ISSN: 3033-358X

Research Article

Journal of Orthopedics and Physiotherapy

Umbrella Review of Quadriceps Muscle - Knee Osteoarthritis Associations: A Case Where Research Diversity Continues to Obscure Clear Cohesive Clinical Understandings

Ray Marks

Osteoarthritis Research Center, Willowbrook-Charnwood Postal Depot, Markham, Ont L3T, 5H3, Canada

Corresponding author
Ray Marks, Osteoarthritis Research Center, Willowbrook-Charnwood Postal Depot, Markham, Ont L3T, 5H3, Canada.

Received: January 23, 2025; **Accepted:** January 23, 2025; **Published:** February 03, 2025

ABSTRACT

Background: Knee joint osteoarthritis, a highly disabling chronic disease with no distinctive cause currently persists unabated among many older adults as well as younger adults. Largely attributed to non-modifiable underpinnings of age, injury, weight status, and genetics, various forms of localized modifiable attributes of muscle dysfunction may however be implicated

Aim: Building on prior comprehensive reviews, here we strove to uncover any novel 2024-2025 research highlights concerning the key knee extensor functional complex termed the quadriceps femoris muscle given the belief that its decreased strength is a key knee osteoarthritis disabling factor.

Methods: The 2024/5 PUBMED data base and others aligned with this topic were searched carefully to uncover and identify any new clinically relevant insights concerning the natural history of knee joint osteoarthritis.

Results: Even though more than 100 studies within the desired 2024 topical theme prevails, most fail to uncover or affirm any distinctive pathogenic role for the knee extensor muscles in the knee osteoarthritis disease cycle. Moreover, the diverse study themes, designs, research questions, methods, and conclusions remain key challenges to aggregate and apply clinically to prevent the disease or its severity.

Conclusion: Examining knee extensor muscle parameters closely and how their attributes mediate joint viability and function appears promising, but await further study.

Keywords: Knee Extensors, Joint, Osteoarthritis, Quadriceps Muscle, Pathology, Rehabilitation

Introduction

Knee joint osteoarthritis, a chronic health condition inducing a high degree of progressive disability among immense numbers of adults, especially those in the higher ages has no well-defined cause, and very few successful methods for curing or reversing this condition [1]. Possible pathogenic mechanisms that may be harnessed towards preventing the disease, rather than accepting the disease is inevitable, are hence highly sought.

In this regard, a major recent conceptual advancement has been the acceptance that osteoarthritis is a disease of the whole joint, wherein muscle and its integrity and physiology may play a highly salient mediating or moderating role that affects those spatial and temporal joint loading and unloading mechanisms found to strongly influence cartilage structure, function, tissue quality, and viability [2]. As such, one or more muscle associated deficits that have been and are being observed and documented in cases with clinical knee osteoarthritis manifestations are hence considered of considerable import as regards understanding the natural history of the disease as well as how to possibly mitigate knee osteoarthritis successfully [2].

Citation: Ray Marks. Umbrella Review of Quadriceps Muscle - Knee Osteoarthritis Associations: A Case Where Research Diversity Continues to Obscure Clear Cohesive Clinical Understandings. J Ortho Physio. 2025. 3(1): 1-8. DOI: doi.org/10.61440/JOP.2025.v3.17

Here the key muscles that may have a bearing on the quality of the knee joint cartilaginous tissue matrix and cells that govern overall knee joint status are the anterior located quadriceps muscles, the primary extensors of the knee, and the posterior located hamstrings that flex the knee and that are both essential for fostering joint stability, as well as mobility and desirable muscle forces at low energy cost [3-6]. However, if the normal degrees of functionality and/or muscle composition compromise joint protection forces as well as joint lubrication for example by fostering abnormalities in the subject's knee extensor muscle strength contractile profile and/or muscle cross-sectional area and content dimensions, it appears knee osteoarthritis and its symptoms may not only ensue, but may progress adversely to some degree in the absence of effective identification and remediation [6]. Moreover, a great deal of long-term suffering may persist, even in the face of knee joint replacement surgery due to persistent forms of muscle dysfunction and degradation, muscle tendon asymmetries, low muscle mass, and/or sarcopenic obesity, poorly timed and coordinated muscle contractile interactions [7-10].

Indeed, the ability of muscle to contract effectively under ever changing conditions and demands, is not only paramount to optimal joint function at all ages, but of great import to the maintenance of normal joint cartilage and its role in joint protection and shock absorption and cartilage metabolism [11-13]. However, a high percentage of non-contractile muscle tissue in the vastus medialis muscle, not only contractile elements that may prevail may impair joint protection as well as fostering muscle weakness that often degrades timely leg functions [14]. Yet others show the presence of central nervous system correlates such as decreased quadriceps muscle spindle responsiveness may have an additionally strong bearing on knee osteoarthritis disability and its progression [15-21].

It thus appears that

1. In addition to static factors, abnormal muscle dynamics, as well as muscle weakness, or poor coordination may contribute towards the onset or progression of cartilage damage, as well as joint inflammation and progressive degradation processes and losses.
2. A failure to generate those specific and precisely modulated and coordinated muscle forces needed to protect a vulnerable joint such as the knee may lead to immense pain and functional disability plus a detrimental imbalance between cartilage cell anabolic and catabolic processes that are load sensitive.
3. Whether knee extensor muscle dysfunction is indeed a significant causative factor in knee osteoarthritis or even if not, this possibility seems worthy of future study.
4. Given that joint surgery does not always improve the osteoarthritis individual's mobility, nor their strength capacity, and is often followed by symptom re-occurrences it appears the knee muscles can potentially play both causative as well as a reactive role in explaining and mediating knee osteoarthritis functional weight bearing limitations and progression, rather than not.

Specific Aim

This current brief work was specifically targeted toward examining the most current research documenting any knee osteoarthritis-knee extensor muscle associations, and whether pursuing this topic appears of merit from an etiological and/or preventive vantage point. Building on 25 years of related investigations, novel data to this end was sought, so as to possibly advance current clinical practices, including primary prevention efforts, sorely needed globally to reduce multiple well documented disabling knee osteoarthritis life impacts and increasingly high public health and social costs.

Conversely, it is possible some degree of suffering that currently prevails and might do so in the future will persist if the role of muscle is not well understood as an osteoarthritis mediator or etiological factor and is thus not treated accordingly. Indeed, the variations identified in the past evidence base have not permitted any meaningful aggregation or conclusive insights to emerge as regards knee osteoarthritis, the most common form of the disease, and the most well studied. For example, study and measurement methods used to date have generally been quite non uniform or not necessarily robust, or fail to represent population wide disease features and the older adult population, osteoarthritis sub groupings, disease severity and extent, or any actual functional and serum biochemistry ramifications. As such, while promising, these data have been difficult to synthesize so as to collectively render the ability to predict the natural course of the disease and how to intervene across this, let alone provide for tailored targeted approaches.

Materials and Methods

Item search approach

To achieve the current research aims, the **PUBMED** data base, plus **PubMed Central** and **Google Scholar** were predominantly selected as housing the world's largest medically oriented peer reviewed research reports. The key terms applied alone or in combination were: knee osteoarthritis and quadriceps or knee extensor muscles or muscle dysfunction. The time frame was limited to the periods January 1, 2024- January 20, 2025, and some prior data previously reported on, and as cited in references [15,19-24]. Excluded were simulation studies, and those with a focus on proprioception, balance, ligament and meniscus topics, exercise or physical intervention studies, post-surgical studies, lab studies, and mixed studies that did not focus solely on the knee extensors/quadriceps muscles in the context of knee osteoarthritis.

Analysis

Despite our comprehensive search, no quantitative analyses were clearly possible on any issue and a decision to accept information from all research designs and modes of assessment. It was believed that **PUBMED** peer reviewed current journals and others viewed would provide some current insights into what is needed and why in the future, regardless of any research flaws. Only research pertaining to the quadriceps femoris muscle and its components (rectus femoris, vastus intermedius, vastus medialis, and vastus lateralis) were examined given its accepted importance in knee rehabilitation, stability, and function. All forms of knee osteoarthritis as well as muscle measurements were deemed acceptable as muscle, deemed to be mutable, may be one factor that can induce or influence the disease process,

possibly quite markedly, even though not well recognized. For an update on the role of the hamstring muscles in knee osteoarthritis investigations, readers can refer to reference [5].

Results

Key Findings

When applying the PUBMED data base and noteworthy others directly focused on one or more knee extensor muscle attributes published between January, 1 2024 and January 20, 2025, as has been observed for some time, one cannot help but conclude that there is more diversity in the body of current data than uniformity. For example, even among those reporting predominantly on measures of knee extensor strength, these measurement approaches tend to be largely non uniform and to test parameters difficult to aggregate meaningfully across studies. As well, even when salient observations are made when comparing diseased and 'non diseased' knee joints, these measures may be conducted in modes that restrain movement or represent nonfunctional static positions, such as sitting on a chair with restraints, that may commonly fail to address their salient functional, biomechanical, inflammatory biomarkers, and structural attributes, and especially their pain and cartilage destruction associations, even if reliable. Similar arguments can be made for measures of muscle volume and quality conducted at a single session and commonly captured during nonfunctional positioning situations. As highlighted in the past, it is not surprising that no matter what is currently researched, most current researchers argue in favor of more focused decisive homogenous and reliable data at many levels, not only muscle, are sorely needed so as to arrive at clinically meaningful or scientifically valid synthesis of the current research topic and its broad practice-based implications crucial for preventing or treating knee osteoarthritis optimally [9].

At the same time, glaring current topical omissions are reports pertaining to knee extensor muscle force generation temporal features and contractile characteristics, knee extensor muscle fiber analyses, muscle quality and thickness, and muscle reflex mechanisms. As well, which of the four quadriceps muscle components - if any - are implicated and of highest significance to treat cannot be readily discerned at present. Additionally, most current studies referring to knee osteoarthritis do not specifically use the same diagnostic criteria or explain how muscle and the differing compartments or sites of the knee joint appear to interact to either offset the disease or enhance its progression. At the same time, various modes of treating osteoarthritis appear to focus on muscle, even though very few explain why this modality is of import, and most fail to target muscle fat mass and muscle spasm, stiffness, and inflammation plus reflexive control features.

In sum, even though a case can be made for a role for the knee extensors as knee osteoarthritis mediators or moderators, other than muscle strength what the relative attributes of muscle rate of force development, the separate forces produced by each quadriceps head under low load conditions, quadriceps muscle volume, fiber losses and regroupings is impossible to discern as a whole.

Moreover, even if reliable, the validity of diverse muscle related attributes may not be assured without further study. As well, confusion is increased when considering the inclusion of studies in systematic reviews that have measured diverse movement patterns, walked attributes, and conducted these using varying contractile speeds among varied samples but often omitting knee extensor muscle endurance, reactivity, and shock absorbing features.

Fortunately, there has been more and more attention paid to the research of muscle mass and muscle quality and function in osteoarthritis over time, and at the knee, a role for the knee extensors or quadriceps femoris muscles and its possible progressive influence on susceptible knee joints [3]. This was demonstrated in a recent study that explored the asymmetric changes of muscle mass, biomechanical property and muscle activation in both limbs of the knee osteoarthritis patient that showed muscle thickness, shear modulus and muscle activation asymmetries, as well as knee extensor muscle compartment differences in cases representing differing degrees of joint pathology. Another noted similar quadriceps femoris muscle activation asymmetries between the affected and unaffected sides of cases with unilateral knee osteoarthritis, as well as a difference between the dominant side of healthy older individuals and the affected side [12]. Consequently, Wang et al. advocate for strengthening of both weak quadriceps and hamstring muscles, regardless of whether the individual is in the early or end-stages of the disease [13]. Timely and persistent intervention here seems strongly indicated given that joint related muscle abnormalities may not only foster a variety of joint attrition processes, but more widespread adaptations within the motor cortices, corticospinal tract, and motoneuron pool that can impact the disease progress as well as muscle stiffness - a recently discussed potential knee osteoarthritis disease correlate [15-18].

Additional Observations

In addition to neuromotor adaptations, the associations of thigh muscle and fat volumes and structural abnormalities related to knee osteoarthritis may be a pathogenic one, especially in women [19]. Another view is that it is differences in muscle tightness between symptomatic and asymptomatic knees in individuals with unilateral knee osteoarthritis that induce pain, and limited functionality [20]. Another is the presence of any form of muscle imbalance and impaired force generating capacity that can lead to progressive or summative subnormal force generating adaptations that alter joint reaction force responses quite significantly and with adverse consequences, such as the adoption of a stiff knee form of gait and possible heightened knee adduction moments [21-24].

Another muscle associated factor discussed recently implies a role for the features of the prevailing joint moment arm in mediating knee extensor joint torque as well as quadriceps muscle volume that can affect the knee extensor moment arm [25]. Another has indeed demonstrated that the formation and localization of patellar chondral lesions can be affected by the nature of the insertion width of the muscle into the patella that governs quadriceps tendon passive stiffness or elasticity as well as quadriceps muscle volume [26-30]. It also appears there may be some functional association between the existing degree of knee extensor muscle strength and postural stability in the presence of osteoarthritis, along with changes in muscle architectural properties depending on the nature of the magnitude of any muscular fat infiltration rectus femoris

overstrain, biomechanical changes, muscle biomechanics and/or varus malalignment of the lower leg [31-37].

Indeed, as observed in prior reports, almost all current researchers located in the **PUBMED, PubMed Central, and Google Scholar** 2024/5 data bases found more differences than similarities in their observations than not, while strongly advocating for continuing careful research. At present, however, even though atrophy of the quadriceps muscle is generally accepted to be a consequence of knee osteoarthritis, there are recent and past studies pointing to a role for quadriceps muscle sarcopenia as a causative factor in the genesis of primary knee osteoarthritis, but this and other muscle-oriented knee osteoarthritis mediation hypotheses need to be examined more intently in the future [11-44]. In addition to comparison studies, those that employ multiple functional measures need to ensure they do not unwittingly elicit muscle fatigue, muscle inhibition, or pain reactions and do not fail to represent loading movements as used in the natural environment. Whether knee strength deficits of the affected as well as the unaffected leg as commonly observed are due to fears of moving the painful joints and contracting the muscles forcefully as opposed to the possible muscle fat infiltration and degeneration, inflammation, or atrophy also needs more thorough investigation [45-49]. Alongside, efforts to uncover and measure muscle spindle and joint sensory mechanism deficits and osteoarthritis biomarker assays may help to offer some insights on future intervention practices and outcome expectations, as may muscle volume, quality, or stiffness abnormalities [48,50].

Discussion

Knee osteoarthritis, a highly common painful disabling joint disease continues to pose an enormous burden on many adults in all parts of the world, especially older adults. In addition to its increasing prevalence and limited responses to current interventions, despite years of study, efforts in this regard, while noteworthy have not produced returns commensurate with these immense investments to either the realm of understanding the disease etiology and risk factors and hence its optimum prevention potential. Moreover, even though a considerable effort has been made to address the specific role for muscle in this regard, as outlined in this report covering the majority of the current body of related salient studies, while premised on some tentative support for a possible clinically important knee extensor muscle influence in knee osteoarthritis, the data as a whole clearly fail to point towards any definitive deterministic findings or unifying set of understandings that could explain the presence of knee extensor weakness and other forms of muscle dysfunction that might well affect the nature of clinical practices significantly and favorably [46]. Moreover, it is only quite recently that it has been observed that muscles other than those at the knee or only one component of the knee extensors not others are of potential import in explaining knee osteoarthritis biomechanics and related functional limitations [47]. Alternately, muscle weakness and its presence may yet implicate a complex array of pain factors, body weight losses or gain, and joint effusion, leg alignment and loading issues, rather than knee strength alone, but this is not well researched to any degree.

In short, given the considerable volume of research that was available and proposed, it is clear there is a belief in the need to examine muscle osteoarthritis linkages. Indeed, even if negative studies have not been published, many muscle factors that are studied appear relevant in one or more ways to explaining the sources and persistence of knee osteoarthritis pain and dysfunction and that clearly differentiate the healthy and osteoarthritis knee joint. But how these diverse findings relate collectively or which parameter examined to date is of highest significance, is impossible to elucidate. Moreover, a role for muscle as regards the natural history of knee osteoarthritis pathology remains elusive, especially in regards to observed muscle strength deficits, quadriceps muscle atrophy, inhibition, rate of force development, and endurance [38-41].

Another view not yet carefully explored, but noteworthy in our view, is a role for selected knee extensor strength positioning modes and methods that if not carefully considered can evoke reflex muscle inhibition or obscure actual force generating capacity at the knee inadvertently. For example, if the knee extensors are tested at the extremes of joint extension, or unrestrained via a hand-held dynamometer. Another is the omission of tests to identify compensatory structural changes in one or more quadriceps muscle components and possible flattening of their central aponeurosis curvature that could cause abnormal stress loading of the knee cartilage when the limb is used or exercised along with muscle architecture and capacity alterations [33,34,41,42].

Nonetheless, based on what has been found, key selected attributes of muscle that could influence knee joint status and might prove valuable for purposes of future inquiry include, but are not limited to-

* Muscle asymmetry, atrophy, fatigue [21]
* Muscle capacity [42]
* Muscle mass [9]
* Muscle responsiveness, strength, and composition [43]
* Sarcopenic obesity [45]

In addition, in the context of the development of a more accurate knee osteoarthritis predictive model, it is suggested isokinetic knee extensor force measures that incorporate angle-specific and/or speed-specific analyses of qualitative and quantitative data will prove highly valuable. Furthermore, the utilization of artificial intelligence image recognition technology may prove beneficial for analyzing large datasets in the future as may the use of functional kinetic studies, muscle composition, function, and osteoarthritis serum biomarkers [4,21,44,46].

Careful evaluations that can enhance the evidence base are hence strongly indicated as are comparative studies and those that assess any pathogenic linkage attributable to muscle composition and power and possibly mitochondria energetics and muscle quality [34-37,48]. In addition, more case as well as population wide studies that proceed over substantive time periods using advanced technologies are indicated [38,43].

In particular, early carefully construed and timely longitudinal assessments that examine the degree to which knee extensor muscle strength, endurance, fat mass, cross-sectional area, and reactivity in its own right influence knee osteoarthritis in any way and if so, what can be learned using agreed upon measures is highly indicated. In addition, applied to samples that include

adults in the higher age ranges, along with well-conceived inclusion and exclusion criteria can potentially advance the wellbeing of many over the next decade or so and should be cast so as to allow for AI generated solutions to prevent or allay the condition and/or the extent of any ensuing additional joint involvement and deterioration routinely and substantively. In particular, the need for surgery may decline, and even if needed-surgical outcomes may be improved.

Unfortunately, even if publication bias is not a concern in the current realm, some data sources that clearly highlight the role of one factor and not others, or do not always yield like results when using comparable approaches remain key impediments to progress in our view. Moreover, some are intuitively confusing and may reflect challenges in comparing data based on subjective measures, lengthy time periods, secondary data sets, and mathematical models that may not be generalizable. At the same time, the data measures applied are consistently variable rather than standardized even when the same muscle attribute is being assessed and cannot be expected to yield comparable findings. It also seems the varied measures employed are largely assumed reliable valid, and sensitive to change, but many are potentially untested in this regard.

Implications

Despite its current research gaps, it is our view that clinicians can yet be confident that even if some current assumptions may not hold true universally, acknowledging a significant role for muscle in the knee osteoarthritis disease cycle will ensure more favorable outcomes than not. Studying what is needed therapeutically to mitigate or avert knee osteoarthritis, if anything, and why, and for what duration and purpose, and at what disease stage is strongly advocated here. As well, advancements can be made currently in our view if clinical preceptors as well as clinicians can be encouraged and motivated to actively become better informed about the nature of osteoarthritis and its possible associations with muscles such as the knee extensors and the most insightful measurement tools with which to examine this system of influence.

In addition, an open mind about more recent findings that imply differences in the organization of the motor cortex may have a bearing on knee osteoarthritis along with the motor pathways themselves, including the understudied gamma motor neuron pathway. As such, neuromotor rather than strength training rehabilitation efforts may be indicated in some cases. Alternately, we propose that unless this body of muscle-associated influences is acknowledged, it may be difficult to observe any long-term intervention impact either non-operatively or via corrective joint surgery.

Muscle attributes requiring more study are those associated with muscle fat mass, muscle inhibition, muscle spasm, muscle rate of force development, muscle inflammation, muscle contractures, muscle size, muscle endurance, and their association with mobility, pain, clinical presentation, and mobility limitations across a wide spectrum of the knee osteoarthritis.

Until then, it is predicted that the opportunity for effective remediation of this disease will remain poor even after surgery, especially if inherent muscle aberrations that are treatable persist and/or the intervention advocated is not specific and carefully titrated [7].

Alternately, having a better understanding of all the mechanisms that might contribute to the disease, especially those that underlie its biomechanical abnormalities and pain found in knee osteoarthritis may provide some hope for minimizing the immense burden of this prevalent disorder, as well as for improving outcomes, which currently remain suboptimal as far as pain and disability are concerned. In particular, the ability to intervene as early as possible and to apply well-reasoned evidence-based observations towards preventing the emergence and persistence of quadriceps muscle coordination deficits and others is essential. Since the four key components of the quadriceps muscles may undergo differing rates or mechanisms of pre-or post-arthritic change, uncovering those most relevant in this regard, and applying target specific treatment approaches accordingly may prove especially helpful for maximizing life quality, plus the status of the knee muscles in the event of surgery. At the very least it may help avert the spread of the disease to other knee and/or distant joint sites.

Routine assessments of muscle circumference, muscle fat and tissue content using body impedance tests, coupled with an exam of basic reflexive neurological status, gait and lower limb loading using a walkway, plus the assessment of quadriceps power and endurance as well as strength in early as well as moderate cases of knee osteoarthritis may be especially helpful in securing more precise insights into any prevailing quadriceps pathology and its potential for optimal restoration.

Encouraging those at risk for the disease or its worsening to be vigilant about adhering ro their exercise recommendations, as well as being more mindful to avert any harm that could occur consequent to excessive exercise or incorrect joint usage is also indicated. Those in the higher age ranges, those with multiple chronic health conditions, those in pain, and exhibiting excess body weight, and those scheduled for knee replacement surgery might be selectively targeted in this regard.

In the interim, and in view of the increasing evidence that multiple pharmacologic approaches do not yield long term benefits, and joint injections, and surgery are not without risk and high costs, we encourage researchers and clinicians to pursue this line of inquiry notwithstanding the obvious limitations of this review. Moreover, if an individual with knee osteoarthritis is not responding to conservative or surgical treatment after several weeks of intensive intervention or is showing declining function, rather than any improvements at any time, the presence of irreversible damage within the confines of the neuromotor system should be carefully sought.

On the other hand, based on the conclusions of most current authors listed here, it is probable that without a concerted effort to extend and clearly delineate and possibly group muscle related knee osteoarthritis underpinnings that appear to have a bearing on knee joint status, many older adults and others will continue to suffer unduly. However, interventions for reducing increased passive properties of the quadriceps and knee joint stiffness and those fostering strength and activity rather than prolonged sitting may yet be beneficial for maintaining healthy knees in the aging population [51-53].

Moreover, concerted efforts to overcome the present lack of harmonization of various study protocols, measurement validity and reliability shortcomings, and the implementation of long-term studies with adequate representative samples and designs that enable valid comparisons between labs may help to advance this field of endeavor quite significantly [37]. Additionally, the generation of more dedicated robust data on large samples and dose-response associations as regards interventions such as strength training are advocated along with reliable data that can be duly synthesized via AI is likely to be advantageous as well [54].

Conclusions

Despite the limited progress made over more than a century to garner a clear understanding of how the key extensor muscles at the knee joint are implicated in knee osteoarthritis, if at all, it is concluded:

1. Knee osteoarthritis will continue to induce immense adverse impacts at the individual and societal levels that will not be readily ameliorated in the near future without concerted and well-designed multi center collaborative research efforts that carefully examine the structural and functional properties and adaptations of the knee extensor muscles, among other muscles and joint structural and functional features.
2. More insightful inclusive empirically derived study questions, reproducible universally agreed upon objectively valid assessments among subgroups conducted at different disease stages in well-designed trials using carefully conceived and implemented imaging joint biochemistry, and biomechanical examinations are essential starting points.
3. Efforts to assess the temporal role of the knee muscles in the disease process in tandem with available biomechanical, radiographic, and joint serum and inflammatory biomarker assays may provide the best path to comprehending how to reduce its immense burden
4. Conversely, variously recommended interventions that fail to address those differing modes of muscle dysfunction that might prevail and their key features will continue to prove suboptimal at best in all likelihood.

In sum, while it appears safe to say meaningful intervention and prevention impacts are possible, it appears the best ideas are yet to come and will likely be attained only in tandem with global and local efforts to provide safe indoor and outdoor environments, food security, and sound health practices and provisions for all, as well as insightful carefully designed and controlled research, and an appreciation of muscle-based aging and physiology science. In turn, outcomes of validated evidence-informed quadriceps-knee osteoarthritis research should be made more mainstream to minimize and help moderate the pervasive negative oftentimes fatalistic ageist view of knee osteoarthritis and convey a sense of optimism that this disease is understandable, somewhat preventable, and/or remediable. Additional integration of current understandings regarding the interaction of mechanical factors that influence knee osteoarthritis pathogenesis and that emphasize the importance of mechanotransduction in the realm of arthritis inflammatory responses may further improve the capacity of clinicians and others to engender more optimal prevention and rehabilitation outcomes for many. As well, the necessity of maintaining a balance of adequate, but not excessive, mechanical loading to foster knee joint 'health' appears crucial [55-58].

To advance the wellbeing of the multitudes who remain susceptible in this regard, it appears attention to assessing the status of a host of knee extensor muscle attributes alongside standard clinical tests will greatly help to render a salient framework of causation and sound intervention schedule and selection as follows:

Muscle imbalances [3,11,12]
Muscle atrophy
Muscle contractures
Muscle fatigue/endurance [52]
Muscle fiber losses
Muscle mechanics [12]
Muscle pain and force steadiness [58]
Muscle fat volume [10,19,45]
Muscle force contractile abnormalities [4]
Impaired/efferent pathways/inhibited muscle reflexes [15-17]
Muscle length [52]
Muscle protein degradation [15]
Muscle spasm/tightness [15,20]
Muscle strength/power declines [7,14,36,43,51,57]
Muscle stiffness [18,28,51]
Muscle quality/volume declines [10,15,21,22,56]
Muscle tendon elasticity [8]

Acknowledgements: None

Conflicts of Interest: N/A

Funding: N/A

References

1. Johnson AJ, Barron SM, Nichols JA, Cruz-Almeida Y. Association of muscle quality and pain in adults with symptomatic knee osteoarthritis, independent of muscle strength: findings from a cross-sectional study. Arthritis Rheumatol. 2024. 76: 1062-1070.
2. Brandt KD, Radin EL, Dieppe PA, van de Putte L. Yet more evidence that osteoarthritis is not a cartilage disease. Ann Rheum Dis. 2006. 65: 1261-1264.
3. Chen W, Li C, Wang Y, Shen X, Wu Z, et al. Comparison of the asymmetries in muscle mass, biomechanical property and muscle activation asymmetry of quadriceps femoris between patients with unilateral and bilateral knee osteoarthritis. Front Physiol. 2023. 14: 1126116.
4. Zheng F, Jia R, Ye J, Li M, Zhang Y, et al. Prediction of specific structural damage to the knee joint using qualitative isokinetic analysis. BMC Musculoskelet Disord. 2024. 25: 382.
5. Lopes HS, Waiteman MC, Priore LB, Glaviano NR, Bazett-Jones DM, et al. There is more to the knee joint than just the quadriceps: a systematic review with meta-analysis and evidence gaps map of hamstring strength, flexibility, and morphology in individuals with gradual-onset knee disorders. J Sport Health Sci. 2024.13: 521-536.
6. He ZJ, Wei JT, Jiang HM, Wang JY, Lai JY, et al. Trajectories and predictors of weight-bearing and non-weight-bearing pain in knee osteoarthritis: a 9-year follow-up study. J Pain Res. 2024. 17: 3385-3395.
7. Kubo Y, Fujita D, Sugiyama S, Takachu R, Sugiura T, et al. Quadriceps strength loss following total knee arthroplasty

as a predictor of three-month strength recovery: a secondary analysis of a randomized controlled trial. Cureus. 2024. 16: 68244.
8. Dickson DM, Smith SL, Hendry GJ. Association between quadriceps tendon elasticity and neuromuscular control in individuals with knee osteoarthritis. Clin Biomech. 2024. 111: 106159.
9. Chen L, Zhou H, Gong Y, Tang Y, Su H, et al. How do muscle function and quality affect the progression of KOA? A narrative review. Orthop Surg. 2024. 16: 802-810.
10. Wu Q, Xu Z, Ma X, Li J, Du J, et al. Association of low muscle mass index and sarcopenic obesity with knee osteoarthritis: a systematic review and meta-analysis. J Int Soc Sports Nutr. 2024. 21: 2352393.
11. Hajnovic L, Matziolis G, Schütz L, Röhner E. Causal relation between functional muscular dysbalance and osteoarthritis. J Orthop Sports Med. 2024. 6: 255-260.
12. Li J, Wu Z, Lu B, Li C, Wang S, et al. The differences in parameters in ultrasound imaging and biomechanical properties of the quadriceps femoris with unilateral knee osteoarthritis in the elderly: a preliminary observational study. Clin Interv Aging. 2024. 19: 1479-1491.
13. Wang QW, Man GC, Choi BC, Yeung YM, Qiu JH, et al. The predictors to self-reported and performance-based physical function in knee osteoarthritis patients: a cross-sectional study. Front Cell Dev Biol. 2024. 12: 1406830.
14. van den Noort JC, van der Leeden M, Stapper G, Wirth W, Maas M, et al. Muscle weakness is associated with non-contractile muscle tissue of the vastus medialis muscle in knee osteoarthritis. BMC Musculoskelet Disord. 2022. 23: 91.
15. Marks R. Quadriceps muscle mechanics and knee osteoarthritis-a 2022 update. J Ortho Sci Res. 2022. 3: 1-21.
16. Sherman DA, Rush J, Glaviano NR, Norte GE. Knee joint pathology and efferent pathway dysfunction: Mapping muscle inhibition from motor cortex to muscle force. Musculoskelet Sci Pract. 2024. 74: 103204.
17. Konishi Y, Yoshii R, Ingersoll CD. Gamma loop dysfunction as a possible europhysiological mechanism of arthrogenic muscle inhibition: a narrative review of the literature. J Sport Rehabil. 2022. 31: 736-741.
18. Li Z, Leung KL, Huang C, Huang X, Su S, et al. Associations amongst dynamic knee stiffness during gait, quadriceps stiffness, and the incidence of knee osteoarthritis over 24 months: a cohort study with a mediation analysis. BMC Musculoskelet Disord. 2024. 25: 511.
19. Manatrakul R, Pirmoazen AM, Bharadwaj UU, Akkaya Z, Giesler PJ, et al. Thigh muscle and fat volumes are associated with knee cartilage abnormalities and bone marrow edema-like lesions: data from the osteoarthritis initiative. Skeletal Radiol. 2024. 53: 1279-1286.
20. Unuvar BS, Tufekci O, Gercek H, Torlak MS, Erbas O. Comparison of muscle tightness between knees in individuals with unilateral osteoarthritis and its relationship with pain and function. J Back Musculoskelet Rehabil. 2024. 37: 1269-1276.
21. Marks R. Muscle and osteoarthritis joint status: current research highlights and their implications. SM J Orthop. 2017. 3: 1050.
22. Zhang H, Shuai T, Wang J, Li K, Nie Y. Relationship between 2 years of muscle strength decrease and volume loss of menisci and cartilage according to knee pain in mild and moderate knee osteoarthritis. Am J Phys Med Rehabil. 2024. 104: 1-7.
23. Endo N, Aoyama T, Yamamoto S, Ishibashi K, Ishii D, et al. Factors associated with stiff knee gait in patients with knee osteoarthritis. J Orthop. 2024. 64: 81-85.
24. Mills Remedios S, Rutherford D. Lower extremity muscle patterns and frontal plane biomechanics are altered in the contralateral knee of adults with osteoarthritis compared to asymptomatic adults. J Electromyogr Kinesiol. 2024. 75: 102865.
25. Taniguchi M, Asayama A, Yagi M, Fukumoto Y, Hirono T, et al. Examination of knee extensor and valgus moment arms of the patellar tendon in older individuals with and without knee osteoarthritis. Clin Biomech. 2024. 113: 106212.
26. Davut S, Doğramacı Y. Evaluation of the relationship between the anatomical characteristics of the vastus medialis obliquus muscle and the patella chondral lesion occurrence. Jt Dis Relat Surg. 2024. 35: 330-339.
27. Gong Z, Li S, Cao P, Ruan G, Zhang Y, et al. The association between quadriceps strength and synovitis in knee osteoarthritis: an exploratory study from the Osteoarthritis Initiative. J Rheumatol. 2023. 50: 548-555.
28. Li Z, Leung KL, Huang C, Huang X, Chung R, et al. Passive stiffness of the quadriceps predicts the incidence of clinical knee osteoarthritis in twelve months. Eur J Phys Rehabil Med. 2023. 59: 65-74.
29. Dickson DM, Smith SL, Hendry GJ. Association between quadriceps tendon elasticity and neuromuscular control in individuals with knee osteoarthritis. Clin Biomech. 2024. 111: 106159.
30. Taniguchi M, Asayama A, Yagi M, Fukumoto Y, Hirono T, et al. Examination of knee extensor and valgus moment arms of the patellar tendon in older individuals with and without knee osteoarthritis. Clin Biomech. 2024. 113: 106212.
31. Ucurum SG, Kirmizi M, Umay Altas E, Ozer Kaya D. Postural stability and its relation to knee flexor/extensor strength ratio in women with mild to moderate unilateral knee osteoarthritis: a case-control study. Somatosens Mot Res. 2024. 41: 69-76.
32. Karapınar M, Ayyıldız VA, Unal M, Fırat T. Effect of intramuscular fat in the thigh muscles on muscle architecture and physical performance in the middle-aged women with knee osteoarthritis. J Orthop Sci. 2024. 29: 194-199.
33. Takahashi Y, Okura K, Kinoshita K, Seto A, Saito A, et al. Assessment of central aponeurosis curvature as an index of rectus femoris muscle overstrain in individuals with knee osteoarthritis. J Back Musculoskelet Rehabil. 2022. 35: 141-146.
34. Yang L, Sinsurin K, Shen F, Zhao B, Gao T. Biomechanical changes in lower extremity in individuals with knee osteoarthritis in the past decade: a scoping review. Heliyon. 2024. 10: 32642.
35. Wu Y, Boer CG, Hofman A, Schiphof D, van Middelkoop M, et al. Weight-bearing physical activity, lower-limb muscle mass, and risk of knee osteoarthritis. JAMA Netw Open. 2024. 7: 248968.
36. Li J, Wu Z, Lu B, Li C, Wang S, et al. The differences in parameters in ultrasound imaging and biomechanical properties of the quadriceps femoris with unilateral knee osteoarthritis in the elderly: a preliminary observational study. Clin Interv Aging. 2024. 19: 1479-1491.

37. Bae KC, Son ES, Yon CJ, Park J, Kim DH. Assessment of quadriceps muscle in advanced knee osteoarthritis and correlation with lower limb alignment. Medicina (Kaunas). 2024. 60: 1983.
38. Lisboa VT, Arruda BPL, Tambascia RA, Zorzi AR, Cliquet A Jr, et al. A complete functional characterization of patients with severe knee osteoarthritis in need of total knee replacement. J Funct Morphol Kinesiol. 2024. 9: 216.
39. Losciale JM, Truong LK, Zhang K, Silvester-Lee T, Miciak M, et al. Assessing the efficacy of the Stop OsteoARthritis (SOAR) program: a randomized delayed-controlled trial in persons at increased risk of early onset post-traumatic knee osteoarthritis. Osteoarthritis Cartilage. 2023. 2: 1001-1012.
40. Holm PM, Blankholm AD, Nielsen JL, Bandholm T, Wirth W, et al. Effects of neuromuscular control and strengthening exercises on MRI-measured thigh tissue composition and muscle properties in people with knee osteoarthritis - an exploratory secondary analysis from a randomized controlled trial. Semin Arthritis Rheum. 2024. 65: 152390.
41. Cigercioglu NB, Bazancir-Apaydin Z, Apaydin H, Baltaci G, Guney-Deniz H. Differences in ankle and knee muscle architecture and plantar pressure distribution among women with knee osteoarthritis. J Foot Ankle Res. 2024. 17: 12028.
42. Maciukiewicz JM, Tung EV, Brenneman Wilson EC, Maly MR. Improving muscle capacity utilization with a 12-week strengthening program for females with symptomatic knee osteoarthritis. Gait Posture. 2024. 108: 341-346.
43. Distefano G, Harrison S, Lynch J, Link TM, Kramer PA, et al. Skeletal muscle composition, power, and mitochondrial energetics in older men and women with knee osteoarthritis. Arthritis & Rheumatology. 2024. 76: 1764-1774.
44. Smith SL, Paul L, Steultjens MPM, Jones RL. Associations between biomarkers and skeletal muscle function in individuals with osteoarthritis: a systematic review and meta-analysis. Arthritis Res Ther. 2024. 26: 189.
45. Yan L, Ge H, Wang Z, Shen A, Xu Q, et al. Roles of low muscle strength and sarcopenic obesity on incident symptomatic knee osteoarthritis: a longitudinal cohort study. Plos One. 2024. 19: 0311423.
46. Gorski T, Casartelli NC, Fitzgerald G, Horstman AMH, Masschelein E, et al. Intramuscular fatty infiltration and its correlation with muscle composition and function in hip osteoarthritis. Skelet Muscle. 2024. 14: 32.
47. Liu T, Xie H, Yan S, Zeng J, Zhang K. The effect of thigh muscle forces on knee contact force in female patients with severe knee osteoarthritis. Bioengineering. 2024. 11: 1299.
48. Fanget Q, Verdilos A, Adelou S, Reynaud V, Boisgard S, et al. Abnormality in field physical test predicts a reduced quadriceps strength in patients with hip- or knee-osteoarthritis. a prospective observational study. PLoS One. 2024. 19: 0314524.
49. Kono K, Kinoshita T, Soufi M, Otake Y, Masaki Y, et al. Artificial intelligence-based analysis of lower limb muscle mass and fatty degeneration in patients with knee osteoarthritis and its correlation with Knee Society Score. Int J Computer Assisted Radiol Surg. 2024. 1-8.
50. Akagawa M, Saito H, Takahashi Y, Iwamoto Y, Iida J, et al. The impact of reduced skeletal muscle mass on patients with knee osteoarthritis. Acta Medica Okayama. 2024. 78: 245-250.
51. Li Z, Leung KL, Huang C, Huang X, Su S, et al. Associations amongst dynamic knee stiffness during gait, quadriceps stiffness, and the incidence of knee osteoarthritis over 24 months: a cohort study with a mediation analysis. BMC Musculoskelet Disord. 2024. 25: 511.
52. Cavalcante JGT, Ribeiro VHS, Marqueti RC, Paz IA, Bastos JAI, et al. Effect of muscle length on maximum evoked torque, discomfort, contraction fatigue, and strength adaptations during electrical stimulation in adult populations: a systematic review. PLoS One. 2024. 19: 0304205.
53. Chun S, Park J. Exploring quadriceps activity variations in women: the role of seated posture during stair climbing. Peer J. 2024. 12: 18547.
54. Ding X, Yang Y, Xing Y, Jia Q, Liu Q, et al. Efficacy of lower limb strengthening exercises based on different muscle contraction characteristics for knee osteoarthritis: a systematic review and network meta-analysis. Front Med. 2024. 11: 1442683.
55. Jahn J, Ehlen QT, Huang CY. Finding the Goldilocks zone of mechanical loading: a comprehensive review of mechanical loading in the prevention and treatment of knee osteoarthritis. Bioengineering. 2024. 11: 110.
56. Watabe T, Sengoku T, Sakurai G, Yoshida S, Taniguchi Y. Association of physical function, quantity, and quality of the quadriceps with postoperative physical activity before total knee arthroplasty. J Clin Med. 2025. 14: 294.
57. Luo X, Wang Q, Tan H, Zhao W, Yao Y, et al. Digital assessment of muscle adaptation in obese patients with osteoarthritis: insights from surface electromyography (sEMG). Digit Health. 2025. 11: 20552076241311940.
58. Arvanitidis M, Falla D, Sanderson A, Martinez-Valdes E. Does pain influence control of muscle force? A systematic review and meta-analysis. Eur J Pain. 2025. 29: 4716.