



Evaluation of vastus lateralis architecture and strength of knee extensors in middle-aged and older individuals with knee osteoarthritis

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Abstract

Objectives To investigate any differences in muscle architecture (fascicle angle, fascicle length, and muscle thickness) and muscle strength in people of different ages with and without knee osteoarthritis (OA).

Methods This is a cross-sectional study conducted with 40 individuals with and 40 without knee OA. Four groups were analyzed, middle-aged OA group (KL II/III) aged 40–50 years ($n=20$), middle-aged healthy (H) group aged 40–50 years ($n=20$), older OA group (KL II/III) aged 70 years and over ($n=20$), and older H group, aged 70 years and over ($n=20$). Outcomes analyzed were isometric and isokinetic peak torque of knee extensors, level of physical activity, self-reported pain level, and vastus lateralis fascicle length, fascicle angle, and muscle thickness assessed by ultrasound. One-way ANOVA was used to identify differences between groups, followed by the Tukey post hoc test.

Results There were no differences between the middle-aged OA group and older H group for any variables. The older OA group presented the smallest muscle architecture parameters and worst isometric and concentric peak torques compared to the other three groups ($p < 0.001$). In contrast, the middle-aged H group presented the largest muscle architecture parameters and was the strongest group compared to the others ($p < 0.001$).

Conclusions The presence of knee OA is associated with early muscular changes and seems to intensify these thigh changes that are similar to the effects of the aging process.

Keywords Aging · Isokinetic peak torque · Muscle architecture · Strength · Ultrasound

Introduction

Osteoarthritis (OA) is one of the most common chronic-degenerative joint diseases in people aged ≥ 50 years [1]; OA is characterized by progressive degeneration of the articular cartilage, weakening of subchondral bone,

synovial inflammation, meniscal degeneration, and intra-articular osteophytes [1–3]. The knee is the most affected joint, with 44% of older adults aged 70 years and over presenting radiographic OA signs and/or clinical symptoms [4]. Consequently, patients with knee OA usually seek medical care due to joint pain and loss of knee function [5], causing a significant burden on the health care system [6]. Beyond joint structure, knee OA has a negative impact on adjacent tissues, such as muscles.

Muscle weakness has been described as one of the earliest signs of knee OA, and the most frequently occurring sign in this population [7]. Muscle strength around the knee is frequently assessed via isometric and isokinetic strength tests [8], but also via thigh cross-sectional area (magnetic resonance and computed tomography imaging) [9]. However, these measures do not provide information on how muscle weakness was related to changes in other architecture parameters, usually affected in people with knee OA [10].

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The muscle architecture parameters more recently considered to be associated with strength are fascicle angle and length [11]. These muscle architecture parameters have been assessed using ultrasound imaging which is a non-invasive, safe, and accessible method that can provide reliable information on skeletal muscles [12]. Furthermore, some studies with older-aged people have shown that muscle ultrasound measures of quadriceps thickness, fascicle angle (FA), and fascicle length (FL) are significantly correlated with isometric and isokinetic strength of knee extensors [13–15]. FA is associated with the number of sarcomeres in parallel in the muscle, which is correlated with the maximal force capacity of a muscle fiber [16]. Muscle FL is associated with the number of sarcomeres in series and is proportional to maximum contraction velocity [17]. Muscle thickness is correlated with muscle cross-sectional area, and therefore, muscle strength [13]. In addition, one previous study has shown that muscle thickness for the vastus lateralis in isolation is significantly associated with isometric maximum contraction force of the quadriceps femoris muscle [15]. Blazeovich et al. [18] considered the vastus lateralis as an adequate muscle to be used in ultrasound assessment as it generates less measurement error when compared to the other muscles of the quadriceps [18].

Knee extensor strength has been described as a predictor of independence in the elderly [19]. Similarly, quadriceps weakness has been described as the most frequent sign in patients with knee OA, and the first to be detected [7]. This sign is usually associated with decreases in joint stabilization [5], shock absorption [20], and an increase in pain [21]. However, it is not unreasonable to expect that people with knee OA, of different age ranges, are likely to present alterations in muscle architecture and strength in different levels. Nevertheless, there are no studies investigating these differences in muscle architecture (fascicle angle, fascicle length, and muscle thickness) or even muscle strength, in people with knee OA of different ages.

Therefore, the objectives of the present study were to investigate whether there are differences in muscle architecture and muscle strength in people of different ages and with and without the presence of knee OA. Our main hypothesis was that the presence of knee OA causes early muscle architecture changes, characterized by a reduction in fascicle angle, fascicle length, and muscle thickness. Furthermore, we hypothesized that people with knee OA would present decreased isometric and isokinetic knee extensor peak torques when compared to age-matched controls.

Methods

This was a cross-sectional study to investigate whether there are differences in muscle strength and architecture, and

physical activity and function in middle-aged and older individuals, with and without knee OA.

Participants

Participants were recruited from the community via radio, newspaper, and social media. To be included, participants were required to be between 40 and 50 years of age or ≥ 70 , have a BMI ≤ 30 kg/m², and report persistent pain in at least one of the knees (to be included in the knee OA group) or no pain (to be included in the non-knee OA group). The presence or absence of knee OA was confirmed for all participants through anterior-posterior and lateral radiographic images while weight-bearing, and skyline radiographic images with no weight-bearing. The radiographic images were also used to grade bilateral tibiofemoral and patellofemoral OA [22] according to the Kellgren and Lawrence criteria (KL) [23] by an experienced radiologist who was blinded to any other assessment [24–26]. Participants were eligible for the groups with knee OA if they were classified as grades II and III on the KL (unilateral or bilateral) and presented clinical signs according to the American College of Rheumatology criteria (ACR) [27]. Thus, 20 participants (10 men and 10 women; Table 1) composed the middle-aged osteoarthritis group (middle-aged OA) and 20 participants (10 men and 10 women) composed the older osteoarthritis group (older OA). For these groups, when a participant had bilateral knee OA, the most symptomatic limb was selected for analysis.

Participants were eligible for the groups without knee OA if their knees were classified as 0 or 1 on the KL and were asymptomatic. They were also matched to the middle-aged OA and older OA groups by sex and BMI. Thus, 20 participants (10 men and 10 women, Table 1) composed the middle-aged healthy group (middle-aged H) and 20 participants (10 men and 10 women) composed the older healthy group (older H). For the middle-aged H and older H groups, one limb was randomly selected for analysis.

Exclusion criteria for any groups were the presence of systemic inflammatory arthritis, a previous history of trauma in the lower limbs and/or ligament and meniscus injuries of the knee, having undergone physical therapy treatment for the knee in the previous 6 months, previous surgery in the lower limbs, use of corticosteroid infiltration in the knees in the previous 6 months, presence of pain predominantly in another region of the body, any medical condition which precluded participation in the proposed assessments, and/or the inability to comprehend and follow instructions [28].

Prior to testing, this study was approved by the local Human Research Ethics Committee of the Federal University of São Carlos (UFSCar) and written informed consent was obtained from all participants.

Table 1 Characteristics of participants

	OA groups		Healthy groups	
	Middle-aged (<i>n</i> = 20)	Older (<i>n</i> = 20)	Middle-aged (<i>n</i> = 20)	Older (<i>n</i> = 20)
Age (years)	45.3 (2.7) ^{ac}	74.3 (2.8) ^b	45.2 (3.7) ^c	74.6 (3.1)
Body mass index (kg/m ²)	26.8 (2.7)	27.2 (2.9)	26.0 (3.3)	25.4 (3.0)
Physical activity				
Sitting/lying down, <i>h</i>	16.5 (2.0)	16.4 (2.6)	17.1 (1.1)	15.7 (2.0)
Standing, <i>h</i>	5.4 (1.4)	5.8 (2.0)	4.9 (1.2)	6.2 (1.6)
Walking, <i>h</i>	1.8 (0.7)	1.7 (0.9)	1.9 (0.5)	2.1 (0.7)
Number of steps, (<i>n</i>)	8188 (3094)	7456 (4729)	9292 (3631)	9924(4021)
Transitions, (<i>n</i>)	56 (15)	49 (16)	56 (16)	56 (16)
MET, <i>h</i>	33.8 (1.9)	33.8 (2.0)	34.4 (1.3)	34.8 (1.7)
WOMAC, total score	37.9 (18.1)	39.1 (16.4)		
VAS, mm	5.3 (1.5)	6.2 (1.9)		

VAS, visual analog scale; MET, metabolic equivalent of task; OA, osteoarthritis

Values are expressed as mean (SD)

^a $p < 0.05$, significantly different compared with older-aged OA group

^b $p < 0.05$, significantly different compared with middle-aged healthy group

^c $p < 0.05$, significantly different compared with older-aged healthy group

Procedures

To measure muscle strength, participants underwent isometric and isokinetic testing of knee extensors. Muscle architecture of the vastus lateralis was measured via ultrasonography. Physical activity levels were measured through a triaxial accelerometry system, and function and pain were measured using the WOMAC questionnaire and visual analog scale (VAS), respectively. For this, the WOMAC, VAS, and strength tests were performed on the same day, which was also the first day of wearing the accelerometry system. After 7 days wearing the accelerometry system, participants returned to the laboratory to have the equipment removed and for reassessment of muscle architecture.

Muscle architecture

Fascicle angle (FA), muscle thickness (MT), and fascicle length (FL) of the vastus lateralis were obtained using a two-dimensional (2D) B-mode ultrasonography (Acuson X300 PE, Siemens) and a linear array transducer (4–11.4 MHz). All data on muscle architecture were collected by a single radiologist. The vastus lateralis was the muscle of choice due to its simple alignment of fascicles when compared to other quadriceps muscles [18].

For image acquisition, participants were instructed to lie down on a plinth in supine, with legs fully extended and relaxed for 20 min, to ensure fluid redistribution [29]. Three images of the vastus lateralis were then collected at the point corresponding to the middle of the thigh, measured as the midpoint between the greater trochanter and the lateral

epicondyle of the femur [18]. Water-soluble gel was applied between the transducer and the skin to support acoustic coupling, without applying pressure to the muscle. The transducer was oriented parallel to the muscle fascicles and perpendicular to the skin.

All images were manually traced and then measured by a second investigator using ImageJ software (National Institutes of Health, USA) as shown in Fig. 1. MT was defined as the distance between the deep and superficial aponeurosis [14, 18]. FA was defined as the angle between the muscle fascicle line and the deep aponeurosis [11]. FL was defined as the distance between the origin of the fascicle at the superficial aponeurosis and insertion of the same fascicle in the deep aponeurosis [11, 16]. When fascicles extended off the acquired image, the length of the missing portion was estimated through linear extrapolation of the length of both the fascicle and aponeurosis [18, 30]. The mean of the three measures of MT, FA, and FL was then used for analysis.

Data on FL were normalized by femur length [10]. Test-retest inter-rater reliability was calculated with ten participants from two images taken on the same day and two images taken on two different days. Intra-class correlation coefficients for MT, FA, and FL ranged from 0.97 to 0.99, 0.91 to 0.98, and 0.89 to 0.95, respectively.

Isokinetic and isometric strength

Concentric isokinetic and isometric knee extensor peak torques were recorded using a Biodex System dynamometer (Biodex Medical Systems 3 Pro, Shirley, New York, USA) with a sampling frequency of 100 Hz. The knee extensors

were chosen as quadriceps weakness is associated with knee OA [31].

The assessments were conducted with the participant seated on the device chair, with knees flexed at 90°. The participant was stabilized on a chair with a strap over the hips, two straps on the shoulders that crossed the chest, and a strap across the thigh of the tested limb. The dynamometer's axis of rotation was aligned with the lateral epicondyle of the femur and the dynamometer lever pad was positioned 5 cm above the medial malleolus. Participants were instructed to hold handles positioned on both sides of the seat during contractions.

Before testing and after receiving instructions, the participant performed five submaximal isokinetic concentric contractions and three submaximal isometric contractions on the equipment in order to become familiar with the test procedure. The participant rested for 2 min between the familiarization and the actual tests. The isokinetic concentric test consisted of five maximal contractions at 60°/s, and the isometric test consisted of three maximal contractions held for 3 s each, with a 1-min rest between contractions [15, 31, 32]. The order of tests was randomly assigned and standard verbal encouragement was given during all contractions.

Isometric peak torque was calculated as the average of the three maximal contractions, and the isokinetic peak torque was calculated as the average of the three central maximal contractions [14]. Isometric and isokinetic average peak torques were normalized by body mass (kg) (peak torque/body mass × 100) and used for statistical analysis.

Physical activity

The level of physical activity was monitored through a triaxial accelerometry system (activPAL3™, PAL Technologies Ltd., Glasgow, UK) for all participants. The device (dimension = 35 × 53 × 7 mm and 20 g) was attached to the middle third of the thigh with tape. Participants were instructed to wear the monitor continuously for a week and to maintain their daily routine during that time, only avoiding water immersion of the device. Data from the accelerometer allowed estimation of the time spent on daily activities (sitting/lying, standing, and walking), number of steps, and the energy expenditure in MET/h. These outcomes are presented as the average activity per day; data from the first and last day were excluded.

Pain and disability

Pain was assessed through the VAS, a 100-mm line on which the participant places a mark between the left end (0), representing “no pain” and the right end (100), representing “the worst pain imaginable” [33]. Disability was assessed via the Western Ontario and McMaster Universities Osteoarthritis

Index (WOMAC) [34]. This is a self-reported tool composed of 24 items divided into three subscales: pain, stiffness, and physical function, where higher scores (0–96) indicate a worse condition.

Statistical analysis

The sample size for the current study was calculated based on pilot data with ten participants in four groups, with similar characteristics to those of the current study (age, BMI < activity level, OA severity). A significance level of 0.05 and power of 0.95 to detect a FA difference between groups of at least 2.96° (SD = 2.5°) was considered. Thus, at least seven participants were required for each group. Descriptive statistics are presented as means and standard deviations. Normal distribution of data was assessed using the Kolmogorov-Smirnov test, and skewness values, where values inside the range –1.0–1.0 indicate normal distribution [35].

One-way analysis of variance (ANOVA) was used to compare age, BMI, physical activity, muscle architecture, and isometric and isokinetic strength, followed by a post hoc Tukey test. Differences between WOMAC scores and VAS scores were examined using the independent *t* test. Mean differences and confidence intervals of the differences between middle-aged OA, older OA, middle-aged H, and older H groups were calculated to estimate the magnitude of the differences between groups. Mean differences for the same comparisons were also calculated.

Results

Muscle architecture

For muscle architecture, as expected, the vastus lateralis of the middle-aged H group presented the highest FA when compared to the other three groups. In addition, the older OA group demonstrated the lowest FA when compared to the other groups (Table 2). The comparison between the middle-aged OA and older H groups showed no difference in FA between these groups (Table 2). Regarding FL, the middle-aged H group had the longest fascicles when compared to the other three groups. However, the comparison between the middle-aged OA, older OA, and older H groups showed no differences in FL between these groups (Table 2). Lastly, with respect to MT, the older OA group presented the lowest MT when compared to the other groups (Table 2). There were no differences in MT between the middle-aged H, middle-aged OA, and older H groups (Table 2).

Table 4 presents the mean differences and 95% confidence interval for between-group comparisons of vastus lateralis (VL) architecture.

Isometric and isokinetic peak torque

Table 3 shows the differences between groups related to knee joint concentric and isometric peak torques. The middle-aged H group had the highest concentric peak torque when compared to the other three groups, while the older OA group had the lowest peak torque when compared to the other groups (Table 3). The comparison between the middle-aged OA and older H groups showed no differences in concentric peak torque (Table 3). With respect to isometric peak torque, the middle-aged H group was the strongest group compared to the other groups (Table 3). Among the other three groups, the only statistical difference was between the older OA and older H groups (Table 3).

Table 4 also presents the mean differences and 95% confidence interval for between-group comparisons of isometric and concentric knee extensor torque.

Physical activity, pain, and disability

For physical activity, the comparison between groups (middle-aged OA, older OA, middle-aged H, and older H) did not present statistical differences in time spent on daily activities (sitting/lying, standing, and walking), number of steps and transitions, or the energy expenditure in MET/h (Table 1). In addition, there were no between-group differences for pain intensity and WOMAC total score (Table 1).

Discussion

To the best of our knowledge, this is the first study to assess how the presence of knee OA can change muscle architecture and strength in middle-aged and older individuals. Our main

findings show that the changes in VL of middle-aged people with knee OA present similar characteristics to healthy older people (approximately 20 years older) regarding muscle architecture. The same groups were also similar regarding knee extensor isometric and concentric torques. These findings suggest that people with knee OA are likely to experience early muscle changes that are usually experienced at an older age.

Previous studies have shown that people with knee OA present morphological changes to the quadriceps. Ikeda et al. [36] compared young women with knee OA (around 30 years of age) with older women with knee OA (around 60 years of age) and found that the older group presented smaller quadriceps cross-sectional areas and lower intermuscular density. However, the authors did not present any analysis on muscle architecture, not allowing more comprehensive analysis on how muscle architecture is altered in these individuals. The present study corroborates the findings by Ikeda et al. [36] as we found that older individuals with knee OA had lower VL FA and MT when compared to the middle-aged OA group. MT is directly influenced by both FA and FL [37]; therefore, it is possible to speculate that if older individuals with knee OA had shorter FL, MT would be even lower for these individuals.

Another important finding of the current study is related to the similarity of muscle architecture and strength observed between the middle-aged OA and older H groups. Previous studies have shown that healthy older individuals present worse lower limb muscle architecture when compared to a healthy, middle-aged population [15, 38, 39]. Furthermore, Vaz et al. [10] showed that older women with knee OA are weaker and have smaller muscles and shorter VL FL compared to matched (age and sex) healthy individuals. Since, in our study, we were able to compare muscle architecture

Fig. 1 Ultrasonographic imaging of the vastus lateralis. Ultrasound image demonstrates the measurement of the fascicle angle, fascicle length, and muscle thickness. SA, superficial aponeurosis; DA, deep aponeurosis; VL, vastus lateralis; VI, vastus intermedius; FA, fascicle angle; FL, fascicle length; MT, muscle thickness

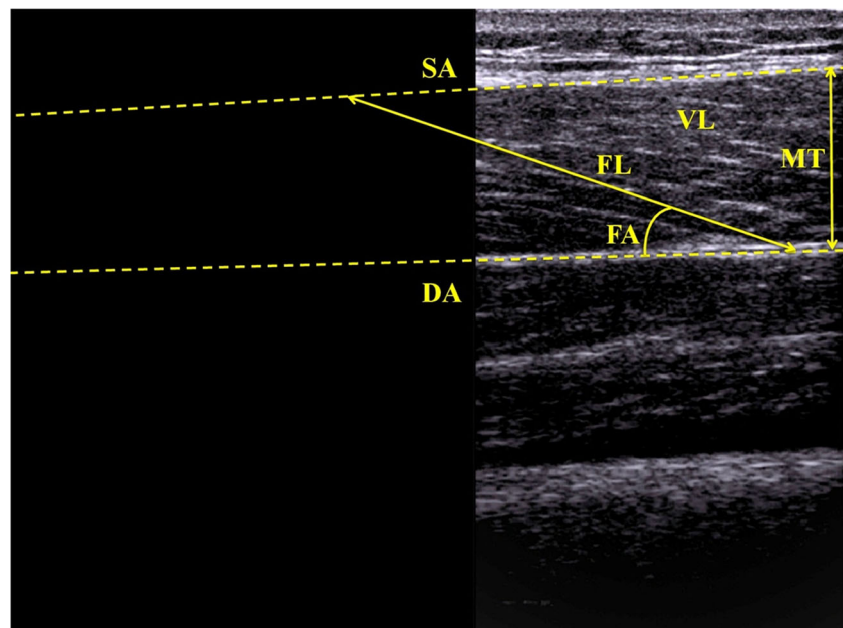


Table 2 Muscle architecture for vastus lateralis

	OA groups		Healthy groups	
	Middle-aged (<i>n</i> = 20)	Older (<i>n</i> = 20)	Middle-aged (<i>n</i> = 20)	Older (<i>n</i> = 20)
Fascicle angle, deg	12.2 (2.3) ^{ab}	10.1 (1.7) ^{bc}	15.6 (3.4) ^c	13.4 (1.8)
Fascicle length (FL), (FL/femur length)	0.13 (0.03) ^b	0.12 (0.02) ^b	0.15 (0.02) ^c	0.13 (0.02)
Muscle thickness, cm	1.5 (0.3) ^a	1.0 (0.3) ^{bc}	1.7 (0.4) ^c	1.3 (0.2)

Values are expressed as mean (SD); OA, osteoarthritis

^a *p* < 0.05, significantly different compared with older-aged OA group

^b *p* < 0.05, significantly different compared with middle-aged healthy group

^c *p* < 0.05, significantly different compared with older-aged healthy group

between people of different age ranges, with and without knee OA, we were able to detect similar VL FA, FL, MT, and extensor peak torques between the middle-aged OA and older H groups. This finding suggests that the changes occurring in the muscles of middle-aged people with knee OA are similar to those seen in a natural aging process, and are likely to have implications for function.

The present study also reinforces previous knowledge that the aging process is characterized by muscle architecture changes [15]. The results confirm that middle-aged individuals have thicker muscles, longer muscle fascicles, and a larger pennation angle than older people, regardless of the presence of knee OA. Thus, the current study corroborates the study of Strasser et al. [15], which compared young (18 to 35 years) and older (60 to 80 years) healthy individuals and found that fascicle angle and muscle thickness of the VL were significantly lower in the older group.

Similar to muscle architecture, no previous studies have compared muscle strength between middle-aged individuals with knee OA and healthy older individuals. The present study demonstrates an alignment between the results for muscle strength and the results for muscle architecture. The middle-aged knee OA individuals presented no difference in isometric and concentric peak torques when compared with healthy older individuals. Thus, these findings suggest that knee OA is associated with early muscular changes, similar

to the changes seen in aging. Furthermore, we found that isometric and concentric peak torques were significantly lower for the groups with knee OA when compared to the age-matched healthy individuals, suggesting that the presence of knee OA is an important factor leading to a loss in muscle strength. Our findings add knowledge to the findings from the study by Taniguchi et al. [32], which compared 21 women with knee OA and 21 healthy women, and also reported that the group with knee OA presented significantly lower knee extension force than the healthy group.

In addition, the older individuals presented lower concentric peak torque than the middle-aged participants, with and without knee OA, confirming previous studies that described a decline in strength as part of aging [15, 40–43]. However, in contrast to current literature [15, 40–43], the older OA group presented similar isometric torque production to the middle-aged OA group. One possible explanation for this finding is based on the lack of difference in pain intensity (VAS) between these groups. As quadriceps force generation is affected by knee pain in individuals with knee OA [44], it is possible that the level of pain felt by all participants with knee OA was sufficiently high to generate large variability in isometric peak torque, which could have led to the lack of differences found.

The results of the present study show that the use of ultrasound to measure architecture of the VL is a safe and accessible method to assess early muscular changes in patients with

Table 3 Isometric and concentric maximum muscle torque for knee extensors

	OA groups		Healthy groups	
	Middle-aged (<i>n</i> = 20)	Older (<i>n</i> = 20)	Middle-aged (<i>n</i> = 20)	Older (<i>n</i> = 20)
Concentric torque (Nm/kg × 100)	139.5 (57.9) ^{ab}	100.0 (32.0) ^{bc}	191.9 (48.4) ^c	145.8 (41.7)
Isometric torque (Nm/kg × 100)	170.7 (63.6) ^b	131.6 (39.6) ^{bc}	238.3 (64.0) ^c	186.4 (45.8)

Values are expressed as mean (SD); OA, osteoarthritis

^a *p* < 0.05, significantly different compared with older-aged OA group

^b *p* < 0.05, significantly different compared with middle-aged healthy group

^c *p* < 0.05, significantly different compared with older-aged healthy group

Table 4 Mean differences and 95% confidence interval for between group comparisons of vastus lateralis (VL) architecture and isometric and concentric knee extensor torque

	Middle-aged OA versus older OA	Middle-aged OA versus middle-aged H	Middle-aged OA versus older H	Older OA versus middle-aged H	Older OA versus older H	Middle-aged H versus older H
VL fascicle angle, deg	2.1 (0.0 to 4.2)	- 3.5 (- 5.5 to - 1.4)	- 1.3 (- 3.3 to 0.8)	- 5.6 (- 7.6 to - 3.5)	- 3.4 (- 5.4 to - 1.3)	2.2 (0.2 to 4.3)
VL fascicle length, cm	0.02 (0.00 to 0.04)	- 0.02 (- 0.04 to 0.00)	0.00 (- 0.02 to 0.02)	- 0.04 (- 0.06 to - 0.02)	- 0.01 (- 0.04 to 0.01)	0.02 (0.00 to 0.04)
VL muscle thickness, cm	0.4 (0.2 to 0.7)	- 0.2 (- 0.5 to 0.0)	0.2 (- 0.8 to 0.4)	- 0.7 (- 0.9 to - 0.4)	- 0.3 (- 0.5 to 0.0)	0.4 (0.1 to 0.6)
Isometric torque (Nm/kg × 100)	39.1 (- 7.5 to 85.6)	- 67.6 (- 114.2 to - 21.1)	- 15.7 (- 62.2 to 30.9)	- 106.7 (- 153.2 to - 60.1)	- 54.7 (- 101.3 to - 8.2)	51.9 (5.4 to - 98.5)
Concentric torque (Nm/kg × 100)	39.5 (0.1 to 78.9)	- 52.4 (- 91.8 to - 13.0)	- 6.3 (- 45.7 to 33.1)	- 91.9 (- 131.3 to - 52.6)	- 45.8 (- 85.2 to - 6.4)	46.1 (6.7 to 85.5)

knee OA. This finding has potential important clinical impact, because this technique is inexpensive, it does not expose patients to radiation and allow for immediate results. Furthermore, the ultrasound may be an alternative or complementary exam to assess the presence of knee OA, even from early stages. However, more research is needed to establish whether muscle architecture parameters obtained from ultrasound are sufficiently correlated to the KL grading system. Also, future research on whether muscle architecture can be considered a risk factor for the development of knee OA would allow new strategies to prevent the onset and progression of the disease. Future investigations also should focus on evaluating whether this technique in other clinical presentations, such as immobilization, aging, and obesity.

The authors recognize some limitations of this study. The cross-sectional design of the present study does not allow us to determine a cause-and-effect relationship between the variables explored. Therefore, it was not possible to identify whether the change in knee extensor strength and muscle architecture of the VL precede knee OA or are a consequence of the disease. Furthermore, although we decided to analyze only the VL with the intention of minimizing measurement error, muscle architecture from other quadriceps muscles, such as the rectus femoris, should be analyzed in order to further understand the association of muscle architecture and isokinetic strength in people with knee OA. Also, the present study focused only on individuals with BMI < 30, excluding obese people. Thus, considering that obesity is largely related to the development of knee OA, future studies are necessary to understand if individuals with higher BMI would present similar changes in muscle architecture to the ones seen in the current study.

In conclusion, our study shows that knee OA is associated with early muscular changes. Knee OA also seems to facilitate changes in thigh muscles that are similar to the effects of aging. Clinicians and researcher would benefit from future larger studies investigating the relationship of knee OA with a wider range of knee muscles and how any potential change in muscle architecture and strength are likely to affect function, pain, and quality of life of this population. It is hoped our study will also stimulate further studies investigating interventions to decrease the changes seen in aging.

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Compliance with ethical standards

Disclosures None.

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