P-Y, Panton LB, Ilich JZ. Physical performance in relation to body composition and bone mineral density in healthy, overweight, and obese postmenopausal women. J. Geriatr. Phys. Ther. [Internet]. 2014 [cited 2014 Oct 10]; 37(1):7–16. doi:10.1519/JPT.0b013e31828af203.

66. Wang L, Song Y, Manson JE, Pilz S, März W, Michaëlsson K, et al. Circulating 25-hydroxy-vitamin D and risk of cardiovascular disease: a meta-analysis of prospective studies. Circ. Cardiovasc. Qual. Outcomes [Internet]. 2012 [cited 2016 May 2]; 5(6):819–29. doi:10.1161/CIRCOUTCOMES.112.967604.

67. Bin CM, Flores C, Álvares-da-Silva MR, Francesconi CFM. Comparison Between Handgrip Strength, Subjective Global Assessment, Anthropometry, and Biochemical Markers in Assessing Nutritional Status of Patients with Crohn's Disease in Clinical Remission. Dig. Dis. Sci. [Internet]. 2010 [cited 2018 Apr 24]; 55(1):137–144. doi:10.1007/s10620-008-0692-1.

68. Brooks N, Layne JE, Gordon PL, Roubenoff R, Nelson ME, Castaneda-Sceppa C. Strength training improves muscle quality and insulin sensitivity in Hispanic older adults with type 2 diabetes. Int. J. Med. Sci. [Internet]. 2006 [cited 2018 Apr 24]; 4(1):19–27. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17211497.

69. Wood RJ, Gregory S, Maneen J, Sullivan R, Richard J, Sawyer J, et al. Weight loss and muscle quality in older men with metabolic syndrome | The FASEB Journal [Internet]. FASEB J. 2011 [cited 2018 Apr 24]; Available from: https://www.fasebj.org/doi/10.1096/fasebj.25.1_supplement.982.18.

70. Taaffe DR, Henwood TR, Nalls MA, Walker DG, Lang TF, Harris TB. Alterations in muscle attenuation following detraining and retraining in resistance-trained older adults. Gerontology [Internet]. 2009 [cited 2018 Apr 25]; 55(2):217–23. doi:10.1159/000182084.

71. Nevitt MC, Cummings SR, Kidd S, Black D. Risk factors for recurrent nonsyncopal falls. A prospective study. JAMA [Internet]. 1989 [cited 2018 Apr 25]; 261(18):2663–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/2709546.

72. Lord SR, Murray SM, Chapman K, Munro B, Tiedemann A. Sit-to-Stand Performance Depends on Sensation, Speed, Balance, and Psychological Status in Addition to Strength in Older People. Journals Gerontol. Ser. A Biol. Sci. Med. Sci. [Internet]. 2002 [cited 2018 Apr 25]; 57(8):M539–M543. doi:10.1093/gerona/57.8.M539.

73. Lindemann U, Claus H, Stuber M, Augat P, Muche R, Nikolaus T, et al. Measuring power during the sit-to-stand transfer. Eur. J. Appl. Physiol. [Internet]. 2003 [cited 2018 Apr 25]; 89(5):466–470. doi:10.1007/s00421-003-0837-z.

74. Centers for Disease Control and Pervention. 30-Second Chair Stand [Internet]. 2017 [cited 2018 Apr 25]; Available from: https://www.cdc.gov/steadi/pdf/STEADI-Assessment-30Sec-508.pdf.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 2 May 2018 doi:10.20944/preprints201805.0014.v1

Peer-reviewed version available at J. Funct. Morphol. Kinesiol. 2018, 3, 31; doi:10.3390/jfmk3020031

75. Bernabeu-Mora R, Medina-Mirapeix F, Llamazares-Herrán E, Oliveira-Sousa SL de, Sánchez-Martinez MP, Escolar-Reina P. The accuracy with which the 5 times sit-to-stand test, versus gait speed, can identify poor exercise tolerance in patients with COPD: A cross-sectional study. Medicine (Baltimore). [Internet]. 2016 [cited 2018 Apr 25]; 95(35):e4740. doi:10.1097/MD.0000000000004740.

76. Drey M, Sieber CC, Bertsch T, Bauer JM, Schmidmaier R, FiAT intervention group. Osteosarcopenia is more than sarcopenia and osteopenia alone. Aging Clin. Exp. Res. [Internet]. 2016 [cited 2018 Apr 25]; 28(5):895–899. doi:10.1007/s40520-015-0494-1.

77. Theou O, Jones GR, Jakobi JM, Mitnitski A, Vandervoort AA. A comparison of the relationship of 14 performance-based measures with frailty in older women. Appl. Physiol. Nutr. Metab. [Internet]. 2011 [cited 2018 Apr 25]; 36(6):928–938. doi:10.1139/h11-116.

78. Lusardi MM. Is Walking Speed a Vital Sign? Absolutely! Top. Geriatr. Rehabil. [Internet]. 2012 [cited 2018 Apr 25]; 28(2):67–76. doi:10.1097/TGR.0b013e31824385a4.

79. Middleton A, Fritz SL, Lusardi M. Walking speed: the functional vital sign. J. Aging Phys. Act. [Internet]. 2015 [cited 2018 Apr 25]; 23(2):314–22. doi:10.1123/japa.2013-0236.

80. Najafi DA, Dahlberg LE, Hansson EE. A combination of clinical balance measures and FRAX® to improve identification of high-risk fallers. BMC Geriatr. [Internet]. 2016 [cited 2018 Apr 25]; 16(1):94. doi:10.1186/s12877-016-0266-6.

81. Peirone E, Goria PF, Anselmino A. A dual-task home-based rehabilitation programme for improving balance control in patients with acquired brain injury: a single-blind, randomized controlled pilot study. Clin. Rehabil. [Internet]. 2014 [cited 2018 Apr 25]; 28(4):329–38. doi:10.1177/0269215513501527.

82. Sànchez-Riera L, Carnahan E, Vos T, Veerman L, Norman R, Lim SS, et al. The global burden attributable to low bone mineral density. Ann. Rheum. Dis. [Internet]. 2014 [cited 2016 Jan 25]; 73(9):1635–45. doi:10.1136/annrheumdis-2013-204320.

83. Falls are leading cause of injury and death in older Americans | CDC Online Newsroom | CDC [Internet]. CDC. 2016 [cited 2018 Apr 24]; Available from: https://www.cdc.gov/media/releases/2016/p0922-older-adult-falls.html.

84. Falls [Internet]. World Heal. Organ. 2018 [cited 2018 Apr 24]; Available from: http://www.who.int/en/news-room/fact-sheets/detail/falls.

85. Kanis JA, Johnell O, Oden A, Jonsson B, De Laet C, Dawson A. Risk of hip fracture according to the World Health Organization criteria for osteopenia and osteoporosis. Bone [Internet]. 2000 [cited 2016 Jan 25]; 27(5):585–90. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11062343.

86. Eastell R, Wahner HW, O'Fallon WM, Amadio PC, Melton LJ, Riggs BL, et al. Unequal decrease in bone density of lumbar spine and ultradistal radius in Colles' and vertebral fracture syndromes. J. Clin. Invest. [Internet]. 1989 [cited 2017 Jan 25]; 83(1):168–74. doi:10.1172/JCI113854.

87. Deandrea S, Lucenteforte E, Bravi F, Foschi R, Vecchia C La, Negri E. Risk Factors for Falls in Community-dwelling Older People: A Systematic Review and Meta-analysis. Epidemiology [Internet]. 2010 [cited 2018 Apr 24]; 21(5):658–668. doi:10.1097/ede.0b013e3181e89905.

88. Valderrama-Hinds LM, Al Snih S, Chen N, Rodriguez MA, Wong R. Falls in Mexican older adults aged 60 years and older. Aging Clin. Exp. Res. [Internet]. 2018 [cited 2018 Apr 24]; doi:10.1007/s40520-018-0950-9.

89. Murphy SL, Williams CS, Gill TM. Characteristics associated with fear of falling and activity restriction in community-living older persons. J. Am. Geriatr. Soc. [Internet]. 2002 [cited 2018 Apr 27]; 50(3):516–20. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11943049.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 2 May 2018 doi:10.20944/preprints201805.0014.v1

Peer-reviewed version available at J. Funct. Morphol. Kinesiol. 2018, 3, 31; doi:10.3390/jfmk3020031

90. Hita-Contreras F, Martínez-Amat A, Lomas-Vega R, Álvarez P, Aránega A, Martínez-López E, et al. Predictive value of stabilometry and fear of falling on falls in postmenopausal women. Climacteric [Internet]. 2013 [cited 2018 Apr 27]; 16(5):584–9. doi:10.3109/13697137.2012.733464.

91. Scheffer AC, Schuurmans MJ, van Dijk N, van der Hooft T, de Rooij SE. Fear of falling: measurement strategy, prevalence, risk factors and consequences among older persons. Age Ageing [Internet]. 2008 [cited 2016 Jan 30]; 37(1):19–24. doi:10.1093/ageing/afm169.

92. Scott D, Sanders KM, Aitken D, Hayes A, Ebeling PR, Jones G. Sarcopenic obesity and dynapenic obesity: 5-year associations with falls risk in middle-aged and older adults. Obesity (Silver Spring). [Internet]. 2014 [cited 2016 Jan 12]; 22(6):1568–74. doi:10.1002/oby.20734.

93. Kaji H. Linkage between muscle and bone: common catabolic signals resulting in osteoporosis and sarcopenia. Curr. Opin. Clin. Nutr. Metab. Care [Internet]. 2013 [cited 2016 May 16]; 16(3):272–7. doi:10.1097/MCO.0b013e32835fe6a5.

94. Hita-Contreras F, Martínez-López E, González-Matarín P, Mendoza N, Cruz-Díaz D, Ruiz-Ariza A, et al. Association of bone mineral density with postural stability and the fear of falling in Spanish postmenopausal women. Maturitas [Internet]. 2014 [cited 2016 Feb 3]; 79(3):322–8. doi:10.1016/j.maturitas.2014.07.015.

95. Baumgartner RN. Body composition in healthy aging. Ann. N. Y. Acad. Sci. [Internet]. 2000 [cited 2016 Feb 2]; 904:437–48. Available from: http://www.ncbi.nlm.nih.gov/pubmed/10865787.

96. Burton LA, Sumukadas D. Optimal management of sarcopenia. Clin. Interv. Aging [Internet]. 2010 [cited 2018 Apr 27]; 5:217–28. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20852669.

97. Beavers DP, Beavers KM, Loeser RF, Walton NR, Lyles MF, Nicklas BJ, et al. The independent and combined effects of intensive weight loss and exercise training on bone mineral density in overweight and obese older adults with osteoarthritis. Osteoarthritis Cartilage. 2014; 22(6):726–33. doi:10.1016/j.joca.2014.04.002.

98. Villareal DT, Apovian CM, Kushner RF, Klein S, American Society for Nutrition, NAASO, The Obesity Society. Obesity in Older Adults: Technical Review and Position Statement of the American Society for Nutrition and NAASO, The Obesity Society. Obes. Res. [Internet]. 2005 [cited 2018 Apr 27]; 13(11):1849–1863. doi:10.1038/oby.2005.228.

99. Morley JE, Argiles JM, Evans WJ, Bhasin S, Cella D, Deutz NEP, et al. Nutritional recommendations for the management of sarcopenia. J. Am. Med. Dir. Assoc. [Internet]. 2010 [cited 2015 Dec 16]; 11(6):391–6. doi:10.1016/j.jamda.2010.04.014.

100. Pérez-López FR, Brincat M, Erel CT, Tremollieres F, Gambacciani M, Lambrinoudaki I, et al. EMAS position statement: Vitamin D and postmenopausal health. Maturitas [Internet]. 2012 [cited 2016 Feb 3]; 71(1):83–8. doi:10.1016/j.maturitas.2011.11.002.

101. Tanaka K, Kanazawa I, Yamaguchi T, Yano S, Kaji H, Sugimoto T. Active vitamin D possesses beneficial effects on the interaction between muscle and bone. Biochem. Biophys. Res. Commun. [Internet]. 2014 [cited 2018 Apr 27]; 450(1):482–7. doi:10.1016/j.bbrc.2014.05.145.

102. Petridou ET, Manti EG, Ntinapogias AG, Negri E, Szczerbińska K. What Works Better for Community-Dwelling Older People at Risk to Fall? J. Aging Health [Internet]. 2009 [cited 2018 Apr 27]; 21(5):713–729. doi:10.1177/0898264309338298.

103. Dukyoo Jung, Juhee Lee, Lee S-M. A Meta-Analysis of Fear of Falling Treatment Programs for the Elderly. West. J. Nurs. Res. [Internet]. 2009 [cited 2018 Apr 27]; 31(1):6–16. doi:10.1177/0193945908320466.

104. Madureira MM, Bonfá E, Takayama L, Pereira RMR. A 12-month randomized controlled trial of balance

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 2 May 2018 doi:10.20944/preprints201805.0014.v1

Peer-reviewed version available at J. Funct. Morphol. Kinesiol. 2018, 3, 31; doi:10.3390/jfmk3020031

542 training in elderly women with osteoporosis: improvement of quality of life. Maturitas [Internet]. 2010
543 [cited 2018 Apr 27]; 66(2):206–11. doi:10.1016/j.maturitas.2010.03.009.
544 105. Schleicher MM, Wedam L, Wu G. Review of Tai Chi as an effective exercise on falls prevention in elderly.
545 Res. Sports Med. [Internet]. 2012 [cited 2018 Apr 27]; 20(1):37–58. doi:10.1080/15438627.2012.634697.
546 106. Álvarez-Barbosa F, del Pozo-Cruz J, del Pozo-Cruz B, Alfonso-Rosa RM, Rogers ME, Zhang Y. Effects of
547 supervised whole body vibration exercise on fall risk factors, functional dependence and health-related
548 quality of life in nursing home residents aged 80+. Maturitas [Internet]. 2014 [cited 2018 Apr 27];
549 79(4):456–63. doi:10.1016/j.maturitas.2014.09.010.
550 107. Ribom EL, Piehl-Aulin K, Ljunghall S, Ljunggren O, Naessén T. Six months of hormone replacement
551 therapy does not influence muscle strength in postmenopausal women. Maturitas [Internet]. 2002 [cited
552 2018 Apr 27]; 42(3):225–31. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12161047.
553 108. Rodrigues Barral ABC, Nahas EAP, Nahas-Neto J, Cangussu LM, Buttros D de A. Effect of hormone
554 therapy on postural balance in postmenopausal women. Menopause J. North Am. Menopause Soc.
555 [Internet]. 2012 [cited 2018 Apr 27]; 19(7):768–775. doi:10.1097/gme.0b013e318240fc36.
556 109. Randell KM, Honkanen RJ, Komulainen MH, Tuppurainen MT, Kröger H, Saarikoski S. Hormone
557 replacement therapy and risk of falling in early postmenopausal women - a population-based study.
558 Clin. Endocrinol. (Oxf). [Internet]. 2001 [cited 2018 Apr 27]; 54(6):769–74. Available from:
559 http://www.ncbi.nlm.nih.gov/pubmed/11422111.
560 110. Kawai M, de Paula FJA, Rosen CJ. New insights into osteoporosis: the bone-fat connection. J. Intern.
561 Med. [Internet]. 2012 [cited 2016 Oct 18]; 272(4):317–29. doi:10.1111/j.1365-2796.2012.02564.x.
562 111. Hamrick MW, McGee-Lawrence ME, Frechette DM. Fatty infiltration of skeletal muscle: mechanisms
563 and comparisons with bone marrow adiposity. Front. Endocrinol. (Lausanne). [Internet]. 2016 [cited
564 2016 Oct 17]; 7:69. doi:10.3389/fendo.2016.00069.
565 112. Domiciano DS, Figueiredo CP, Lopes JB, Caparbo VF, Takayama L, Menezes PR, et al. Discriminating
566 sarcopenia in community-dwelling older women with high frequency of overweight/obesity.
567 Osteoporos. Int. [Internet]. 2013 [cited 2016 Aug 22]; 24(2):595–603. doi:10.1007/s00198-012-2002-1.
568 113. Mijnarends DM, Schols JMGA, Meijers JMM, Tan FES, Verlaan S, Luiking YC, et al. Instruments to
569 Assess Sarcopenia and Physical Frailty in Older People Living in a Community (Care) Setting:
570 Similarities and Discrepancies. J. Am. Med. Dir. Assoc. [Internet]. 2015 [cited 2018 Apr 24]; 16(4):301–
571 308. doi:10.1016/j.jamda.2014.11.011.
572 114. Liu P-Y, Ilich JZ, Brummel-Smith K, Ghosh S. New insight into fat, muscle and bone relationship in
573 women: determining the threshold at which body fat assumes negative relationship with bone mineral
574 density. Int. J. Prev. Med. 2014; 5(11):1452–63.
575