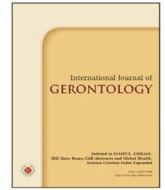




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Review Article

Sarcopenia, Frailty and Fall Risk-Narrative Review

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SUMMARY

The biggest impact of Taiwan's population aging on society is the increase in the demand for geriatric medical care and the increase in the burden of social and economic welfare. It will have an impact on domestic consumption, domestic demand and labor supply, and changes in the demographic structure will also have an impact on the economy. There will be a series of changes in consumer demand and infrastructure as the workforce shrinks and productivity weakens. The negative effects of sarcopenia in obese or osteoporotic populations are greater than those in the general healthy population, and sarcopenia is additive to the effects of obesity and osteoporosis on metabolism and physical activity. The increase of adipose tissue in the elderly can also lead to an increase in chronic inflammation in the body, increase insulin resistance, reduce muscle synthesis and increase muscle breakdown, resulting in an increase in the prevalence of sarcopenic obesity in the elderly. Studies have shown that sarcopenia increases the risk of falls in the elderly, and also causes obese elderly people to easily lose muscle under a calorie-restricted diet. It can be seen from the above that nutritional supplementation and moderate aerobic and resistance exercise can reduce the risk of sarcopenia and falls in the obese elderly. Falls and their related injuries represent one major health care issue in the elderly population. Falls are a common event among older adults and are associated with increased morbidity and disability.

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1. Introduction

The risk of fall is an important issue for elderly in countries of aging population, especially for those with sarcopenia or osteoporosis. The aging process will have degeneration of motor neurons, reduced protein synthesis and insufficient nutritional intake that sedentary lifestyle or chronic diseases will further add to the cause of forcing individual to become bedridden or physically disabled. As an effect of such rare disease,¹ falling is a major concern for causing disability and being bedridden. Sarcopenia is an age-related chronic inflammatory condition, which involves changes to hormonal imbalance. Frailty is characterized by a decline of physiological functions of various systems that a person becomes less inclined to respond to stress.

2. Frailty

The outcome of such frailty in elderly is often associated with decreased quality of life and mobility,² which may contribute to reduced ability to perform common daily functions and even falling, as well as observing an increase in hospital stay. When an elderly person is obese and suffers from muscular deficiency, the condition is called sarcopenic obesity.³ In addition, the loss of muscle mass, as well as changes in muscular composition, including increased visceral fat, which infiltrates and obstructs the innervation of muscle cells, will have complication effect and increase cardiovascular risk.⁴

The risk of fall in elderly women is about 1.5 to 2 times that of elderly men.⁵ The annual chance of falling for elderly over the age of 65 is approximately 28–35% and the rate increases to 32–42% over the age of 70. The incidence rate of falling is 30% to 40% in real life and this number can reach as high as 50% for elderly over the age of 80. In fact, the incidence rate of falling for elderly in long-term care institutions is even higher up to 50% per year.⁶ Many literatures have focused on the pathophysiology of sarcopenia and the effect of frailty, as well as some on osteoporosis, in relation with falls in the elderly. Sarcopenia is defined as a decrease in muscle mass and strength, which is considered a natural phenomenon of aging.⁷ In 2001, the scholar, Fried, proposed five main clinical indicators of frailty (aka. Fried's frailty phenotype), including unintentional weight loss, self-reported fatigue, decreased muscle strength, slow walking, low physical performance which usually shows as slower speed, and less physical activeness.^{9,10}

3. Sarcopenia

In 1997, American scholar, Rosenberg, first coined the Greek term "Sarcopenia" for the condition.⁸ It is mainly observed as a decline in muscle strength, which leads to reduced mobility in elderly, that these senior citizens will have more difficulty in performing daily activities, such as walking, sitting and lifting heavy objects, eventually becoming susceptible to postural imbalance and falling. Muscle mass generally declines with age and is often accelerated by infrequent use of muscles, easily affecting gait and balance. This will end up with falls and decreased mobility, which in turns lead to an endless cycle of

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faster deterioration. Degenerative changes from disease to frailty (de-conditioning) involves risk factors, such as age, genetics or environment, and chronic condition, which may lead to frailty, disability, cognitive impairment, and even death. The National Nutrition and Health Status Survey from 2014 to 2015 found that the prevalence of frailty among Taiwanese aged 65 and over was 7.8%, and the prevalence of pre-frailty was 50.8%.¹¹ Compared with normal people, patients with sarcopenia have significantly lower body weight and lean body mass, significantly lower grip strength, and significantly weakened lower extremity flexors, so they fall quite frequently.^{12–16} Sarcopenia is associated with poor physical fitness, lack of exercise, slowed gait speed, and decreased mobility, as these are also the common features of frailty, contributing to an increase of falling.

De-conditioning is a continuous process and an indication of an urgent need for more efficient and more effective medical intervention. De-conditioning is an independent indicator that can help to predict multiple comorbidities and disability, in which the measurement of biomarkers such as body mass index, blood pressure, waist-to-hip ratio, cardiorespiratory fitness, and even the function of mastication is part of assessment for frailty. There are many different causes and risk factors that predispose elderly to fall, and they can be classified as intrinsic or extrinsic in characteristics.^{20–26} Intrinsic factors include those related to bodily function and health condition such as physiological dysfunction or balance disorder. Extrinsic factors include adverse drug reaction, use of restraints, and environmental factors such as poor lighting or lack of safety equipment in bathroom. Physiologically, the degeneration of nervous system will affect the maintenance of stability and symmetry of an individual's gait, making the person prone to falls. Compared with young people, the total muscle mass and the number of muscle fibers in the elderly often show a significant decrease, as aging does cause muscle atrophy. From the age of 60 to 90, the average muscle strength decreases by 20% to 30%. These physical problems will make the elderly unable to cope with falling. Furthermore, concomitant medical diseases such as inappropriate hypoglycemic and hypertensive drugs, antihistamines and sedatives, etc., may affect the sense of balance and make the elderly more prone to falls, as well.²⁷ In recent years, the public has become more attentive to the problem of sarcopenia, especially in the health sports centers, nutrition associations and experts in geriatric medicine, since the definition of the disease was established in 2010 by the European Working Group on Sarcopenia (EWGSOP), which stated sarcopenia as “progressive” loss of muscle mass and reduced muscle function (in terms of strength and physiological activeness), eventually leading to a syndrome of increased late incidence, poor quality of life, and death.¹⁴ The diagnostic standard and classification are based on three components: low muscle mass, low muscle strength and low physical performance. Sarcopenia is determined by factors of muscle mass, muscle strength, and physical performance and it is positively correlated with falls in the elderly. Decreased muscle strength is a major cause of falls in patients with sarcopenia. For example, muscle weakness in the calf, inability to lift the foot higher or the stride becoming smaller, etc.^{15,16} Interventions to prevent sarcopenia may be important in preventing falls in older adults. According to recent studies, approximately 6% of all medical expenditures for older Americans were related to falls, and 5% of older adults who fell must be admitted for treatment.²⁰ Elderly with frailty is more vulnerable to injury as they have less physiological reserve capacity to maintain the required stability in face of stress. They also have poor prognosis or even death from falls, fractures and disability, since they are more dependent and may need long-term care. Sarcopenia and osteoporosis can coexist and are closely related; thus, preventing sarcopenia

will help to prevent falls and reduce fractures.

4. Frailty, sarcopenia and fall risk

Frailty is described as a syndrome of loss of physiological functions, where the individual is prone to falls. Clinical manifestations include decreased activity, weight loss, fatigue, decreased appetite, muscle wasting, bone loss, abnormal gait and balance, and cognitive dysfunction. Sarcopenia is a geriatric syndrome characterized by decreased muscle mass and strength, as well as decreased bodily function. After the age of 30, muscle mass decreases by 8% every ten years and it is accompanied by weakness, fatigue and falls. The most profound symptom is weight loss.¹⁶ Whereas medical care in the past focused on prevention, early diagnosis, and long-term care, the current approach has recognized aging as a key cause of frailty, which interacts with other age-related physiological changes, environment, diseases and medications,¹⁷ all lead to debilitating symptoms in the elderly. Changes in the musculoskeletal composition may be due to nutritional deficiency, of which sarcopenic obesity is one of the considerations. Many physiological mechanisms are considered to be related to frailty, among which is the disease of sarcopenia, as one can say that sarcopenia and frailty are the two sides of the same coin.¹⁸ The accumulation of deficiencies (Frailty Index) proposed by Rockwood and Mitnitski is a classification of 30 to 70 different defective states on a scale of 0 and 1. The higher the score, the higher the risk of death is for the individual. If the Frailty Index shows more than 30 items of health defects, such as multiple comorbidities, mental issues, symptoms and disability, the factor of age will further add to the morbidity rate of frailty. Disability, as defined by WHO, consists of six major aspects, including cognition, action, self-care, social competence, physical activity and social participation.¹⁹

5. Osteosarcopenia

Osteosarcopenia is a combination of osteopenia or osteoporosis with sarcopenia.²¹ Both diseases can mutually affect each other. Since 2001, some researchers have meticulously studied the relationship between muscles and bones in the elderly to find that muscle mass can help to predict bone density in both genders at older age, especially being strongly correlated as evidenced in postmenopausal women.²² Therefore, this synergistic relationship between sarcopenia and osteoporosis may be better viewed as an interaction of five factors, which are muscle mass, muscle strength, bone mineral density, fracture, and quality of life.²³ After the age of 50, the muscle mass decreases by approximately 1% to 2% every year and the muscle strength decreases by 1.5% to 3%. Some studies concluded that this was due to the decline of estrogen after menopause in women.²⁴ Sarcopenia and osteoporosis often occur together, which is referred to as sarcopenic syndrome.

6. Sarcopenic obesity

If an elderly were with muscle atrophy and obesity, the combination will have multiple negative implications on the health, in which it will accelerate the deterioration of physical ability and may lead to morbidities and even mortality.²⁸ Vitamin D supplement appears to reduce the risk of falls by more than 20 percent in the elderly population. According to the “British Medical Journal” report, people over the age of 65 who can consume 700 to 1,000 international units of vitamin D a day may reduce the risk of falling by 19%. Vitamin D can increase muscle strength, and people who consume more than 700 units of vitamin D per day have a reduced risk of fall-

ing.^{29–31} Studies have found that 400 IU of vitamin D did not significantly reduce fracture risk, but an increase to 700 to 800 IU/day of vitamin D did show a significant reduction in observable fractures. These findings should be further validated and followed up to examine alternatives and their dosage, in terms of calcium and vitamin D in men.³² Musculoskeletal aging is a major public health problem and burden in Taiwan due to increased pool of aging population being susceptible to frailty, loss of autonomy and risk of falls, especially in long-term care institutions.³³ Bone mass, muscle mass, and strength increase in late adolescence and early adulthood, but decrease significantly after age of 50. These three factors are closely related, and it is now widely accepted that bones and muscles are part of endocrine organs that interact through paracrine and endocrine signaling pathways.³⁴ Frailty can cause multiple organs and systems to fail in function. The most common indirect causes of death in the elderly population are frailty (27.9 %), organ failure (21.4 %), cancer (19.3 %), dementia (13.8 %), etc.³⁵ Frailty is common among elderly, and the emphasis is on its prevention, early diagnosis and care. Interaction among these factors may further contribute to the incidence of frailty in elderly. And, these factors can also be roughly summarized as part of endocrine system disorder, systemic inflammatory response, change in the musculoskeletal system, and nutritional deficiencies, that among which sarcopenia is the most prominent factor.³⁶ The same is seen in the elderly with sarcopenia and osteoporosis, which significantly contribute to frailty. These diseases have led to an increased risk of falls in the elderly. According to research, falls in long-term care institutions are the primary cause of death and disability for elderly, since the result corresponded to studies that have investigated “environmental factors” accounting for a large proportion of falls in the elderly, which was as high as 50%.^{37,38} More than 1/3 of the seniors had fallen at least once in a year, that 30% to 50% of the fall incidents were due to environmental problems.³⁹

7. Sarcopenia and balance

Being strangled in this cycle, muscles begin to deteriorate.⁴⁰ Gait and balance are important to the stability of walking and standing posture of the elderly. Normally, everyone is different in their standing and walking posture due to their physical condition, as the elderly also vary due to their own elderly diseases, which have come to play a role in falling. Maintaining body balance requires coordination of 3 systems: 1. Vestibular system with sensory organs that regulate balance by interpreting forces and directional information in relation with the head position (namely the internal gravity and linear and angular acceleration); 2. Somatosensory system for joint proprioception and kinematic sensation, as well as information from skin and joints, to determine the spatial position and motion relative to the supporting surfaces and body parts; 3. Vision for controlling the vertical movement of body and head, relative to the spatial position of objects in sight.⁴¹ Once elderly falls, they will become less confident in walking and prefer to stay in bed or sit in a wheelchair all day, where their muscles and joints will gradually deteriorate, which is a cycle of endless degradation.⁴² Tai Chi specializes in muscle control, helping an individual to strengthen their upper and lower limbs to achieve an overall balance and stability. Some studies have pointed out that practicing Tai Chi could reduce the risk of falling by as much as 50% after 12 months.⁴³ Teeth will affect physiological functions, such as causing sarcopenia, etc., and the function of bad masticatory muscles will lead to insufficient protein intake, leading to the occurrence of severe sarcopenia, forming a vicious circle. Therefore, occlusion of the teeth and oral cavity is also important to affect falls.

8. Conclusion

Many literatures have pointed out that the elderly in a frail state can rapidly deteriorate in cognitive functions and withdraw from daily activities, since they are prone to falls and have higher chance of being hospitalized or dead.⁴⁴ An important body part affected by aging is the muscles.⁴⁵ The world is aging, and life expectancy is increasing, leading to more health problems. In particular, musculoskeletal deterioration like sarcopenia and osteoporosis is now a common problem, which has a variety of causes, involving changes in body composition, inflammation, and hormonal imbalance. Sarcopenia, osteoporosis, and sarcopenic obesity are often closely associated with frailty and can lead to the development of geriatric syndrome.⁴⁶ Frailty increases the risk of immobility or falls during daily activities, and increases the risk of cardiovascular diseases, cancers, and even death.⁴⁷ As our population continues to age, it is most important to identify the elderly at risk of frailty early and treat or prevent progression to poor prognostic outcome⁴⁸ that these interventional measures must be able to promote healthy aging. The complex relationship between sarcopenia and frailty requires a comprehensive geriatric assessment, such as nutritional supplement,^{49–51} regular physical exercise, and various clinical measures to ensure patient’s psychosocial well-being and medication intake. The treatment will hopefully prevent the condition and truly improve the quality of life under long life expectancy, as well as reducing mortality from falls,^{49,50} especially when falling and sarcopenia are correlated. Without effective prevention and interventional measures, the elderly may suffer from disability early on, placing more burden on the patient and the caregiver. Given this reason, it is necessary to understand more about the condition by conducting more clinical studies to understand the complex physiology of sarcopenia, osteoporosis, and frailty that leads to falls in the elderly, so that we can eventually take effective measures at younger age to prevent and treat sarcopenia. It has been estimated that, in such population, two-thirds of the death from unintentional injuries are related to a fall event.^{51–53} And improve the mobility of the elderly, so pay attention to the problems of sarcopenia and frailty in the elderly, and early and active intervention can prevent subsequent disability and the disadvantages of sarcopenia and frailty.

References

1. Dupuy C, Lauwers-Cances V, Guyonnet S, et al. Searching for a relevant definition of sarcopenia: results from the cross-sectional EPIDOS study. *J Cachexia Sarcopenia Muscle*. 2015;6(2):144–154. doi:10.1002/jcsm.12021
2. Dawson-Hughes B, Bischoff-Ferrari H. Considerations concerning the definition of sarcopenia. *Osteoporos Int*. 2016;27(11):3139–3144. doi:10.1007/s00198-016-3674-8
3. Kalinkovich A, Livshits G. Sarcopenic obesity or obese sarcopenia: a cross talk between age-associated adipose tissue and skeletal muscle inflammation as a main mechanism of the pathogenesis. *Ageing Res Rev* 2017; 35:200–221. doi:10.1016/j.arr.2016.09.008
4. Migliaccio S, Greco EA, Wannenes F, Donini LM, Lenzi A. Adipose, bone and muscle tissues as new endocrine organs: role of reciprocal regulation for osteoporosis and obesity development. *Horm Mol Biol Clin Investig*. 2014;17(1):39–51. doi:10.1515/hmbci-2013-0070
5. Stel VS, Smit JH, Pluijm SM, Lips P. Consequences of falling in older men and women and risk factors for health service use and functional decline. *Age Ageing*. 2004;33(1):58–65. doi:10.1093/ageing/afh028
6. Masud T, Morris RO. Epidemiology of falls. *Age Ageing*. 2001;30(suppl_4):3–7.
7. Cruz-Jentoft AJ, Sayer AA. Sarcopenia. *Lancet*. 2019;393(10191):2636–2646. doi:10.1016/S0140-6736(19)31138-9
8. Marzetti E, Calvani R, Tosato M, et al. Sarcopenia: an overview. *Ageing Clin Exp Res*. 2017;29(1):11–17. doi:10.1007/s40520-016-0704-5

9. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci*. 2001;56(3):M146–M157. doi:10.1093/gerona/56.3.m146
10. Von Haehling S, Morley JE, Anker SD. An overview of sarcopenia: facts and numbers on prevalence and clinical impact. *J Cachexia Sarcopenia Muscle*. 2010;1(2):129–133. doi:10.1007/s13539-010-0014-2
11. Lo YL, Hsieh YT, Hsu LL, et al. Dietary pattern associated with frailty: results from nutrition and health survey in Taiwan. *J Am Geriatr Soc*. 2017;65(9):2009–2015. doi:10.1111/jgs.14972
12. Guirguis-Blake JM, Michael YL, Perdue LA, Coppola EL, Beil TL. Interventions to prevent falls in older adults: Updated evidence report and systematic review for the US Preventive Services Task Force. *JAMA*. 2018;319(16):1705–1716. doi:10.1001/jama.2017.21962
13. Ensrud KE, Ewing SK, Taylor BC, et al. Comparison of 2 frailty indexes for prediction of falls, disability, fractures, and death in older women. *Arch Intern Med*. 2008;168(4):382–389. doi:10.1001/archinternmed.2007.113
14. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, 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):412–423. doi:10.1093/ageing/afq034
15. Chen LK, Woo J, Assantachai P, et al. Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. *J Am Med Dir Assoc*. 2020;21(3):300–307. doi:10.1016/j.jamda.2019.12.012
16. Moncada LJV, Mire LG. Preventing falls in older persons. *Am Fam Physician*. 2017;96(4):240–247.
17. Visser M, Schaap LA. Consequences of sarcopenia. *Clin Geriatr Med*. 2011;27(3):387–399. doi:10.1016/j.cger.2011.03.006
18. Morley JE. Diabetes, sarcopenia, and frailty. *Clin Geriatr Med*. 2008;24(3):455–469. doi:10.1016/j.cger.2008.03.004
19. Mlinac ME, Feng MC. Assessment of activities of daily living, self-care, and independence. *Arch Clin Neuropsychol*. 2016;31(6):506–516. doi:10.1093/arclin/acw049
20. Chuang SY, Hsu YY, Chen RC, et al. Abdominal obesity and low skeletal muscle mass jointly predict total mortality and cardiovascular mortality in an elderly Asian population. *J Gerontol A Biol Sci Med Sci*. 2016;71(8):1049–1055. doi:10.1093/gerona/glv192
21. Ormsbee MJ, Prado CM, Ilich JZ, et al. Osteosarcopenic obesity: the role of bone, muscle, and fat on health. *J Cachexia Sarcopenia Muscle*. 2014;5(3):183–192. doi:10.1007/s13539-014-0146-x
22. Greco EA, Pietschmann P, Migliaccio S. Osteoporosis and sarcopenia increase frailty syndrome in the elderly. *Front Endocrinol (Lausanne)*. 2019;10:255. doi:10.3389/fendo.2019.00255.
23. Gielen E, Bergmann P, Bruyère O, et al. Osteoporosis in frail patients: a consensus paper of the Belgian bone club. *Calcif Tissue Int*. 2017;101(2):111–131. doi:10.1007/s00223-017-0266-3
24. Yeung SSY, Reijnierse EM, Pham VK, et al. Sarcopenia and its association with falls and fractures in older adults: a systematic review and meta-analysis. *J Cachexia Sarcopenia Muscle*. 2019;10(3):485–500. doi:10.1002/jcsm.12411
25. Marques A, Queirós C. Frailty, Sarcopenia and Falls. In: Hertz K, Santy-Tomlinson J, eds. *Fragility Fracture Nursing: Holistic Care and Management of the Orthogeriatric Patient*. Springer Cham;2018:15–26. doi:10.1007/978-3-319-76681-2_2
26. Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society. Summary of the Updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons. *J Am Geriatr Soc*. 2011;59(1):148–157. doi:10.1111/j.1532-5415.2010.03234.x
27. Phelan EA, Mahoney JE, Voit JC, Stevens JA. Assessment and management of fall risk in primary care settings. *Med Clin North Am*. 2015;99(2):281–293. doi:10.1016/j.mcna.2014.11.004
28. Öztürk ZA, Türkbeyler İH, Abiyev A, et al. Health-related quality of life and fall risk associated with age-related body composition changes; sarcopenia, obesity and sarcopenic obesity. *Intern Med J*. 2018;48(8):973–981. doi:10.1111/imj.13935
29. Kim J, Lee Y, Kye S, Chung YS, Lee O. Association of serum vitamin D with osteosarcopenic obesity: Korea National Health and Nutrition Examination Survey 2008–2010. *J Cachexia Sarcopenia Muscle*. 2017;8(2):259–266. doi:10.1002/jcsm.12154
30. Mosekilde L. Vitamin D and the elderly. *Clin Endocrinol (Oxf)*. 2005;62(3):265–281. doi:10.1111/j.1365-2265.2005.02226.x
31. Bischoff-Ferrari HA, Dawson-Hughes B, Willett WC, et al. Effect of vitamin D on falls: a meta-analysis. *JAMA*. 2004;291(16):1999–2006. doi:10.1001/jama.291.16.1999
32. Thanaplueti Wong S, Chewcharat A, Takkavatakarn K, Praditpornsilpa K, Eiam-Ong S, Suntasitaphong P. Vitamin D supplement on prevention of fall and fracture: a meta-analysis of randomized controlled trials. *Medicine (Baltimore)*. 2020;99(34):e21506. doi:10.1097/MD.00000000000021506
33. Fhon JR, Rodrigues RA, Neira WF, Huayta VM, Robazzi ML. Fall and its association with the frailty syndrome in the elderly: systematic review with meta-analysis. *Rev Esc Enferm USP*. 2016;50(6):1005–1013. doi:10.1590/S0080-623420160000700018
34. Konopka AR, Harber MP. Skeletal muscle hypertrophy after aerobic exercise training. *Exerc Sport Sci Rev*. 2014;42(2):53–61. doi:10.1249/JES.0000000000000007
35. Gill TM. Disentangling the disabling process: insights from the precipitating events project. *Gerontologist*. 2014;54(4):533–549. doi:10.1093/geront/gnu067
36. van den Beld AW, Kaufman JM, Zillikens MC, Lamberts SWJ, Egan JM, van der Lely AJ. The physiology of endocrine systems with ageing. *Lancet Diabetes Endocrinol*. 2018;6(8):647–658. doi:10.1016/S2213-8587(18)30026-3
37. Gandham A, Mesinovic J, Jansons P, et al. Falls, fractures, and areal bone mineral density in older adults with sarcopenic obesity: A systematic review and meta-analysis. *Obes Rev*. 2021;22(5):e13187. doi:10.1111/obr.13187
38. Vlaeyen E, Coussement J, Leysens G, et al. Characteristics and effectiveness of fall prevention programs in nursing homes: a systematic review and meta-analysis of randomized controlled trials. *J Am Geriatr Soc*. 2015;63(2):211–221. doi:10.1111/jgs.13254
39. Brouwer B, Musselman K, Culham E. Physical function and health status among seniors with and without a fear of falling. *Gerontology*. 2004;50(3):135–141. doi:10.1159/000076771
40. Marzetti E, Calvani R, Tosato M, et al. Physical activity and exercise as countermeasures to physical frailty and sarcopenia. *Aging Clin Exp Res*. 2017;29(1):35–42. doi:10.1007/s40520-016-0705-4
41. Kelsey JL, Berry SD, Procter-Gray E, et al. Indoor and outdoor falls in older adults are different: the maintenance of balance, independent living, intellect, and zest in the Elderly of Boston Study. *J Am Geriatr Soc*. 2010;58(11):2135–2141. doi:10.1111/j.1532-5415.2010.03062.x
42. Cruz-Jentoft AJ. Perspective: protein and exercise for frailty and sarcopenia: still learning. *J Am Med Dir Assoc*. 2013;14(1):69–71. doi:10.1016/j.jamda.2012.09.024
43. Schleicher MM, Wedam L, Wu G. Review of Tai Chi as an effective exercise on falls prevention in elderly. *Res Sports Med*. 2012;20(1):37–58. doi:10.1080/15438627.2012.634697
44. Lang PO, Michel JP, Zekry D. Frailty syndrome: a transitional state in a dynamic process. *Gerontology*. 2009;55(5):539–549. doi:10.1159/000211949
45. Conte M, Vasuri F, Trisolino G, et al. Increased Plin2 expression in human skeletal muscle is associated with sarcopenia and muscle weakness. *PLoS One*. 2013;8(8):e73709. doi:10.1371/journal.pone.0073709
46. Huo YR, Suriyaarachchi P, Gomez F, et al. Comprehensive nutritional status in sarco-osteoporotic older fallers. *J Nutr Health Aging*. 2015;19(4):474–480. doi:10.1007/s12603-014-0543-z
47. Lana LD, Schneider RH. The frailty syndrome in elderly: a narrative review. Article in Portuguese. *Rev Bras Geriatr Gerontol*. 2014;17(3):673–680. doi:10.1590/1809-9823.2014.12162
48. Lang T, Streeter T, Cawthon P, Baldwin K, Taaffe DR, Harris TB. Sarcopenia: etiology, clinical consequences, intervention, and assessment. *Osteoporos Int*. 2010;21(4):543–559. doi:10.1007/s00198-009-1059-y
49. Hernández Morante JJ, Gómez Martínez C, Morillas-Ruiz JM. Dietary factors associated with frailty in old adults: a review of nutritional interventions to prevent frailty development. *Nutrients*. 2019;11(1):102. doi:10.3390/nu11010102
50. Tanimoto Y, Watanabe M, Sun W, et al. Sarcopenia and falls in community-dwelling elderly subjects in Japan: Defining sarcopenia according to criteria of the European Working Group on Sarcopenia in Older People. *Arch Gerontol Geriatr*. 2014;59(2):295–299. doi:10.1016/j.archger.2014.04.016
51. Bian A, Ma Y, Zhou X, et al. Association between sarcopenia and levels of growth hormone and insulin-like growth factor-1 in the elderly. *BMC Musculoskelet Disord*. 2020;21(1):214. doi:10.1186/s12891-020-03236-y
52. Murakami M, Hirano H, Watanabe Y, Sakai K, Kim H, Katakura A. Relationship between chewing ability and sarcopenia in Japanese community-dwelling older adults. *Geriatr Gerontol Int*. 2015;15(8):1007–1012. doi:10.1111/ggi.12399
53. Runyan CW, Casteel C, Perkins D, et al. Unintentional injuries in the home in the United States: Part I: Mortality. *Am J Prev Med*. 2005;28(1):73–79. doi:10.1016/j.amepre.2004.09.010