ARCHIVES OF HELLENIC MEDICINE: ISSN 11-05-3992

REVIEW
ΑΝΑΣΚΟΠΗΣΗ

ARCHIVES OF HELLENIC MEDICINE 2025, 42(4):470–474
ΑΡΧΕΙΑ ΕΛΛΗΝΙΚΗΣ ΙΑΤΡΙΚΗΣ 2025, 42(4):470–474

Sarcopenia and hip fractures

M. Tsekoura

Laboratory of Clinical Physiotherapy and Research, Department of Physiotherapy, School of Health Rehabilitation Sciences, University of Patras, Rion, Greece

Hip fractures are a common occurrence in older adults. Their prevalence is increasing globally and have a significant impact on older adults. Sarcopenia could be considered as a hip fracture risk factor. The diagnosis of sarcopenia in hip fracture patients is a challenge for health professionals. A multidisciplinary rehabilitative intervention seems to be effective in functioning in hip fracture patients with sarcopenia. Evidence shows that multicomponent exercise interventions that encompass strength training and balance exercise may increase mobility and quality of life. The nutritional supplementation and exercise programs are mandatory for sarcopenia prevention and treatment.

Σαρκοπενία και κατάγματα ισχίου

Περίληψη στο τέλος του άρθρου

Key words

Hip fractures
Prevention
Rehabilitation
Sarcopenia

Submitted 11.6.2024
Accepted 6.7.2024

1. INTRODUCTION

Hip fracture is an important medical condition worldwide particularly in the elderly population.[1,2] The incidence of hip fractures is expected to increase due to aging populations worldwide.[1] Higher hip fracture incidence is observed in industrialized countries (northern Europe, the US) compared to developing countries in Latin America and Africa.[3] The majority of hip fractures are the result of a fall, especially among older people.[2,4]

Hip fractures are associated with adverse outcomes, including poor mobility, reduced activities of daily living (ADL), decrease in quality of life, social costs, economic consequences and mortality.[2,5] Half of all hip fracture survivors will develop permanent impairments in mobility and 10–20% will become institutionalized.[6] Many people who have had a hip fracture are unable to return to their pre-fracture level of autonomy. Some risk factors may be age, presence of comorbidities, lack of autonomy prior to the fracture and prolonged bed rest.[7] Sarcopenia, malnutrition and comorbidity are factors associated with poor functional outcomes and an increased mortality post-surgery.[8–11]

Geriatric patients with sarcopenia are vulnerable to both falls and hip fractures.[11,12] Sarcopenia could be considered as a hip fracture risk factor.[5,13] There is also a link between sarcopenia and falls in the older adults with a hip fracture.[14] Various researchers record a high prevalence of sarcopenia in geriatric patients with hip fracture.[15–17] A greater sarcopenia prevalence and more diminished leg muscle mass has been reported in people following a hip fracture than uninjured subjects with the same age.[15] However, further studies are needed to determine the relationship between muscle mass and type of hip fracture.[13]

Sarcopenia was first defined by Rosenberg as an age-associated loss of skeletal muscle mass.[18] According to the Second European Working Group on Sarcopenia in Older People (EWGSOP2), sarcopenia is defined as a *"progressive and generalized skeletal muscle disorder that is associated with increased likelihood of adverse outcomes including falls, fractures, physical disability and mortality"*.[19] Possible explanation for the relationship between sarcopenia and the risk of hip fracture may be that sarcopenic patients have low muscle strength and muscle mass which increases the risk of falls. Poor muscle strength, poor gait speed and previous falls could all independently predict near-term fracture risk in community-dwelling older adults.[20] In addition, muscle mass may be positively related to lower quality of bones.[21,22] Several studies have shown that patients diagnosed with osteoporosis and sarcopenia, so-called osteosarcopenia, have a higher risk of falls and fractures.[23,24] Aging is also

related to the decrease of mass and strength of skeletal muscles (especially for people after 65 years of age), leading to an increased risk of adverse outcomes such as hip fractures.[5,25]

Sarcopenia in patients' post-surgery may have nearly double the mortality risk compared to non-sarcopenic patients following hip fractures.[26] It was also proven that hip fracture patients with sarcopenia have lower mobility at one-year after surgery.[27] It has been reported that about 5% to 6% of muscle loss occurs within one year after hip fracture.[28] Sarcopenia may be an independent predictor of poor functional recovery and a decrease in life quality for geriatric hip fracture patients at 6-months after surgery.[11] Sarcopenia could significantly increase the risk of future hip fracture in old people; thus, the prevention of hip fractures in patients with sarcopenia is considered crucial for preserving an acceptable quality of life in community dwelling older adults.[5,22]

The aim of this review is to summarize evidence and evaluate preventive and rehabilitation strategies of sarcopenia in patients with hip fracture.

2. DIAGNOSIS OF SARCOPENIA IN PATIENTS WITH HIP FRACTURE

The assessment of sarcopenia is based on low levels of three measured parameters: muscle strength, muscle quantity/quality and physical performance, as an indicator of its severity. In its 2018 definition, EWGSOP2 uses low muscle strength as the primary parameter of sarcopenia. Hand grip strength measurement using a calibrated handheld dynamometer is proposed for muscle strength measurement. When measurement of grip is not possible due to hand disability, chair stand test may be performed.[19] For patients with hip fractures, it remains controversial whether measurement of grip strength alone is an effective evaluation method for the management of sarcopenia. In addition, many patients have postoperative delirium or neurological disease, making measurement of handgrip strength difficult using current standardized protocols.[29]

Muscle mass can be estimated by a variety of techniques such as magnetic resonance imaging (MRI) and computed tomography (CT), dual-energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA).[19,30] CT and MRI have a high cost and it is difficult to find institutes where it is possible to quickly perform them. In patients with hip fracture, diagnosis with DXA is difficult due to surgical implant metal artifacts.[29,31] Health professionals also report the difficulty of performing this examination in patients with hip fracture due to post-surgical pain and immobility.[5] In addition, the lack of whole body DXA software in many hospitals makes a body composition assessment in a hip fractured subject almost impossible, at least in the early stages.[32]

Physical performance can be variously measured by gait speed, the short physical performance battery (SPPB), and the Timed-up and Go test (TUG).[19] However, evaluation of physical ability in patients with hip fractures is not possible. These tests are not useful during the acute phase of hip fracture in the hospital.[32] Gait status and lower extremity strength cannot be properly evaluated in patients with hip fractures due to their pain and loss of walking ability at the time of injury. Only hand grip strength can be measured.[29]

For all the above, previous studies have reported on the usefulness of the SARC-F questionnaire for screening sarcopenia in community dwellings.[19,33] SARC-F is a quick, inexpensive and convenient for sarcopenia self-reported risk screening tool.[19] However, the SARC-F can detect with precision the absence of sarcopenia and is proposed as an effective tool for selecting persons who should undergo further testing for confirming a diagnosis of sarcopenia.[33,34]

3. PREVENTION AND TREATMENT OF SARCOPENIA IN PATIENTS WITH HIP FRACTURE

The management of sarcopenia in hip fractured patients is extremely challenging, as there are no standardized and treatment protocols.[32]

3.1. Prevention of sarcopenia in patients with hip fracture

The prevention of hip fractures is considered crucial for preserving an acceptable quality of life in older patients. For these reasons, the role of the muscles function is crucial to prevent various consequences (e.g., traumas) in older patients.[5,35] Health professionals need to understand its risk factors in order to reduce the incidence of fracture. Among the risk factors identified for fracture, sarcopenia and falls are two important components that could be potentially modified in short term.[20] Physical activity programs have been suggested as a relevant technique in reducing the risk of hip fracture in older patients.[5] In addition, older adults who are physically active, maintain higher upper and lower body strength, and may have significantly lower odds of sarcopenia.[36]

Existing evidence indicates the potential importance of diets of adequate quality, to ensure sufficient intakes

of protein, vitamin D, and antioxidant nutrients. Recommended protein intakes may, therefore, need to be raised in older people in order to maintain nitrogen balance and to protect them from sarcopenic muscle loss.[37] Proper nutrition is important in hip fracture patients. In rehabilitation settings malnutrition is associated with functional decline, especially protein-energy malnutrition, worse functional status and poor recovery.[32] However, muscle mass and strength achieved in later life reflect the peak attained earlier in life. Optimizing diet and nutrition throughout life may be key to preventing sarcopenia and promoting physical capability in older age.[38]

Several authors promoted for patients with hip fracture, the combination of oral nutritional supplementation with proteins and amino acids and therapeutic exercise programs.[5,39] It has been proved that exercise can prevent or slow the progression of sarcopenia.[40] Resistance exercise training may be performed for treating, slowing, and or preventing.[41] A multimodal exercise program (including balance and strength exercises of major muscle groups) may also improve muscle strength and physical performance.[40]

3.2. Treatment of sarcopenia in patients with hip fracture

Treatment of sarcopenia is mainly non pharmacological.[42] The treatment of sarcopenia in patients affected by hip fractures is a multidisciplinary challenge. In elderly hip fracture patients the recovery of functionality and mobility to restore the independence of patients after hip surgery and in the following 6 months is a key point.[43] When sarcopenia is present, the muscle quantity is decreased and therefore, developing an adjusted intervention is extremely important to promote safety and recovery.[19,43]

Intervention for sarcopenia may include nutritional interventions.[9] First, adequate nutrition to ensure the intake of micronutrients and macronutrients is needed.[42] A report from the International Sarcopenia Initiative (EWGSOP and IWGS) concluded that essential amino acids, including 2,5 g of leucine, β-hydroxy β-methylbutyrate (HMB) and the increase of protein intake to 1,2 g/kg/day, could improve the muscle parameters.[44] Literature shows that the protein intake should spread equally over three meals and maintenance of serum vitamin D levels to 100 nmoL/L (40 ng/mL) from vitamin D-rich diet or vitamin D supplementation.[42]

Exercise training will increase muscle mass and strength, helping outpatient recovery, which is the primary outcome in these patients. The most effective physical therapy seems to be exercise of progressive resistance.[42] Both for sarcopenia and patients with hip fracture the literature has shown that multicomponent exercise interventions that encompass strength training and balance exercise may increase mobility and quality of life.[43,45,46] In addition fall prevention education, counseling and home ergonomic interventions may also help these patients.[42,47] Progressive resistance training, associated with occupational therapy may show improvements in walking ability, strength and general mobility, especially in the short-term rehabilitation of sarcopenic patients.[48]

In two studies researchers applied exercise programs for ten days after surgery in hip fracture patients with sarcopenia.[48,49] No significant improvement in handgrip strength was observed. Therefore exercise for 10 days after surgery is considered too short to improve sarcopenia. Further research is needed on the intensity and duration of exercise that can increase muscle mass in hip fracture patients.[29]

Nutritional support, combined with task-specific repetitive exercises, is supported by accumulating evidence for improving sarcopenia and preventing disability.[50] A multidisciplinary rehabilitation and nutritional intervention seems to be effective in functioning in hip fracture patients, in particular sarcopenic ones.[43]

As for medical therapy, no drugs are specifically designed for the treatment of sarcopenia. Testosterone, growth hormone and beta-adrenergic receptor agonists are commonly used to improve sarcopenia,[51] but more research is needed because they do not always improve muscle function.

4. CONCLUSIONS

Sarcopenia is associated with poor functional recovery and a decrease in quality of life and could also increase the risk of future hip fracture in old people. The treatment of sarcopenia should be a combination of methods including nutritional intervention and therapeutic exercise. Health professionals should design effective interventions for muscle regeneration in order to improve the quality of life of postoperative patients with sarcopenia.

ΠΕΡΙΛΗΨΗ

Σαρκοπενία και κατάγματα ισχίου

Μ. ΤΣΕΚΟΥΡΑ

Εργαστήριο Κλινικής Φυσικοθεραπείας και Έρευνας, Τμήμα Φυσικοθεραπείας, Σχολή Επιστημών Αποκατάστασης Υγείας, Πανεπιστήμιο Πατρών, Ρίο

Αρχεία Ελληνικής Ιατρικής 2025, 42(4):470–474

Τα κατάγματα ισχίου είναι πολύ συχνά σε ηλικιωμένα άτομα. Η συχνότητα εμφάνισης των καταγμάτων αυξάνεται παγκοσμίως και επηρεάζει σημαντικά τους ηλικιωμένους. Ένας σημαντικός παράγοντας κινδύνου για την εμφάνιση των καταγμάτων είναι η σαρκοπενία. Η διάγνωση της σαρκοπενίας συνιστά πρόκληση για τους επαγγελματίες υγείας. Απαιτείται διεπιστημονική προσέγγιση στην αποκατάσταση ώστε να βελτιωθεί η λειτουργικότητα στους ασθενείς με σαρκοπενία και κάταγμα ισχίου. Η εφαρμογή προγραμμάτων με συνδυασμό ασκήσεων με αντιστάσεις και ασκήσεων ισορροπίας πιθανόν να βελτιώσει την κινητικότητα και την ποιότητα ζωής των ασθενών αυτών. Τα συμπληρώματα διατροφής και η εφαρμογή προγραμμάτων άσκησης είναι υποχρεωτικά για την πρόληψη και την αντιμετώπιση της σαρκοπενίας σε ασθενείς με κάταγμα ισχίου.

Λέξεις ευρετηρίου: Αποκατάσταση, Κατάγματα ισχίου, Πρόληψη, Σαρκοπενία

References

1. GULLBERG B, JOHNELL O, KANIS JA. World-wide projections for hip fracture. *Osteoporos Int* 1997, 7:407–413
2. ILIC I, RISTIC B, STOJADINOVIC I, ILIC M. Epidemiology of hip fractures due to falls. *Medicina (Kaunas)* 2023, 59:1528
3. DHANWAL DK, DENNISON EM, HARVEY NC, COOPE C. Epidemiology of hip fracture: Worldwide geographic variation. *Indian J Orthop* 2011, 45:15–22
4. JAMES SL, LUCCESI LR, BISIGNANO C, CASTLE CD, DINGELS ZV, FOX JT ET AL. The global burden of falls: Global, regional and national estimates of morbidity and mortality from the Global Burden of Disease Study 2017. *Inj Prev* 2020, 26(Suppl 1):i3–i11
5. TESTA G, VESCIO A, ZUCCALÀ D, PETRANTONI V, AMICO M, RUSSO GI ET AL. Diagnosis, treatment and prevention of sarcopenia in hip fractured patients: Where we are and where we are going: A systematic review. *J Clin Med* 2020, 9:2997
6. OSNES EK, LOFTHUS CM, MEYER HE, FALCH JA, NORDSLETTEN L, CAPPELEN I ET AL. Consequences of hip fracture on activities of daily life and residential needs. *Osteoporos Int* 2004, 15:567–574
7. KOUDOUNA S, EVANGELOPOULOS DS, SARANTIS M, CHRONOPOULOS E, DONTAS IA, PNEUMATICOS S. The effect of postoperative physical therapy following hip fracture: A literature. *Cureus* 2023, 15:e37676
8. FRIED LP, TANGEN CM, WALSTON J, NEWMAN AB, HIRSCH C, GOTTDIENER J ET AL. Frailty in older adults: Evidence for a phenotype. *J Gerontol A Biol Sci Med Sci* 2001, 56:M146–M156
9. PROBERT N, LÖÖW A, AKNER G, WRETENBERG P, ANDERSSON ÅG. A comparison of patients with hip fracture, ten years apart: Morbidity, malnutrition and sarcopenia. *J Nutr Health Aging* 2020, 24:870–877
10. GONZÁLEZ-MONTALVO JI, ALARCÓN T, GOTOR P, QUEIPO R, VELASCO R, HOYOS R ET AL. Prevalence of sarcopenia in acute hip fracture patients and its influence on short-term clinical outcome. *Geriatr Gerontol Int* 2016, 16:1021–1027
11. CHEN YP, WONG PK, TSAI MJ, CHANG WC, HSIEH TS, LEU TH ET AL. The high prevalence of sarcopenia and its associated outcomes following hip surgery in Taiwanese geriatric patients with a hip fracture. *J Formos Med Assoc* 2020, 119:1807–1816
12. ELHAKEEM A, HARTLEY A, LUO Y, GOERTZEN AL, HANNAM K, CLARK EM ET AL. Lean mass and lower limb muscle function in relation to hip strength, geometry and fracture risk indices in community-dwelling older women. *Osteoporos Int* 2019, 30:211–220
13. IIDA H, SEKI T, SAKAI Y, WATANABE T, WAKAO N, MATSUI H ET AL. Low muscle mass affect hip fracture treatment outcomes in older individuals: A single-institution case-control study. *BMC Musculoskelet Disord* 2021, 22:259
14. LIM SK, BEOM J, LEE SY, KIM BR, CHUN SW, LIM JY ET AL. Association between sarcopenia and fall characteristics in older adults with fragility hip fracture. *Injury* 2020, 51:2640–2647
15. HIDA T, ISHIGURO N, SHIMOKATA H, SAKAI Y, MATSUI Y, TAKEMURA M ET AL. High prevalence of sarcopenia and reduced leg muscle mass in Japanese patients immediately after a hip fracture. *Geriatr Gerontol Int* 2013, 13:413–420
16. DI MONACO M, CASTIGLIONI C, VALLERO F, DI MONACO R, TAPPERO R. Sarcopenia is more prevalent in men than in women after hip fracture: A cross-sectional study of 591 inpatients. *Arch Gerontol Geriatr* 2012, 55:e48–e52
17. HO AW, LEE MM, CHAN EW, NG HM, LEE CW, NG WS ET AL. Prevalence of pre-sarcopenia and sarcopenia in Hong Kong Chinese geriatric patients with hip fracture and its correlation with different factors. *Hong Kong Med J* 2016, 22:23–29
18. ROSENBERG IH. Sarcopenia: Origins and clinical relevance. *Clin Geriatr Med* 2011, 27:337–339
19. CRUZ-JENTOFT AJ, BAHAT G, BAUER J, BOIRIE Y, BRUYÈRE O, CEDERHOLM T ET AL. Sarcopenia: Revised European consensus on definition and diagnosis. *Age Ageing* 2019, 48:16–31
20. SU Y, LAM FMH, LEUNG J, CHEUNG WH, HO SC, KWOK T. The predictive value of sarcopenia and falls for 2-year major osteoporotic fractures in community-dwelling older adults. *Calcif Tissue*

Int 2020, 107:151–159
21. SZULC P, BLAIOZOT S, BOUTROY S, VILAYPHIU N, BOONEN S, CHAPURLAT R. Impaired bone microarchitecture at the distal radius in older men with low muscle mass and grip strength: The STRAMBO study. *J Bone Miner Res* 2013, 28:169–178
22. HUANG P, LUO K, XU J, HUANG W, YIN W, XIAO M ET AL. Sarcopenia as a risk factor for future hip fracture: A meta-analysis of prospective cohort studies. *J Nutr Health Aging* 2021, 25:183–188
23. 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* 2016, 28:895–899
24. TSEKOURA M, BILLIS E, TSEPIS E, FOUSEKIS K, GLIATIS J. Osteosarcopenia: A brief overview of the disease of the future. *Arch Hellen Med* 2020, 37:752–757
25. CRUZ-JENTOFT AJ, BAEYENS JP, AUER JM, BOIRIE Y, CEDERHOLM T, LANDI M ET AL. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age Ageing* 2010, 39:412–423
26. MALAFARINA V, MALAFARINA C, UGARTE AB, MARTINEZ JA, GOÑI IA, ZULET MA. Factors associated with sarcopenia and 7-year mortality in very old patients with hip fracture admitted to rehabilitation units: A pragmatic study. *Nutrients* 2019, 11:2243
27. STEIHAUG OM, GJESDAL CG, BOGEN B, KRISTOFFERSEN MH, LIEN G, HUFTHAMMER KO ET AL. Does sarcopenia predict change in mobility after hip fracture? A multicenter observational study with one-year follow-up. *BMC Geriatr* 2018, 18:65
28. FOX KM, MAGAZINER J, HAWKES WG, YU-YAHIRO J, HEBEL JR, ZIMMERMAN SI ET AL. Loss of bone density and lean body mass after hip fracture. *Osteoporos Int* 2000, 11:31–35
29. YOO JI, KIM JT, PARK CH, CHA Y. Diagnosis and management of sarcopenia after hip fracture surgery: Current concept review. *Hip Pelvis* 2022, 34:1–9
30. TSEKOURA M, BILLIS E, GLIATIS J, MATZAROGLOU C, KOUTSOJANNIS C, TSEPIS E ET AL. Assessment of muscle mass in the elderly in clinical practice. *Arch Hellen Med* 2017, 34:745–753
31. SPIRO AJ, HOANG TD, SHAKIR MKM. Artifacts affecting dual-energy X-ray absorptiometry measurements. *AACE Clin Case Rep* 2019, 5:e263–e266
32. DIONYSSIOTIS Y, LEÓN AOG. Sarcopenia and hip fractures. *J Frailty Sarcopenia Falls* 2024, 9:1–3
33. TSEKOURA M, BILLIS E, TSEPIS E, LAMPROPOULOU S, BEAUDART C, BRUYERE O ET AL. Cross-cultural adaptation and validation of the Greek version of the SARC-F for evaluating sarcopenia in Greek older adults. *J Musculoskelet Neuronal Interact* 2020, 20:505–512
34. IDA S, NAKAI M, ITO S, ISHIHARA Y, IMATAKA K, UCHIDA A ET AL. Association between sarcopenia and mild cognitive impairment using the Japanese version of the SARC-F in elderly patients with diabetes. *J Am Med Dir Assoc* 2017, 18:809.e9–809.e13
35. AUAIS M, MORIN S, NADEAU L, FINCH L, MAYO N. Changes in frailty-related characteristics of the hip fracture population and their implications for healthcare services: Evidence from Quebec, Canada. *Osteoporos Int* 2013, 24:2713–2724
36. MEIER NF, LEE DC. Physical activity and sarcopenia in older adults. *Aging Clin Exp Res* 2020, 32:1675–1687
37. WOLFE RR, MILLER SL, MILLER KB. Optimal protein intake in the elderly. *Clin Nutr* 2008, 27:675–684
38. ROBINSON S, COOPER C, SAYER AA. Nutrition and sarcopenia: A review of the evidence and implications for preventive strategies. *J Aging Res* 2012, 2012:510801
39. PIASTRA G, PERASSO L, LUCARINI S, MONACELLI F, BISIO A, FERRANDO V ET AL. Effects of two types of 9-month adapted physical activity program on muscle mass, muscle strength, and balance in moderate sarcopenic older women. *Biomed Res Int* 2018, 2018:5095673
40. CHAN DC, CHANG CB, HAN DS, HONG CH, HWANG JS, TSAI KS ET AL. Effects of exercise improves muscle strength and fat mass in patients with high fracture risk: A randomized control trial. *J Formos Med Assoc* 2018, 117:572–582
41. LAW TD, CLARK LA, CLARK BC. Resistance exercise to prevent and manage sarcopenia and dynapenia. *Annu Rev Gerontol Geriatr* 2016, 36:205–228
42. AVOLA M, MANGANO GRA, TESTA G, MANGANO S, VESCIO A, PAVONE V ET AL. Rehabilitation strategies for patients with femoral neck fractures in sarcopenia: A narrative review. *J Clin Med* 2020, 9:3115
43. ROCHA P, BAIXINHO CL, MARQUES A, HENRIQUES MA. Safety-promoting interventions for the older person with hip fracture on returning home: A systematic review. *Int J Orthop Trauma Nurs* 2024, 52:101063
44. CRUZ-JENTOFT AJ, LANDI F, SCHNEIDER SM, ZÚÑIGA C, ARAI H, BOIRIE Y ET AL. Prevalence of and interventions for sarcopenia in ageing adults: A systematic review. Report of the International Sarcopenia Initiative (EWGSOP and IWGS). *Age Ageing* 2014, 43:748–759
45. LEE SY, YOON BH, BEOM J, HA YC, LIM JY. Effect of lower-limb progressive resistance exercise after hip fracture surgery: A systematic review and meta-analysis of randomized controlled studies. *J Am Med Dir Assoc* 2017, 18:1096.e19–1096.e26
46. TSEKOURA M, BILLIS E, KASTRINIS A, KATSOULAKI M, FOUSEKIS K, TSEPIS E ET AL. The effects of exercise in patients with sarcopenia. *Adv Exp Med Biol* 2021, 1337:281–290
47. TSEKOURA M, MATZAROGLOU C, XERGIA S, DIONYSSIOTIS Y, TSEPIS E, SAKELLARI V ET AL. The feasibilty of the motor control home ergonomics elderlies' prevention of falls (McHeELP) programme in patients with sarcopenia: A pilot study. *J Frailty Sarcopenia Falls* 2014, 9:89–95
48. LIM SK, BEOM J, LEE SY, LIM JY. Functional outcomes of fragility fracture integrated rehabilitation management in sarcopenic patients after hip fracture surgery and predictors of independent ambulation. *J Nutr Health Aging* 2019, 23:1034–1042
49. OH MK, YOO JI, BYUN H, CHUN SW, LIM SK, JANG YJ ET AL. Efficacy of combined antigravity treadmill and conventional rehabilitation after hip fracture in patients with sarcopenia. *J Gerontol A Biol Sci Med Sci* 2020, 75:e173–e181
50. INVERNIZZI M, SIRE A, D'ANDREA F, CARRERA D, RENÒ F, MIGLIACCIO S ET AL. Effects of essential amino acid supplementation and rehabilitation on functioning in hip fracture patients: A pilot randomized controlled trial. *Aging Clin Exp Res* 2019, 31:1517–1524
51. TEZZE C, SANDRI M, TESSARI P. Anabolic resistance in the pathogenesis of sarcopenia in the elderly: Role of nutrition and exercise in young and old people. *Nutrients* 2023, 15:4073

Corresponding author:

M. Tsekoura, Panepistimioupoli, Building B, 265 04 Rion, Achaia, Greece
e-mail: mariatsekoura@upatras.gr