

## Hand Osteoarthritis and Motor Function: What Does the 2023 Evidence Base Imply?

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### Abstract

**Background:** Osteoarthritis of the hand, a disabling painful health condition, has been a topic of great interest to clinicians, patients, and researchers for many years with no definitive consensus on its origins or most efficacious form of treatment or prevention. While various determinants such as age and occupation or both have been proposed to have an influence on this condition, perhaps more specific attention to its functional correlates such as muscle, often an osteoarthritis treatment target, may prove enlightening in this regard.

**Aim:** This mini review sought to examine what researchers have reported over the years concerning the role muscle function deficits may play in the progression of hand osteoarthritis in older adults, if any.

**Methods:** A search for the available English language related literature housed in several key data bases detailing the combined topics of hand osteoarthritis and motor/muscle function was undertaken in an effort to uncover what has been observed, and whether any observation is of special interest.

**Results:** Cumulative findings appear to support an important role for efforts to examine muscle function and treat this accordingly where subnormal in adults with or at risk for hand osteoarthritis.

**Conclusion:** Future well-designed case studies of various hand osteoarthritis samples using clinically relevant biomechanical, neurological, and biochemical outcome instruments are likely to prove extremely valuable in explaining the disease etiology and averting the onset and progression of disabling hand osteoarthritis manifestations.

**Keywords:** *Hand Function; Hand Osteoarthritis; Motor Function; Older Adults*

### Background

Chronic osteoarthritis, a disease affecting one or more freely moving joints, such as the hip, knee, and hand joints is commonly accompanied by progressive bouts of disabling pain and declining functional abilities, both weight-bearing as well as non-weight-bearing. Although studied for more than 100 years, the disease features such as pain, stiffness, and reduced function continue to present a challenge to mitigate or prevent especially among those most impacted, namely older adults, and many older women, in particular [1]. A disease associated with a variety of oftentimes progressive biological, biochemical, cellular, molecular, and joint tissue pathological changes, the

condition can 'spread' from affecting a single joint, such as the knee, to affect others, such as the hand, for example if a fall due to knee osteoarthritis disability results in a wrist fracture. Regardless of cause or affected joint site, the manifestations of the disease may extend to involve tissues other than cartilage and bone, and synovial membrane alterations with subsequent multiple cellular and functional alterations, and degradation products that may trigger innate immunity, and a persistent state of low-grade joint tissue inflammation [2].

Unfortunately, despite numerous intensive research studies and the development of various disease modifying drug attempts [3], the condition commonly fails to be improved by one or more available currently advocated pharmacologic approaches. In addition, even when apparently sound recommendations are made, for example, self management, this approach may not be feasible among adults in the higher age groups if their hands are impaired in some way, for example in feeding activities [1]. Moreover, splinting, injection, and some medications may not be helpful in all cases and may prove harmful if either too little movement or too much movement is pursued as a result, among other factors [4]. While surgery may be desirable at some point if the disease worsens with age, that at the hand is often not indicated, nor without complications, and does not always facilitate function in the long-term, or prove aesthetically satisfying. Exercises or rest commonly advocated for treating hand osteoarthritis cannot be said to provide uniform long lasting mitigation of the condition to any degree at present.

Other recommendations such as weight control strategies and joint protection may not prove helpful for achieving pain relief and enhancing joint status in all cases, especially if these are not carefully construed and titrated in light of the individual, and their underlying osteoarthritis pathology. This includes that related to muscle or associated sensory-motor sources of osteoarthritis pathology at the hand that may reside at any point in the hand neural control pathways, although not mentioned by Gabay, *et al.* [5], Leung, *et al.* [6], Shah, *et al.* [7], or Plotz, *et al.* [8].

Since a failure to mitigate the degree of suffering attributable to hand osteoarthritis, the most common form of peripheral osteoarthritis [8], may prevent an older adult from 'aging in place', and heighten the need for some form of assistance and possible full time care, efforts to examine all possible contributing factors that influence this condition may yet have far reaching meaningful life quality as well as economic impacts for a fair number of affected aging individuals as well as society [9]. Alternately, a failure to do this might theoretically exacerbate the multiple adverse disabling consequences of hand osteoarthritis, including emotional, social, and life quality factors [10-17], progressively and severely, especially in the face of persistent or unrelenting hand pain and unidentified muscle abnormalities that are modifiable.

### Rationale and assumptions

As in the case of osteoarthritis at the hip or knee, current options to promote joint comfort in the case of hand osteoarthritis remain limited and rely largely on a variety of medications believed to reduce pain, but that can also have adverse health effects, such as narcotic dependency and local exacerbation of joint cartilage tissue destruction. Some of the pain at the hand experienced by the older osteoarthritis sufferer may however stem from abnormalities in the structure and function, strength, and endurance of one or more muscles surrounding the diseased joints, and hence this possible often unrecognized pain source has been deemed important to consider and possibly to target [18,19]. In turn, severe osteoarthritis associated hand pain may have an unanticipated impact on important protective aspects of joint associated neural programming related to the timely and optimal execution of muscle responses to perturbations and the ability of the affected individual to withstand prolonged hand usage [20]. However, the specific muscle abnormalities that may underpin pain and the risk of hand joint damage and that could impact joint biomechanics as well as biochemistry and neuromotor plus joint physiology or be induced by the disease have not been studied or clearly clarified to any generalizable degree. As supported by most recent authors in this field however, muscles may have a strong bearing on the ability to withstand repetitive loads, as well as on life promoting hand mobility, grasping, pinching, hand dexterity and manipulation activities. Essential too, for fostering joint nutrition processes, bone physiology, and muscle-bone cross-talk, muscle factors may be especially important to identify, characterize, and possibly to specifically

intervene upon strategically in the case of hand, as well as other forms of osteoarthritis [21], and perhaps especially in the relatively challenging subset of hand osteoarthritis where the disease accelerates rapidly [22].

### Aims of the Review

In light of the immense numbers of older adults who may be suffering from both physical pain and disability, as well as emotional pain because their hands may be swollen or the joints enlarged in size at some joint sites, and in light of expectant increases in the disease prevalence and incidence, a strong rationale for exploring all pathways that may lead to some form of osteoarthritis pain relief and possible joint function is strongly indicated.

In particular, and in accord with the conclusions reached by O'Neill, *et al.* [23], knowledge about the occurrence and risk factors for osteoarthritis, are currently very limited [7], even though this is very key to reducing the immense clinical and public health burden of this painful disabling disease. Moreover, a better understanding of the mechanisms of the disease, such as pain and functional limitations occurring at the hand may not only help to expand our disease understandings, and thereby inform the development of more profound individual prevention and intervention strategies prior to the onset of irreversible disease manifestations [24], but may enable more self-management approaches to be effected, and more desirable 'residential and living' environmental options for the older impaired adult.

To this end, the review aimed to examine the evidence regarding one or more aspects pertaining to possible single or multiple abnormal motor system based manifestations that may accompany hand osteoarthritis or increase its risk of excess pain and pathology, as well as skeletal muscle wasting that often accompanies the disease [25]. This review is significant because even though this is a promising topic, this is a topic rarely studied in a comprehensive manner, but is one that may yet prove fruitful and highly insightful [9,27].

This topic was also chosen as a focal one in this mini review because it may also reveal pathways of adaptation that may be intervened upon favorably as well as explaining some manifestations of this heterogeneous disease, that is also largely deemed a biomechanical one [27]. There may also be highly relevant but untested associations of deficient muscle based physiology with a possible link to an obesity or genetic basis for the disease in some cases, for example diabetes [28], as well as disease modifying compensatory muscle and/or motor cortex neural network alterations that warrant consideration [29-31].

### Hypotheses

It was hypothesized that where studied:

1. Hand osteoarthritis cases would exhibit several objectively observable neuromotor patterns of activity that were not the same as control healthy age matched controls.
2. It was further hypothesized that varied forms of muscle abnormalities would be observed, rather than any consistent pattern.

### Methods

To provide background material that may help enhance comprehension of this current idea, available data accessible to the public and located in PUBMED detailing some of the natural features of hand osteoarthritis and possible muscle correlates were initially searched, as this specific data base houses a majority of the world's most salient English language peer reviewed journals published in the medical field. Other sites explored were PubMed Central, Science Direct, and Google Scholar. Studies that did not encompass hand osteoarthritis in the older population in some way were excluded, along with muscle morphology investigations, surgically oriented and exercise studies, measures of muscle that were structural rather than functional, preprints, study proposals, and abstracts. The term motor function was used to describe aspects of muscle coordination, or neuromuscular responses to extrinsic movements or various stimuli. No distinction was made as regards which hand osteoarthritis joints were affected specifically, or whether the hand osteoarthritis was unilateral or bilateral, recent or chronic, and the term applied to one or more joints deemed to exhibit clinical and radiographic pathological changes,

including the carpometacarpal joint, the distal interphalangeal joint, and the joints of the thumb. No subgroup analyses, a topic previously assessed that showed limited discriminatory findings [22], for example those referring to age, gender, or comorbid health status were currently assessed, and genetic versus non genetic types of hand osteoarthritis were treated similarly. No specific time line was pursued, although most relevant data were more recent rather than not. All types of study design were deemed acceptable in light of the diverse and limited numbers of studies that met the inclusion criteria. No distinct cause-effect relationship was assumed as muscle abnormalities at the hand may prove to be precursors, as well as adaptive disease correlates, or both. All modes of assessing muscle function at the osteoarthritic hand were deemed acceptable, including electromyography, electronic force sensors, measures of joint kinematics and muscle timing, for example. With immensely diverse research questions and approaches, only a descriptive summary was deemed feasible.

### Results

#### General findings

While there is limited detailed information about hand osteoarthritis in general, as well as how individuals with hand osteoarthritis perform or have challenges performing activities of daily living, it is clear older adults are at modest to high risk for this condition and a lower than desirable life quality.

The most salient features reported over the years that describe hand osteoarthritis pathology, the most widespread site for osteoarthritis pathology [24], are that it is a symptomatic form of osteoarthritis that is a highly prevalent disease affecting about 10% of the general population. It causes considerable degrees of local pain, stiffness, and impaired physical function, and aesthetic discomfort [32].

In some patients, the global burden of the disease can be as severe as in rheumatoid arthritis, and the disease can affect a single hand joint or multiple hand joints, where the disability is likely to increase incrementally [33]. In addition to pain, functional limitations and frustration in undertaking everyday activities are consistently reported, and deemed attributable to focal changes in the bone, ligaments, cartilage and synovial tissues of the hand. The disease is not uniform though and is said to be a heterogeneous disorder with a multifactorial etiology [24].

Although often underestimated as a cause of disability, the effect on quality of life from limitations in performing activities of daily living such as dressing and feeding may be considerable [34]. The determinants of the magnitude of these are gender, radiological severity, duration of hand osteoarthritis, the presence of erosive joints, and its impact on pain, function, and stiffness.

The presence of hand osteoarthritis may also be an important indicator of a systemic tendency to develop more generalized forms of the disease at other joints, which may involve weight bearing joints, notably the hips and knees. A definitive role for obesity in this regard has not been supported to date and would not explain unilateral hand joint osteoarthritis manifestations in the case of an overweight older person, however [35]. However, prevalent hand osteoarthritis is predicted to increase the risk for acquiring incident knee and hip osteoarthritis [36] and may implicate muscle to some degree [37] and with this deficient muscle or joint sensibility that may play a disease moderating role in the realm of hand trapezeometacarpal osteoarthritis [38]. In addition, even if the disease does not spread, Coughlan, *et al.* [39] point out that advanced thumb carpometacarpal osteoarthritis can cause substantial impairments in hand function, from grasping heavy objects to fine manipulation of implements and tools. At the same time, aesthetic discomfort and damage are significant complaints in patients with hand osteoarthritis in their own right [40], as are complaints of hand pain and the objective severity of the disease [13].

Although motor function and its association with hand osteoarthritis is generally either poorly studied, or is assumed to prevail, even if not carefully examined, the importance of carrying out specific hand exercises rather than generic approaches focusing on fine motor skills alone has recently been stressed [41]. However, a recent report by van Beest, *et al.* [42] reveals a sizeable number of early stage hand osteoarthritis cases may remain undiagnosed and untreated if they exhibit insufficient clinical signs of thumb base osteoarthritis. This may not only reduce the window for any treatment 'opportunity' but may result in an underestimate of hand osteoarthritis preva-

lence data, in general, and a situation where the disease, if diagnosed, is already in a moderate to severe stage category, with less chance for effective remediation. It may also explain the high rate of erosive hand osteoarthritis observed by Auroux, *et al.* [43] of almost 12% of a cohort of 1,189 postmenopausal women aged at least 55. Since the disability scores were higher and grip strength lower in those women with clinically validated moderate-severe symptomatic disease compared to those who did not fulfill the ACR criteria based validation for hand osteoarthritis, factors such as muscle mass deficits, or suboptimal muscle force generating attributes that have been observed, and advocated [46], but are not routinely examined in that inventory may yet be helpful in this regard.

**Specific study findings**

In terms of studies identifying specific or noteworthy muscle adaptations or alterations that may predate or exacerbate hand osteoarthritis, those that were found to support this theme in some way are summarized below.

Authors	Sample	Method	Results	Key conclusions
Brorsonn., <i>et al.</i> [44]	20 women with rheumatoid arthritis, 20 with hand osteoarthritis, 20 healthy subjects	Wrist muscle activity and strength was measured during various hand activities  Muscle activation was presented as a % of maximal strength	The arthritis group used a higher % muscle force than the reference group for both wrist flexors/ extensors when using scissors/ pulling up a zipper, and-for the extensors-when asked to write with a pen/ use a key	Women with arthritis tend to employ higher levels of muscle force in daily tasks than healthy women  Wrist extensors and flexors appear to be similarly affected  Hand re training should reflect real-life situations and focus on wrist extensor strength
Cantero-Téllez., <i>et al.</i> [45]	72 early/moderate trapeziometacarpal hand osteoarthritis cases	Grip strength, pinch, pain/ hand function were measured, and correlations/ regressions were calculated	For function, the most significant model included pain and strength, but tip to tip pinch force had a stronger relationship with function  Pain also influenced strength but it was tip to tip pinch force that was the most affected	There is a significant correlation between function and variables that can be measured in the clinic such as grip strength and pinch
Coughlan., <i>et al.</i> [39]	90 cases with advances thumb carpometacarpal osteoarthritis (CMC OA), 90 healthy controls	Demographics, muscle strength, radiographs and a clinical history were assessed	Cylindrical grasp was weaker in the patient group  When adjusting for age, gender and handedness this deficit was related to the osteoarthritis condition	A reduction in cylindrical grasp is associated with early symptomatic and radiographic CMC OA

Jarque-Bou., <i>et al.</i> [46]	22 healthy controls and 22 hand osteoarthritis (HOA) cases	Records were made of forearm and hand surface muscle activity during varied forms of maximal grip force activities	The forearm muscles are significantly and uniquely affected by HOA as indicated by the hand EMG records	Digit flexors during cylindrical grasp, thumb muscles during oblique palmar grasp, and wrist extensors and radial deviators during the intermediate power-precision grasp are good candidates to help detect the presence of HOA
De Monsabert., <i>et al.</i> [47]	A musculoskeletal modeling approach was used	Forces + pressures acting upon hand joints during two grasping tasks were assessed via during a pinch and power grip task  3-dimensional MRI measurements were used to quantify joint contact areas	When compared with the power grip task, the pinch grip task resulted in 2-8 times higher joint loadings whereas the grip forces exerted on each finger were lower  For both tasks, joint forces and pressures increased in a disto-proximal direction for each finger	The present show there is strong risk associated with pinch grip tasks and the high frequency of thumb-base osteoarthritis
D'Oliviera., <i>et al.</i> [48]	Ten females with hand osteoarthritis (OA) and a group of age-matched females	Subjects: lifted an instrumented object vertically while the load was suddenly changed; + when lifting/placing the object  Load Force Peak, Grip force at liftoff, Grip Force Peak, Time Lag, and Latency were measured and analyzed	Subjects with hand OA were able to modulate the magnitude and temporal parameters of grip force; however, they applied higher grip forces (at liftoff; and Grip Force Peak) and demonstrated a longer Latency in object manipulation compared with the controls	Detailed information about how individuals with hand OA perform prehension activities of daily living will improve understandings regarding the limitations of grip force control in these individuals.
Magni., <i>et al.</i> [49]	20 patients with hand osteoarthritis (OA) and 19 healthy controls	Conducted were a hand left/right judgment task, a control left/right judgement task, 2-point discrimination threshold, neglect-like symptoms and several established measures of hand function	Neglect-like symptoms were experienced more frequently in the hand OA group  Those with hand OA were slower and less accurate in the judgement tasks  Significant associations were found between hand left/right judgement reaction time and pain intensity and accuracy and pain intensity	Adults with hand OA show more frequent neglect-like symptoms and are slower and less accurate compared to healthy controls performing hand left/right judgements, which was indicative of disrupted working body schema.

<p>Nunes., <i>et al.</i> [13]</p>	<p>Ten females with hand osteoarthritis (OA) and ten matched, nondisabled control subjects.</p>	<p>Outcomes of the Moberg Pickup Test (MPUT)/other functional hand tests were correlated with measures of grip force control during lifting and transporting a handheld object</p>	<p>A strong correlations was found between the MPUT and parameters of grip force control, such as latency and force at the moment of lift-off in the patients</p>	<p>The observed strong correlation between the MPUT scores and the parameters of grip force control might help researchers + clinicians better understand how deficits in controlling grip forces affect hand function in patients with hand OA</p>
<p>Ouegnin and Valdes [50]</p>	<p>29 thumbs with carpometacarpal osteoarthritis (CMC OA) and 29 matched-control healthy counterparts  For comparison, participants with unilateral CMC OA were matched against themselves, whereas those with lateral CMC OA were age matched with a healthy participant</p>	<p>Active joint position sense was employed to measure proprioception function</p>	<p>The mean positional error measured from subjects with CMC OA was 9.53° compared with 1.32° for the age-matched healthy subjects  The effect size for the difference in means was D = 1.96</p>	<p>Thumb sensorimotor impairments may be common in subjects with CMC OA but not in healthy adults</p>
<p>Tossini., <i>et al.</i> [51]</p>	<p>32 subjects divided into a: control group (n = 16; 55 ± 7.42 yrs) and a group with hand osteoarthritis (HOA) grades 2/3 (HOAG; n = 16; 57 ± 7.82 yrs).</p>	<p>Muscle activation was measured in wrist/hand flexors and extensors during tests of grip strength and 3 manual activities  A coactivation index was calculated between flexors/ extensors</p>	<p>HOAG subjects showed reduced activation in all tasks, + a difference for the flexor digitorum superficialis + wrist extensors in the scissors activity, and for flexor carpi ulnaris in the bottle activity</p>	<p>In the early stages of HOA, there is a functional deficit associated with a reduced muscle activity of the wrist muscles during manual activities</p>

**Table 1:** Summary of representative studies of hand osteoarthritis motor attributes.

**Discussion**

Osteoarthritis, a chronic, highly prevalent and disabling disease and one expected to increase in prevalence secondary to longer life expectancy and a disproportionately large aging population remains an enormous challenge to treat effectively. Indeed, multiple forms of treatment to address pain accompanying this disease, as well as attempts to restore various degrees of associated joint cartilage tissue damage, remain only marginally effective, despite decades of research. These approaches have commonly included, but are not limited to, weight control, exercise, non-steroidal anti-inflammatory drugs, acetaminophen, intra-articular steroids or viscosupplementation, topical analgesics, and joint replacement surgery, generally regardless of joint site affected. Efforts to establish the origins of hand osteoarthritis

have not uncovered any definitive claims to date, and although age, obesity, gender, and genetics are most commonly cited determinants of the disease, the presence of hand osteoarthritis of a single joint or multiple joints on one side of the body unrelated to handedness cannot be readily explained in this regard.

However, what is not well studied to date are aspects of motor dysfunction that might fail to protect one or more hand joints and that foster a state of progressive dysfunction and derangement, and explain or account for its varied presentation and disease manifestations and progression [9]. In this regard, even if one accepts that only positive studies are likely to be published, the data outlined briefly in table 1, representing a fair cross sectional of studies to date that sought to measure muscle associated factors in various hand osteoarthritis cohorts does show this line of inquiry is a possible highly valuable one. As per Tossini, *et al.* [51], it may be that the presence of a measurable degree of reduced muscle activity in hand cases with advanced disease is due to an inability of the patients to recruit all desirable motor units or to an inhibition related to the presence of pain and possibly contributing to this, if unaddressed specifically. Their hand movements may also be slower and less accurate in judgment tasks [49], as well as exhibiting alterations in muscle activation patterns not found in the healthy state [56]. Expanding this realm of inquiry to incorporate musculoskeletal modeling approaches, functional measures, imaging, and an array of established sensory-motor system measures [57], may further help to affirm that osteoarthritis is in fact not a disease of a single joint tissue alone, but is one that may originate or reside in the tissues supporting the joint, such as muscle and its control mechanism, as implied by De Monsabert, *et al.* [47] and Hagert and Mobargha [52]. As well, expanding upon this line of inquiry so as to examine muscle reflex responses, motor cortical associations, and muscle spindle features in hand osteoarthritis of different degrees may prove highly insightful, while yielding relevant novel data and findings that may be better able to guide comprehensive as well as more selective interventions to avert the spread of osteoarthritis hand joint pathology, and its multiple modes of presentation [9], along with singular and cumulative adverse health and disease ramifications.

In particular, how the adaptive changes in aging muscles as well as arthritic adaptations impact varying manifestations of hand osteoarthritis such as muscle mass quality and quantity declines, as well as possible slowing of one or more linkages of the sensory-motor system, must be considered vitally important to examine and identify in light of its likely bearing on joint loading mechanisms, as well as multiple vital hand based functional correlates. Alternately, where these are not duly considered, or overlooked, stand alone or non tailored treatments may well be expected to fail, even if their basis is justified [53,54].

In short, predicated on the above, and on the basis of a fairly representative set of current supportive observations detailed in table 1, and quite limited results from standard efforts to advance osteoarthritis hand strength and dexterity [18,54], it is reasonable to support the view of most current researchers highlighted in table 1 that examining a possible role for a variety of specific motor based impairments of diverse muscle groups at the hand affected by one or more degenerative joint changes may prove paramount in advancing our disease understandings. Moreover, even a small advancement may mitigate much suffering, and permit or foster more selective, as well as efficacious intervention and disease mitigation approaches in the future.

As such, its pursuit is duly recommended by those who earnestly seek to alleviate the current and predicted future excess burden of hand osteoarthritis disability among the older adult population and that presents such an immense daily living impediment for so many in all parts of the world. In absence of any major insights into hand osteoarthritis epidemiology and what influences its disease prevalence, its rate of progression and oftentimes dire functional and social life negating abilities and desired activities and life quality, it appears intense study to uncover any consistent neuromotor feature that may be explanatory as well as remediable, may offer a ray of light for at least some who are suffering from disabling hand osteoarthritis, as well as the clinician.

In essence, it is this author's view that while somewhat discounted by Calder, *et al.* [55] and Tossini, *et al.* [17] possible muscle functional attributes that may or may not be strictly reactionary in nature, may partially determine the mode of hand muscle adaptations reportedly observed in diverse disabling hand osteoarthritis cases. Consequently, in absence of any identifiable disease cause, their



pathogenic role should not be overlooked, as one or more of these elements residing in the neuromotor system may possibly initiate or perpetuate some forms of the disease, and should be studied accordingly and more intently. In particular if reproducible patterns that reside in the motor system can be successfully identified at any disease stage, it may be possible to prevent the disease from 'spreading' from one joint to another, or erosive hand pathology that requires urgent and costly treatments. Such studies might include some form of replication of those depicted in table 1, or an expansion of these, as well as careful isolated analyses of the most likely key hand associated influential motor correlates of key muscle groups such as:

- Muscle size/cross-sectional areas
- Degree of muscle fat infiltration
- Muscle fiber type distribution
- Muscle architecture/damage
- Muscle timing/coordination/force generation profiles
- Muscle imbalances/co activation alterations
- Muscle spindle and/or joint sensory deficiencies
- Muscle inflammation
- Muscle endurance/power/strength
- Muscle extensibility
- Movement time, speed, and accuracy
- Muscle inhibition [58-60].

In the meantime, while their mechanisms of action remain to be determined, the hypotheses currently generated appear to be supported in that muscle appears of considerable relevance to examine at all stages of the hand osteoarthritis disease state and its identification and attributes if better delineated may yield immense treatment advances, and multiple benefits to many in the higher age ranges where deterioration of hand function involves a combination of joint, muscle, nerve receptor and neural control changes [59].

### Limitations of the Study

While not all works may have been accessed in this report, and no quality assurance mechanism was conducted, those that were found relevant to examine were clearly diverse and represented a mixture of various types of hand osteoarthritis pathology, with differing inclusion and exclusion criteria. In case control studies, even though we cannot be certain if all 'healthy' controls were actually osteoarthritis disease free, or whether those with radiographic osteoarthritis were clinically symptomatic, available studies imply an important differentiating functional role for muscle in the etiology, progression, severity, and proposed efforts to avert the disease severity. As well, important features discriminating healthy from osteoarthritic hands may have been obviated due to the small sample sizes studied, their possible lack of power to detect selected muscle based abnormalities, measurement property issues, and age associated hand weakness and sarcopenia. However, discounting a role for publication bias, and the use of cross sectional study designs, most publications to date have pointed towards one or more practical implications regarding the need to better comprehend the underlying causes of hand osteoarthritis in general, as well as the multiple muscular consequences or determinants of the disease, and its widely varied disease manifestations and presentations. In particular, while limited, the available data, are generally consistent in pointing to the importance of attaining a more complete comprehension of all features of the hand osteoarthritis adaptive processes, including muscle so as to possibly improve upon more sound evidence based effective treatment options and applications, including stimuli that will enhance those muscle properties and function that may have a possible bearing on cartilage reparative responses. However, to ascertain what is needed and why, more

attention to clinical evaluations that convey the multiplicity of the parameters that may be implicated in the disease, along with careful consideration of the impact of the selected measurement procedures on muscle based indicators, such as stiffness or pain, must be carefully weighed. For example, they must not induce muscle fatigue, or test movements unfamiliar to the patient, and should be less reliant on subjective perspectives, for example, to examine pain and function.

### Future Directions

Age, the extent of pathology, role of past and ongoing treatments, comorbid health status, and differentiating disuse atrophy from aging and neurogenic or inflammatory causes should receive due consideration by those who seek to understand the nature of hand osteoarthritis in the older adult. As per Lawrence, *et al.* [57] when assessing the level of hand function in the growing older adult populations, it is particularly important to acknowledge the hand's multidimensional functional nature and its related three key domains of strength, coordination, and sensorimotor processing status and to differentiate hand muscle problems from those of the upper limb in general. Moreover, efforts to distinguish among these functional domains and specific muscle based alterations in both men and women, and those with and without comorbid health conditions such as obesity and diabetes, and muscle force, timing, and endurance measures and the phase and extent of the disease may facilitate the design of more specific preventive as well as treatment options that can foster desired functional, social, independent living, and positive socio-emotional outcomes. More routine use of sonographs, and clinical assays on a case to case basis may prove valuable as well.

### Conclusion

Although generally considered an idiopathic disease with no definitive cause, the current review results have indicated that a variety of structural and functional correlates of the hand muscles may play a role in explaining the variations of hand osteoarthritis pathology and the rate of its progression in the older population.

In addition, it cannot be excluded that some forms of hand osteoarthritis may represent a predictable array of biomechanical responses that commonly emerge over an extended time period in the presence of one or more surrounding muscle abnormalities and that accounts for both its biochemical as well as cellular and molecular joint abnormalities, and possible more virulent erosive state in some cases.

Based on the majority of available clinical studies in this regard, it does appear moreover that considerable benefits at multiple levels are more likely than not to ensue for many if either the early muscle changes at vulnerable hand joints or those that are adaptive over time are clearly identified and treated accordingly.

However, non specific grip strength measures or others used in isolation, and a focus on strength training that does not account for fatigue or the actual sensory-motor deficits that may underlie the disease progression, may be expected to reduce the capability of the hand joint tissues to withstand stress during functional loading and dexterity attempts.

Alternately, it is concluded that careful evaluation and study of how the hand muscles and their neural pathways may impact one or more attributes of both early and late stage hand osteoarthritis pathology of a single as well as multiple joint sites, as well as unilateral versus bilateral joint diagnoses will undoubtedly improve our current understandings of the disease etiology and its pathogenesis, regardless of findings. As well, directives pertaining to how and when to best intervene to alleviate the multiple disabling life consequences found among the older adult population may be considerably improved, thus closing a needed gap in the quest to help a sizeable number of older adults to age more successfully than not.

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