

Can Vitamin D Positively Impact Sarcopenia Severity Among Older Adults with Hand Osteoarthritis: A Review of the Evidence

Ray Marks^{1,*}

¹Department of Health and Behavior Studies, Teachers College, Columbia University, New York, NY 10027, USA

Article Type: Review Article

Open Access & Peer-Reviewed Article

DOI: 10.14302/issn.2474-7785.jarh-23-4550

Received: Apr 03, 2023

Accepted: Apr 04, 2023

Published: Apr 07, 2023

Corresponding author:

Ray Marks, Department of Health and Behavior Studies, Teachers College, Columbia University, New York, NY 10027, USA

Keywords:

Aging, hand osteoarthritis, muscle atrophy, sarcopenia, vitamin D.

Citation:

Ray Marks (2023) Can Vitamin D Positively Impact Sarcopenia Severity Among Older Adults with Hand Osteoarthritis: A Review of the Evidence. - 4(4):1-13. <https://doi.org/10.14302/issn.2474-7785.jarh-23-4550>

Abstract

Aim

This review examines the research base concerning hand osteoarthritis and changes in muscle mass and quality known as sarcopenia and the possible use of vitamin-D supplementation for reducing this potentially adverse functionally disabling state.

Methods

Publications detailing a possible link between hand osteoarthritis manifestations and sarcopenia, plus those discussing vitamin D as a possible intervention strategy for minimizing sarcopenia in the older adult were systematically sought and reviewed.

Results

Collectively, data reveal hand osteoarthritis in the older population is common, and is possibly affected by age as well as disease associated muscle mass declines. Vitamin D, a powerful steroid required by the body to foster many life affirming physiological functions may help reduce the degree of any prevailing sarcopenia and thereby some degree of hand osteoarthritis disability.

Conclusions

Older individuals with hand osteoarthritis, as well as healthy older adults at risk for sarcopenia are likely to benefit physically from efforts to clarify the extent of this association and if indicated, to examine and intervene thoughtfully to maximize muscle composition as well as safe vitamin D levels where subnormal. Researchers can make highly notable impacts in multiple spheres in this regard and are encouraged to do so.

Introduction

Osteoarthritis, the most common joint disease, and one affecting one or more freely moving joints in the older adult population, is not only painful, and disabling, but generally considered to be progressive and incurable. A disease with few universally successful treatments for countering its high personal and collective burden, that occurring at the hand is potentially more disabling than that at the hip or knee where surgical replacement therapy is quite successful, but for many is more challenging to undertake at the hand, especially if the osteoarthritis manifestations are deemed 'erosive' [1]. As opposed to the disease at the hip and/or knee where non-weightbearing functions involving the upper limb can still be undertaken, the ability to carry out those multiple precision hand tasks requiring refined degrees of muscle control and coordination that are commonly required during the course of any day may be increasingly and severely compromised in the face of osteoarthritis of one or more hand joints, thus extremely impairing. Moreover, even if the hand is not used actively, the presence of pain and inflammatory disease processes may weaken the hand muscles, thus exposing the joints to more rather than less stress, along with objective signs of progressive degrees of hand muscle atrophy [2]. At the same time, among the presumed or probable causes of osteoarthritis in general, and possibly in some cases at the hand, in particular, is a condition affecting many older adults known as sarcopenia involving a generalized state of progressive muscle mass and/or muscle quality declines [3, 4], that may be implicated in pain and muscle weakness as well as diverse inflammatory states that commonly accompanies the disease [1, 5, 6]. This narrative report focuses on identifying some aspects of what is known about osteoarthritis and sarcopenia, a commonly observed health state in older adults, as well as cases with advanced osteoarthritis pathology [6, 7], and the possible role that could be played by vitamin D as a possible antidote to the disabling features of hand osteoarthritis in the older adult who may suffer from or develop signs of sarcopenia and its negative functional impacts and ramifications. Since the presence of an adequate serum level of vitamin D may prove helpful for ameliorating pain and fostering muscle function, and sunlight, one source of vitamin D be challenging to harness by many who are home or nursing home bound or live in northern countries, or who are bound by a variety of cultural norms and dress codes, socioeconomic disparities, or living in regions where the potency of ultraviolet light is diminished as a result of global warming, can a case be made for vitamin D supplementation among older at risk adults among those who have definitive hand osteoarthritis or generalized osteoarthritis? Indeed, older adults, especially those who now have restrictions placed on their movements due to pain or inadvertent social disadvantages [8], may not only be highly vulnerable to the consequences of sarcopenia, but also to a state of vitamin D deficiency, and may not be able to readily perform many self-care activities if their hands are weak and painful [9].

Discussed is the evidence base in favor of efforts to ensure all citizens, including older adults, and especially those with chronic health conditions associated with declines in muscle mass for any reason, may benefit from efforts to avert remedial deficiencies of vitamin D, as well as excess muscle mass fat encroachment and its associated sarcopenic determinants. The topic of hand osteoarthritis, generally a progressively highly disabling disease of one or more hand joints, that vastly reduces life quality for many older adults, is poorly understood, hence examining the possible risk factors of sarcopenia and vitamin D deficiencies that are under studied or not studied at all relative to hand osteoarthritis may help to delineate more effective intervention and prevention approaches and outcome benefits in the future [10].

Drawn largely from the **PUBMED** database, the overview should provide the interested reader a general view of past work as well as current trends in this regard that might be worthy of further consideration

and study, as well as applications in the health care field.

Osteoarthritis, which may occur independently as a separate health condition, or in conjunction with one or more chronic health conditions, may not be life threatening, but even if not, may induce or exacerbate the presence of other illnesses, while heightening prevailing adverse life events and functional losses, including immense life quality and socioeconomic losses. While the world waits for a possible breakthrough in pain control and osteoarthritis mitigation [11], remedies to offset excess risk of excess osteoarthritis disability including its association with sarcopenia and its consequences, now shown to be a profound aging determinant in its own right, must surely be earnestly sought and all avenues of possibility linking this adverse health state to osteoarthritis disability in older populations explored. In this regard, another body of mounting evidence points to a possible role for vitamin D in explaining some aspects of obesity-that can produce an excess of muscle fat mass to the exclusion of viable muscle tissue, a well established osteoarthritis determinant, excess or premature joint, bone, and muscle specific degeneration, as well as possible benefits of intervening in this regard to offset or minimize this risk, even though not mentioned directly in a successfully implemented single session of information provided for cases with hand osteoarthritis or a synthesis of its epidemiological or biomechanical determinants [12-14].

Although research in this realm is clearly in its infancy, and based largely on limited numbers of observational and intervention based studies, cases with a dual sarcopenia and osteoarthritis diagnosis do appear to be at risk for a worse prognosis than those with adequate muscle mass, and is a state that may be reversed in the presence of prevailing adequate serum levels of vitamin D and careful early comprehensive joint protection, exercise, orthotics, and pain relief [14]. Since many adults suffer from this particular deficiency, it can be argued that a proportion of hand osteoarthritis cases, where abnormal joint mechanics may be linked to obesity, and metabolic influences [15], the ability to discern this or assess this possibility may be paramount in multiple ways, even if surgery is undertaken. Since serum vitamin D levels may be subnormal due to various factors such as a limited access to sunlight exposure, exposure to foods or beverages containing vitamin D, and/or vitamin D supplementation in vulnerable older adults, consideration of efforts to assess and address any deficiency in this regard, especially in those with muscle pain and hand weakness may yet prove more beneficial than not.

Indeed, if found to be influential in any way, intervention in this regard may provide one reasonably practical pathway for purposes of securing the well-being of the affected older adult suffering from hand osteoarthritis, especially in the case of any associated chronic health condition that alone can heighten risk of sarcopenia and a deficient motivation for any painful hand movement or activity. Others may be given medications that render them susceptible to excessive joint loading and/or to eventual possible narcotic impacts, since older adults with hand osteoarthritis are generally less likely to be targeted surgically [7], or prove 'good' surgical candidates due to the intricacies of the hand structure and its unique functions, especially those who may have healing challenges due to diabetes, as well as being vitamin D deficient and suffering from its negative impact on bone health.

This work is significant because the ability to minimize hand disability and severity must surely be of the highest importance by policy makers and others, as well as the older population who want to 'age in place', rather than be in a passive hospital based setting or a setting requiring outside assistance. Osteoarthritis self-management, while shown to be of value, may be too challenging to pursue in the event unrelenting hand pain and stiffness prevail, especially among the elderly confined to their homes in isolation.

To obtain the data for this review, the electronic data sources **PUBMED**, **Google Scholar**, and **PubMed Central**, believed to hold a majority of prevailing peer reviewed related works were carefully searched. The key time period searched ranged from January 1 2020- March 30, 2023, but background data from earlier periods was deemed acceptable. The key words selected by the author included the topics of: *hand osteoarthritis, muscle atrophy, sarcopenia, vitamin D, older adults, and osteoarthritis*. All forms of study or analysis were deemed acceptable. However, because most studies barely touched on the topics of current interest, no consistent thematic or systematic analytic approach could be conducted among these diverse widely heterogeneous reports. Hence only a narrative summary of all key data embedded in the one or more of the electronic resources databases including case studies, and uncontrolled observational studies was implemented. Selected material had to focus on some aspect of hand osteoarthritis, vitamin D related facts relevant to sarcopenic risk and recovery, as well as to symptoms of hand osteoarthritis in the older adult. Excluded were articles that did not focus specifically on this set of issues, abstracts, and non English based articles.

In addition, the value of vitamin D in the context of health status, including obesity as well as muscle associated physiological benefits that shows this compound in its various forms has the potential to strongly influence overall health status and outcomes across the lifespan, including the manifestations of excess muscle fat mass among the elderly, also termed sarcopenic obesity prevalent in knee osteoarthritis [23] is rarely discussed or supported. Its presence at the desired physiological level can however be demonstrated to influence the extent of any prevailing muscle atrophy [24], as well as possible selected outcomes of incurring osteoarthritis disability [25-27].

Current reports

Among the 2564 listed studies and reports retrieved from the present search between 2017-2023 when using the term 'hand osteoarthritis', very few can be said to focus on the causes of hand osteoarthritis other than joint biomechanics, even though multiple factors have been identified [28]. Some attention is given to surgical interventions, while a fair percentage of listed articles are non English, discuss genetics, or various treatments other than exercise, hand osteoarthritis subsets, and measurement approaches, or disease risk factors that do not discuss muscle or vitamin D in any way, and hence failed to meet criteria for this report. At the same time, the current topic of interest, along with muscle associated factors are rarely discussed even though osteoarthritis is considered a disease of all joint tissues including muscles, as well as being a condition where dysfunctional movements of one or more digits during hand activity can accelerate the disease [29, 30] as well as possible sarcopenia [31], and where pain may have central features as well as neuropathic correlates [22]. Some indication that atherosclerosis may underlie some forms of hand osteoarthritis and that may be informative do not however discuss how this condition and its determinants may impact the mass of the muscles surrounding the affected joints of the hand or wrist as implied by observations of Yoo et al. [32]. In particular, they do not clearly explain whether the vascular disease that was recognized was obesity related or not [33], even though hand osteoarthritis trends appear to map those of increasing obesity trends among women to some degree [34] and may be associated over time with bone attrition rather than bone enlargement [35], a possible correlate of sarcopenia and poor physical conditioning as occurs in many older adults with osteoarthritis [36]. Yet, another report that examined cases with hand osteoarthritis through ultrasound and imaging applications did not discuss the nature of the supporting tissues, such as muscles, that may have been revealing [37], given the high numbers of older adults, especially those with arthritis who are likely to have probable sarcopenia, a progressive health condition that impacts the ability to generate muscle force and physical activities [36, 38, 39] and at the intracellular level, key factors are qualitative changes in posttranslational modifications of muscle proteins and the loss of

coordinated control between contractile, mitochondrial, and sarcoplasmic reticulum protein expression. In addition there may be quantitative and qualitative changes in skeletal muscle that influence wellbeing significantly [4], as well as possible joint laxity due to progressive abnormalities in these structures, along with possible proprioceptive sensorimotor disturbances that may partially implicate muscle spindles [40]. Yet, as per Renjith and George [41] a systematic review of exercise applications and others for mitigating hand osteoarthritis, have continued to underreport features specific to hand osteoarthritis, such as the pattern of joint involvement and numbers of affected joints, and hence why some non-inflammatory cases affected by hand osteoarthritis show no evidence of hand strength and dexterity declines, but possibly show varying degrees of bone margin changes [42].

Another report clearly shows that simply combining several supplements known for their inflammatory potential to cases with hand osteoarthritis does not have any benefit when compared to a control situation [43]. However, even though sarcopenia is more likely to occur in older adults with suboptimal vitamin D serum levels [44-47], and skeletal muscle cell function and dysfunction [48] no allusion to vitamin D was forthcoming or discussed in the article, perhaps because the study conducted in Australia assumed its citizens to have adequate vitamin D exposure.

A further search for almost all non pharmacologic interventions showed a plethora of approaches such as disease modifying drugs, injections and various cartilage building supplements, splinting, various modalities, education, hydrotherapy, and strengthening exercises, but no specific studies on vitamin D or alternately mediated targeted approaches to build muscle mass where deficient or encroached upon by excess muscle fat mass specifically [49], as mentioned for the shoulder [50], and knee [7] and hip [51]. This was despite some evidence that vitamin D inadequacy or deficiency is related to muscle fiber atrophy, elevated risk of chronic musculoskeletal pain, sarcopenia, and falls [52]. Also, the use of splinting as a sole intervention approach must be questioned in those with pain or instability because this approach may induce, rather than mitigate, muscle atrophy of the splinted digit, as well as possible general hand muscle atrophy [53]. In the same vein, denervation surgery and injection of certain substances to alleviate hand pain in cases with osteoarthritis of one or more joints may yield some unwanted side effects [54, 55], especially in the face of a lack of consistent comprehensive global assessment and carefully targeted intervention approaches and follow up. Inclusion of cases with successful outcomes in some studies, while excluding failures or failing to detect adverse impacts because of a lack of timely clinically relevant objective outcome assessments are design attributes that may need serious attention in the future [49].

State of the research

As noted above, the reports documented in this review, which are largely current, show very little progress in either establishing why hand osteoarthritis occurs, why it is so common, and why not all older adults will exhibit this condition. This may be because research in osteoarthritis has mostly focused on examining cartilage pathology and efforts to regenerate this tissue, or various studies on knee, and hip osteoarthritis. When mentioned, sarcopenia, which may be a strong predictor of osteoarthritis in sizeable numbers of older adults is commonly studied in isolation, rather than in realm of osteoarthritis, despite some reasonably obvious overlap between these conditions [56, 57]. Unsurprisingly, remedies advocated for alleviating hand osteoarthritis have literally not changed for decades, and almost no study could be found linking hand osteoarthritis specifically to sarcopenia, especially among those suffering from obesity, which could be highly pertinent. Moreover, the pervasive idea that strengthening the hand muscles will allay the severity of hand osteoarthritis, has not been thoroughly examined as a monotherapy, nor has a rationale for this approach been adequately

demonstrated by employing advanced biomechanical, radiographic, and disease indicators and functional outcome measures.

A role for muscle sarcopenia can however, possibly explain some forms or manifestations of hand osteoarthritis, even if not carefully studied to date in this regard, especially if one considers its association with possible age associated shifts in vitamin D uptake mechanisms and usage [58], plus muscle fiber type distribution alterations, including alterations from from fast to slow twitch muscle fibers, plus adverse muscle proteomic and contractile protein changes [59]. It is possible the lack of any sarcopenic or vitamin D focus in this regard is due to an emergent rather than any past global epidemic of obesity and/or vitamin D deficiencies that may not have been noteworthy at the inception of hand osteoarthritis epidemiological studies. However, since more contemporary studies have been able to demonstrate a key role for the vitamin D/VDR axis in regulating biological processes central to sarcopenic muscle atrophy, such as proteolysis, mitochondrial function, cellular senescence, and adiposity, new research concepts must surely be duly considered of relevance in this line of inquiry in the future in this author's view. The aim of this review was hence to explore if indeed there is a mechanistic linkage between sarcopenia and hand osteoarthritis pathology in at least some older adults, as well whether vitamin D or the vitamin D/VDR axis implicated in sarcopenic muscle atrophy [58] offers some support for exploring vitamin D supplementation in at risk older adults. The possible interaction of factors that might prove fruitful to explore in carefully designed future research are outlined below [see Figure 1].

Discussion

Although modern medicine has previously been quite successful in managing acute health conditions, it is less successful in arresting rates of conditions such as osteoarthritis, regardless of joint site[s] affected. While the world awaits an effective cure for this condition it appears safe to say more might be done in the interim to prevent the condition and to mitigate its impact, especially at the hand, where comparatively fewer reports prevail if contrasted with knee or hip joint osteoarthritis. This is because not

Figure 1. Possible Pathways Underpinning Hand Osteoarthritis Disability in the Older Adult [Adapted from: 32, 40, 57, 60, 61, 72-75]

- Muscle weakness, aging, occupational stresses
- Hand pain, stiffness, joint laxity/deformity
- Immobility, joint inflammation, swelling
- Decreases in hand sensorimotor function, self-care and overall function
- *Obesity/excess weight loss/low vitamin D levels
- *Muscle morphometry changes/wasting/sarcopenia
- Increased hand joint stresses and erosion
- Biomechanically derived bone and cartilage changes/functional impairment/muscle weakness

*Adaptive or predisposing factors or both

only has past evidence indicated that hand osteoarthritis might be incorrectly diagnosed as well as poorly treated [60], but evidence to clearly show what the factors are that are influencing the incidence and severity of hand osteoarthritis may not have been revealed adequately because there are few studies that embody or encompass possible correlates of metabolism, genetics, occupation, nutritional status, health status and weight status among other factors [28]. Thus, modifiable factors or being able to discern who is most at risk for hand osteoarthritis, and why, remains to be uncovered, and possibly directed with greater efficacy towards eliminating abnormal joint forces. Moreover, cumulative evidence of a possible muscle atrophic association, associated with age, as well as the disease, plus possible sarcopenic obesity impacts need to be carefully examined.

A further body of data linking some forms of osteoarthritis to vitamin D points not only to the impact of vitamin D on muscle health, but for maximizing the well being of older adults with osteoarthritis, in general [62]. In contrast, it appears low vitamin D levels, may adversely impact both local as well as general muscle mass and quality in many older adults and that can lead to the risk of hand joint attrition or perpetuate this, among other interactive mechanisms, such as a possible mediating role in obesity and bone strength, inflammation, and physical associated complications along with declining levels of muscle strength and physical ability that may be offset to some degree in the presence of adequate vitamin D levels [63-65]. A role for abnormalities in the muscle vitamin D receptors that can foster varying degrees of muscle atrophy in selected cases of osteoarthritis in some older adults can also not be ruled out [66].

However, to validate these ideas, as well as to solidify the data, and overcome conjecture, well-powered and carefully conceived clinical, as well as epidemiological and neuromuscular oriented biomechanical research of older adults of varying ages with and without hand osteoarthritis and objectively confirmed sarcopenia should be conducted, and less reliance placed on past studies and the aggregation of these diverse studies, even if individually the included studies are deemed rigorous and free of design flaws. A possible role for vitamin D muscle receptors abnormalities or gene expression variations in explaining some forms of sarcopenia in osteoarthritis, as well as why vitamin D supplementation may not prove efficacious for affecting osteoarthritis muscle morphology should not be overlooked [67, 68].

As per Huang et al. [69] the maintenance of muscle homeostasis is vital for life and health, hence it is not surprising that skeletal muscle atrophy not only seriously reduces people's quality of life and increases morbidity and mortality, but also causes a huge socioeconomic burden. To date, no effective treatment has been developed for skeletal muscle atrophy owing to an incomplete understanding of its molecular mechanisms. Exercise therapy is the most effective treatment for skeletal muscle atrophy. Unfortunately, it is not suitable for all patients, such as fractured patients and bedridden patients with nerve damage. Therefore, understanding the molecular mechanism of skeletal muscle atrophy is crucial for developing new therapies for skeletal muscle atrophy.

Future research directions

Areas that could be fruitful to focus on in the future are examining

The correlates of prevailing health status, serum vitamin D status, muscle fat infiltration and mass, plus muscle strength and coordination as well as hand function, dexterity, pain and joint inflammation in carefully designed and documented case studies.

Other topics that might prove fruitful if examined more intently are those examining muscle architecture, muscle fiber and cross sectional variations at the hand in cases with varying degrees of osteoarthritis, plus hand muscle functional and possible morphometric responses to vitamin D, along with weight control strategies relative to any observed muscle fat mass encroachment and extent [70].

Moreover, since the vitamin D dosages that would possibly prove impactful among various older adults at risk for ameliorating sarcopenia are not well established at all, more attention to this issue appears necessary. At the same time, greater efforts towards controlling for current medication and supplement usage, as well as sunlight in forthcoming studies is essential.

In the interim as per Pickering et al. [56], there is a great need for high quality prospective studies on the apparent complex interactions and linkages between concomitant sarcopenic muscle tissue changes and osteoarthritis, plus more translational research, in order to identify common denominators as regards the management and possible prevention of sarcopenia, osteoarthritis, and their comorbidities.

Veronese et al. [71] agree sarcopenia and osteoarthritis are significantly intercorrelated and in the near future should be considered as one entity, as recently proposed for sarcopenia and osteoporosis. The treatment of both sarcopenia and osteoarthritis using physical exercise and nutritional interventions with the aim of improving cartilage, bone and muscle health is hence expected to hold great promise in this regard according to these authors. Future well designed studies are needed though to ascertain the precise prevalence of sarcopenia in older adults with early as well as late stage hand osteoarthritis, and its specific functional consequences. Not only should consideration be given to the bilateral assessment of various forearm muscles, but also to the finger flexors, the wrist muscles and thumb muscles in conjunction with measures of their unique hand associated functions [72, 73]. The parallel associations here to any vitamin D deficits and obesity linkages that are potential pathogenic correlates of the disease also warrant careful study [74, 75].

Conclusions

The present analysis, while not without limitations, appears to clearly and conclusively imply

1. Hand osteoarthritis remains immensely problematic to control and treat, especially among older adults with pre existing muscle weakness, and various metabolic conditions such as obesity.
2. A fair percentage of hand osteoarthritis cases could be impacted favourably by efforts to ascertain the extent of any specific hand muscle mass decline, and to avert this or mitigate this in a targeted manner.
3. A role for the interaction of vitamin D supplements in explaining any muscle mass decline and efforts to ensure its optimal intake or availability, as indicated, may prove highly fruitful as well.
4. Ascertaining whether this approach may help seems imperative in light of the immense suffering incurred by many, and the many gaps in the understandings of this condition that may lessen this.

Acknowledgements

None

Conflicts of Interest

None

Funding

None

References

1. Favero M, Belluzzi E, Ortolan A, Lorenzin M, Oliviero F, et al. Erosive hand osteoarthritis: latest findings and outlook. *Nat Rev Rheumatol.* 2022;18(3):171-183. doi: 10.1038/s41584-021-00747-3.
2. Tossini NB, Lessi GC, Zacharias AL, e Silva GR, Abrantes LS, et al. Impairment of electrical activation of wrist flexor and extensor muscles during gripping and functional activities in the early

- stage of hand osteoarthritis: a cross-sectional study. *J Hand Ther.* 2021;34(1):109-15.
3. Lunt E, Ong T, Gordon AL, Greenhaff PL, Gladman JRF. The clinical usefulness of muscle mass and strength measures in older people: a systematic review. *Age Ageing.* 2021;50(1):88-95. doi: 10.1093/ageing/afaa123.
 4. Larsson L, Degens H, Li M, Salviati L, Lee YI, et al. Sarcopenia: aging-related loss of muscle mass and function. *Physiol Rev.* 2019;99(1):427-511. doi: 10.1152/physrev.00061.2017.
 5. Basat S, Sivritepe R, Ortoboz D, Sevim E, Atay S, et al. The relationship between osteoarthritis and sarcopenia in geriatric diabetic patients. *Sisli Etfal Hastan Tip Bul.* 2021;55(4):516-523. doi: 10.14744/SEMB.2021.42890.
 6. Ueoka K, Kabata T, Kajino Y, Inoue D, Ohmori T, et al et al. The prevalence and impact of sarcopenia in females undergoing total hip arthroplasty: a prospective study. *Mod Rheumatol.* 2022;32(1):193-198. doi: 10.1080/14397595.2021.1899603.
 7. Ho KK, Lau LC, Chau WW, Poon Q, Chung KY, et al. End-stage knee osteoarthritis with and without sarcopenia and the effect of knee arthroplasty - a prospective cohort study. *BMC Geriatr.* 2021;21(1):2. doi: 10.1186/s12877-020-01929-6.
 8. Swan L, Warters A, O'Sullivan M. Socioeconomic inequality and risk of sarcopenia in community-dwelling older adults. *Clin Int Aging.* 2021:1119-1129.
 9. Bevilacqua G, Laskou F, Patel HP, Westbury LD, Fuggle NR, et al. What impact does osteoarthritis have on ability to self-care and receipt of care in older adults? Findings from the Hertfordshire Cohort Study. *Osteoarthr Cartil Open.* 2022;4(4):100310. doi: 10.1016/j.ocarto.2022.100310.
 10. Shah K, Yang X, Lane JCE, Collins GS, Arden NK, et al. Risk factors for the progression of finger interphalangeal joint osteoarthritis: a systematic review. *Rheumatol Int.* 2020;40(11):1781-1792. doi: 10.1007/s00296-020-04687-1.
 11. Tenti S, Bruyère O, Cheleschi S, Reginster JY, Veronese N, et al. An update on the use of conventional and biological disease-modifying anti-rheumatic drugs in hand osteoarthritis. *Ther Adv Musculoskelet Dis.* 2023;15:1759720X231158618. doi: 10.1177/1759720X231158618.
 12. Stoffer-Marx MA, Klinger M, Luschin S, Meriaux-Kratochvila S, Zettel-Tomenendal M, et al. Functional consultation and exercises improve grip strength in osteoarthritis of the hand - a randomised controlled trial. *Arthritis Res Ther.* 2018;20(1):253. doi: 10.1186/s13075-018-1747-0.
 13. Marshall M, Watt FE, Vincent TL, Dziedzic K. Hand osteoarthritis: clinical phenotypes, molecular mechanisms and disease management. *Nat Rev Rheumatol.* 2018;14(11):641-656. doi: 10.1038/s41584-018-0095-4.
 14. Kerkhof F, Kenney D, Ogle M, Shelby T, Ladd A. The biomechanics of osteoarthritis in the hand: implications and prospects for hand therapy. *J Hand Ther.* 2022;35(3):367-376. doi: 10.1016/j.jht.2022.11.007.
 15. Plotz B, Bomfim F, Sohail MA, Samuels J. Current epidemiology and risk factors for the development of hand osteoarthritis. *Curr Rheumatol Rep.* 2021;23(8):61. doi: 10.1007/s11926-021-01025-7.
 16. Bae EJ, Kim YH. Factors affecting sarcopenia in Korean adults by age groups. *Osong Publ Hth Res Perspect.* 2017;8(3):169-178. doi: 10.24171/j.phrp.2017.8.3.03.
 17. Billig JI, Nasser JS, Chung KC. National prevalence of complications and cost of small joint arthro-

- plasty for hand osteoarthritis and post-traumatic arthritis. *J Hand Surg.* 2020;45(6):553-e1.
18. Kulkarni K, Karssiens T, Kumar V, Pandit H. Obesity and osteoarthritis. *Maturitas.* 2016;89:22-8.
 19. Estes JP, Bochenek C, Fassler P. Osteoarthritis of the fingers. *J Hand Ther.* 2000;13(2):108-123. doi: 10.1016/s0894-1130(00)80035-6.
 20. Farrell M, Gibson S, McMeeken J, Helme R. Pain and hyperalgesia in osteoarthritis of the hands. *J Rheumatol.* 2000;27(2):441-447.
 21. Leung GJ, Rainsford KD, Kean WF. Osteoarthritis of the hand I: aetiology and pathogenesis, risk factors, investigation and diagnosis. *J Pharm Pharmacol.* 2014;66(3):339-46. doi: 10.1111/jphp.12196.
 22. van der Meulen C, van de Stadt LA, Rosendaal FR, Runhaar J, Kloppenburg M. Determination and characterization of patient subgroups based on pain trajectories in hand osteoarthritis. *Rheumatol.* 2023;kead017. doi: 10.1093/rheumatology/kead017..
 23. Godziuk K, Prado CM, Woodhouse LJ, Forhan M. Prevalence of sarcopenic obesity in adults with end-stage knee osteoarthritis. *Osteoarthritis Cartilage.* 2019;27(12):1735-1745. doi: 10.1016/j.joca.2019.05.026.
 24. Domingues-Faria C, Chanet A, Salles J, Berry A, Giraudet C, et al. Vitamin D deficiency down-regulates Notch pathway contributing to skeletal muscle atrophy in old wistar rats. *Nutr Metab.* 2014;11(1):1-3.
 25. Solovieva S, Hirvonen A, Siivola P, Vehmas T, Luoma K, et al. Vitamin D receptor gene polymorphisms and susceptibility of hand osteoarthritis in Finnish women. *Arthritis Res Ther.* 2005;8:1-9.
 26. Dechsupa S, Yingsakmongkol W, Limthongkul W, Singhatanadgige W, Jitjumnong M, et al. Vitamin D inadequacy affects skeletal muscle index and physical performance in lumbar disc degeneration. *Int J Mol Sci.* 2023;24(4):3152. doi: 10.3390/ijms24043152.
 27. Chen J, Zhang J, Li J, Qin R, Lu N, et al. 1,25-Dihydroxyvitamin D deficiency accelerates aging-related osteoarthritis via downregulation of Sirt1 in mice. *Int J Biol Sci.* 2023;19(2):610-624. doi: 10.7150/ijbs.78785.
 28. Eaton CB, Schaefer LF, Duryea J, Driban JB, Lo GH, et al. Prevalence, incidence, and progression of radiographic and symptomatic hand osteoarthritis: the Osteoarthritis Initiative. *Arthritis Rheumatol.* 2022;74(6):992-1000. doi: 10.1002/art.42076.
 29. Davis JE, Schaefer LF, McAlindon TE, Eaton CB, Roberts MB, et al. Characteristics of accelerated hand osteoarthritis: data from the Osteoarthritis Initiative. *J Rheumatol.* 2019;46(4):422-428. doi: 10.3899/jrheum.180240.
 30. Gracia-Ibáñez V, Agost MJ, Bayarri-Porcar V, Granell P, Vergara M, et al. Hand kinematics in osteoarthritis patients while performing functional activities. *Disabil Rehabil.* 2023;45(7):1124-1130. doi: 10.1080/09638288.2022.2051082.
 31. Gao Q, Hu K, Yan C, Zhao B, Mei F, et al. Associated factors of sarcopenia in community-dwelling older adults: a systematic review and meta-analysis. *Nutrients.* 2021;13(12):4291. doi: 10.3390/nu13124291.
 32. Yoo JI, Kim MJ, Na JB, Chun YH, Park YJ, et al. Relationship between endothelial function and skeletal muscle strength in community dwelling elderly women. *J Cachexia Sarcopenia Muscle.* 2018;9(6):1034-1041. doi: 10.1002/jcsm.12340.

33. Macêdo MB, Santos VMOS, Pereira RMR, Fuller R. Association between osteoarthritis and atherosclerosis: a systematic review and meta-analysis. *Exp Gerontol.* 2022;161:111734. doi: 10.1016/j.exger.2022.111734.
34. Hoveidaei AH, Nakhostin-Ansari A, Chalian M, Razavi SE, Khonji MS, et al. Burden of hand osteoarthritis in the Middle East and North Africa (MENA): an epidemiological analysis from 1990 to 2019. *J Hand Surg Am.* 2023;48(3):245-256. doi: 10.1016/j.jhsa.2022.11.016.
35. Sowers M, Zobel D, Weissfeld L, Hawthorne VM, Carman W. Progression of osteoarthritis of the hand and metacarpal bone loss. A twenty-year followup of incident cases. *Arthritis Rheum.* 1991;34(1):36-42. doi: 10.1002/art.1780340106.
36. Fox B, Henwood T, Schaap L, Bruyère O, Reginster JY, et al. Adherence to a standardized protocol for measuring grip strength and appropriate cut-off values in adults over 65 years with sarcopenia: a systematic review protocol. *JBIS Database System Rev Implement Rep.* 2015;13(10):50-59. doi: 10.11124/jbisrir-2015-2256.
37. Husic R, Finzel S, Stradner MH, Dreu M, Hofmeister A, et al. Ultrasound in osteoarthritis of the hand: a comparison to computed tomography and histology. *Rheumatol.* 2022;61(SI):SI73-SI80. doi: 10.1093/rheumatology/keab526.
38. Pérez-Sousa MÁ, Pozo-Cruz JD, Cano-Gutiérrez CA, Izquierdo M, Ramírez-Vélez R. High prevalence of probable sarcopenia in a representative sample from Colombia: implications for geriatrics in Latin America. *J Am Med Dir Assoc.* 2021;22(4):859-864.e1. doi: 10.1016/j.jamda.2020.10.021.
39. Wearing J, Konings P, de Bie RA, Stokes M, de Bruin ED. Prevalence of probable sarcopenia in community-dwelling older Swiss people - a cross-sectional study. *BMC Geriatr.* 2020;20(1):307. doi: 10.1186/s12877-020-01718-1.
40. Ouegnin A, Valdes K. Joint position sense impairments in older adults with carpometacarpal osteoarthritis: a descriptive comparative study. *J Hand Ther.* 2020;33(4):547-552.
41. Renjith V, George A. Effect of exercises on clinical outcomes of patients with hand osteoarthritis. *Orthop Nurs.* 2021;40(1):44-45. doi: 10.1097/NOR.0000000000000729.
42. Güven N, Dinçer F, Çetin A, Güven SC. Hand strength and dexterity in interphalangeal hand osteoarthritis and effects of osteophyte formations. *Adv Rheumatol.* 2020;60(1):41. doi: 10.1186/s42358-020-00143-7.
43. Liu X, Robbins S, Eyles J, Fedorova T, Virk S, et al. Efficacy and safety of a supplement combination on hand pain among people with symptomatic hand osteoarthritis an internet-based, randomised clinical trial the RADIANT study. *Osteoarthritis Cartilage.* 2021;29(5):667-677. doi: 10.1016/j.joca.2021.01.011.
44. Remelli F, Vitali A, Zurlo A, Volpato S. Vitamin D deficiency and sarcopenia in older persons. *Nutrients.* 2019;11(12):2861. doi: 10.3390/nu11122861.
45. Uchitomi R, Oyabu M, Kamei Y. Vitamin D and sarcopenia: potential of vitamin D supplementation in sarcopenia prevention and treatment. *Nutrients.* 2020;12(10):3189. doi: 10.3390/nu12103189.
46. Garcia M, Seelaender M, Sotiropoulos A, Coletti D, Lancha AH Jr. Vitamin D, muscle recovery, sarcopenia, cachexia, and muscle atrophy. *Nutrition.* 2019;60:66-69. doi: 10.1016/j.nut.2018.09.031.

47. Ganapathy A, Nieves JW. Nutrition and sarcopenia-what do we know? *Nutrients*. 2020;12(6):1755. doi: 10.3390/nu12061755.
48. Fantini C, Corinaldesi C, Lenzi A, Migliaccio S, Crescioli C. Vitamin D as a shield against Aging. *Int J Mol Sci*. 2023;24(5):4546. doi: 10.3390/ijms24054546.
49. Mi H, Oh C, Towheed T. Systematic review of non-surgical therapies for osteoarthritis of the hand: an update. *Eur J Rheumatol*. 2023 Feb 6. doi: 10.5152/eurjrheum.2023.21197.
50. Sayed-Noor AS, Pollock R, Elhassan BT, Kadum B. Fatty infiltration and muscle atrophy of the rotator cuff in stemless total shoulder arthroplasty: a prospective cohort study. *J Shoulder Elbow Surg*. 2018;27(6):976-982. doi: 10.1016/j.jse.2017.12.021.
51. Chang K, Albright JA, Testa EJ, Balboni AB, Daniels AH, et al. Sarcopenia is associated with an increased risk of postoperative complications following total hip arthroplasty for osteoarthritis. *Biology*. 2023;12(2):295.
52. Abiri B, Vafa M. Vitamin D and muscle sarcopenia in aging. *Methods Mol Biol*. 2020;2138:29-47. doi: 10.1007/978-1-0716-0471-7_2.
53. Arazpour M, Soflaei M, Ahmadi Bani M, Madani SP, Sattari M, et al. The effect of thumb splinting on thenar muscles atrophy, pain, and function in subjects with thumb carpometacarpal joint osteoarthritis. *Prosthet Orthot Int*. 2017;41(4):379-386. doi: 10.1177/0309364616664149.
54. Zhu SL, Chin B, Sarraj M, Wang E, Dunn EE, et al. Denervation as a treatment for arthritis of the hands: a systematic review of the current literature. *Hand*. 2023;18(2):183-191. doi: 10.1177/1558944721994251.
55. Oo WM, Hunter DJ. Efficacy, safety, and accuracy of intra-articular therapies for hand osteoarthritis: current evidence. *Drugs Aging*. 2023;40(1):1-20. doi: 10.1007/s40266-022-00994-3.
56. Pickering ME, Chapurlat R. Where two common conditions of aging meet: osteoarthritis and sarcopenia. *Calc Tissue Int*. 2020;107:203-211.
57. Vlietstra L, Stebbings S, Meredith-Jones K, Abbott JH, Treharne GJ, et al. Sarcopenia in osteoarthritis and rheumatoid arthritis: the association with self-reported fatigue, physical function and obesity. *PLoS One*. 2019;14(6):e0217462. doi: 10.1371/journal.pone.0217462.
58. Bollen SE, Bass JJ, Fujita S, Wilkinson D, Hewison M, et al. The vitamin D/Vitamin D receptor (VDR) axis in muscle atrophy and sarcopenia. *Cell Signal*. 2022;96:110355. doi: 10.1016/j.cellsig.2022.110355.
59. Dowling P, Gargan S, Swandulla D, Ohlendieck K. Fiber-type shifting in sarcopenia of old age: proteomic profiling of the contractile apparatus of skeletal muscles. *Int J Mol Sci*. 2023;24(3):2415. doi: 10.3390/ijms24032415.
60. Swanson AB, de Groot Swanson G. Osteoarthritis in the hand. *Clin Rheum Dis*. 1985;11(2):393-420.
61. Kalichman L, Hernández-Molina G. Hand osteoarthritis: an epidemiological perspective. *Sem Arthritis Rheum*. 2010;39(6):465-476.
62. Rizzoli R, Stevenson JC, Bauer JM, van Loon LJ, Walrand S, et al; ESCEO Task Force. The role of dietary protein and vitamin D in maintaining musculoskeletal health in postmenopausal women: a consensus statement from the European Society for Clinical and Economic Aspects of Osteoporosis and Osteoarthritis (ESCEO). *Maturitas*. 2014;79(1):122-32. doi: 10.1016/j.maturitas.2014.07.005..

63. Cho MR, Lee S, Song SK. A review of sarcopenia pathophysiology, diagnosis, treatment and future direction. *J Korean Med Sci.* 2022;37(18):e146. doi: 10.3346/jkms.2022.37.e146.
64. Udomsinprasert W, Manoy P, Yuktanandana P, Tanavalee A, Anomasiri W, et al. Decreased serum adiponectin reflects low vitamin D, high interleukin 6, and poor physical performance in knee osteoarthritis. *Arch Immunol Ther Exp (Warsz).* 2020;68(3):16. doi: 10.1007/s00005-020-00580-8.
65. Manoy P, Anomasiri W, Yuktanandana P, Tanavalee A, Ngarmukos S, et al. Elevated serum leptin levels are associated with low vitamin D, sarcopenic obesity, poor muscle strength, and physical performance in knee osteoarthritis. *Biomarkers.* 2017;22(8):723-730. doi: 10.1080/1354750X.2017.1315615.
66. Scimeca M, Centofanti F, Celi M, Gasbarra E, Novelli G, et al. Vitamin D receptor in muscle atrophy of elderly patients: a key element of osteoporosis-sarcopenia connection. *Aging Dis.* 2018;9(6):952-964. doi: 10.14336/AD.2018.0215.
67. Cuellar WA, Blizzard L, Hides JA, Callisaya ML, Jones G, et al. Vitamin D supplements for trunk muscle morphology in older adults: secondary analysis of a randomized controlled trial. *J Cachexia Sarcopenia Muscle.* 2019;10(1):177-187. doi: 10.1002/jcsm.12364.
68. Bahat G, Saka B, Erten N, Ozbek U, Coskunpinar E, et al. BsmI polymorphism in the vitamin D receptor gene is associated with leg extensor muscle strength in elderly men. *Aging Clin Exp Res.* 2010;22(3):198-205. doi: 10.1007/BF03324797.
69. Huang L, Li M, Deng C, Qiu J, Wang K, et al. Potential therapeutic strategies for skeletal muscle atrophy. *Antioxidants.* 2022;12(1):44. doi: 10.3390/antiox12010044.
70. Charles J, Kissane R, Hoehfurtner T, Bates KT. From fibre to function: are we accurately representing muscle architecture and performance? *Biol Rev Camb Philos Soc.* 2022;97(4):1640-1676. doi: 10.1111/brv.12856.
71. Veronese N, Punzi L, Sieber C, Bauer J, Reginster JY, et al, Task Finish Group on “Arthritis” of the European Geriatric Medicine Society. Sarcopenic osteoarthritis: a new entity in geriatric medicine?. *Eur Geriatr Med.* 2018:141-148.
72. Jarque-Bou NJ, Gracia-Ibáñez V, Roda-Sales A, Bayarri-Porcar V, Sancho-Bru JL, et al. Toward early and objective hand osteoarthritis detection by using EMG during Grasps. *Sensors.* 2023;23(5):2413.
73. Karademir F, Ayhan Kuru C, Arin G, Soylu R. Morphometry of thenar muscles by water bath ultrasonography in trapeziometacarpal osteoarthritis: intra-and inter-rater reliability. *J Hand Surg.* 2023;48(2):115-22.
74. Iqbal F, Khani GM, Siddiqui MA, Ali A. Risk factors associated with development of early knee osteoarthritis-multicenter cross-sectional study. *J Pakistan Orthop Assoc.* 2023;35(01):07-12.
75. Pegreff F, Balestra A, De Lucia O, Smith L, Barbagallo M, et al. Prevalence of sarcopenia in knee osteoarthritis: a systematic review and meta-analysis. *J Clin Med.* 2023;12(4):1532.