



# Lateral to medial hamstring activation ratio: Individuals with medial compartment knee osteoarthritis compared to asymptomatic controls during gait

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## ABSTRACT

**Background:** Elevated lateral hamstring activity is often found in individuals with knee osteoarthritis during gait. These findings are based on maximal voluntary isometric contraction normalized EMG signals. This choice of amplitude normalization may contribute to differential activation of the hamstrings.

**Research question:** The objective was to determine lateral to medial hamstring root mean square activation ratios of individuals with medial compartment knee osteoarthritis compared to asymptomatic older adults during walking. The secondary objective was to determine whether this ratio differed between ipsilateral and contralateral knees in individuals with knee osteoarthritis.

**Methods:** Surface electromyography of the hamstrings were acquired using standardized techniques from both limbs of 42 individuals with unilateral symptomatic medial compartment knee osteoarthritis and a random limb of 40 asymptomatic individuals during treadmill walking. Root mean squared amplitudes from the gait cycle were calculated. The lateral:medial activation ratio was computed. To address the first objective, an independent *t*-test was performed; both corrected and not corrected for walking velocity. A paired *t*-test was used for the second objective ( $\alpha = 0.05$ ).

**Results:** The lateral:medial activation ratio was greater in the knee osteoarthritis group demonstrating a moderate effect size ( $p < 0.05$ , Cohens  $d = 0.73$ ). The ipsilateral lateral:medial ratio was also greater than the contralateral ( $p < 0.05$ ) in the knee osteoarthritis group, showing a low to moderate effect size (Cohens  $d = 0.53$ ).

**Significance:** The activation ratio of the lateral and medial hamstrings during treadmill walking was unique to the symptomatic leg of individuals with medial compartment knee osteoarthritis. The ratio showed a bias toward greater lateral hamstring activation in the symptomatic leg. While considerations such as the impact of subcutaneous tissue differences between electrode sites should be considered when interpreting un-normalized electromyograms, this technique may be useful in integrating electromyography into clinical knee osteoarthritis functional assessments without the requirement of maximal voluntary isometric contraction-based amplitude normalization.

## 1. Introduction

Knee osteoarthritis (OA) creates an environment of altered pathomechanics during functional activities such as walking [1–3], accompanied by alterations to the neuromuscular system, measured via electromyography (EMG).

Elevated lateral hamstring (LH) activation during the gait cycle, both compared to the LH of an asymptomatic group, and/or compared

to the medial hamstrings (MH) in the OA group has been found in individuals with medial compartment knee OA [4–6]. This differential activation, or elevated LH compared to MH activation, has not been reported in older adults with asymptomatic knees [5] or in younger adults and those with hip injuries [7], suggesting uniqueness to the medial compartment knee OA group.

While differential activation has been interpreted in the context of walking, it is conceivable that this finding is a result of the maximal

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voluntary isometric contraction (MVIC) normalization used in previous studies. It has been shown that maximal MH and LH activation can be generated from different exercises and also from the same exercise but at different knee angles [8,9]. Therefore, it is possible that differential activation during maximal knee flexion could occur and result in the perception of differential EMG levels during walking.

The objective was to evaluate previously collected, non-amplitude normalized hamstring activation to determine the LH:MH activation ratio of individuals with medial compartment knee OA compared to asymptomatic older adults during walking. The secondary objective was to determine whether this ratio differed between ipsilateral and contralateral knees in individuals with knee OA. It was hypothesized that LH:MH ratios based on raw, unprocessed electromyograms would demonstrate characteristic differential activation in these comparisons.

**2. Methods**

Participants with unilateral symptomatic medial compartment knee OA were recruited through local orthopaedic clinics and diagnosed using the American College of Rheumatology criteria [10]. All individuals with OA required a Kellgren Lawrence grade > 1 in the symptomatic knee. All individuals self-reported functional capabilities [5] and those scheduled for a total knee arthroplasty were excluded. An asymptomatic group was recruited from the local community through advertisements. Participants were included if ≥50 years of age, reported no cardiorespiratory disease or neurological disorders and no injuries other than a sprain or strain within the last year. The protocol was approved by local ethics review committee.

Participants changed into tight fitting shorts, a t-shirt and removed their footwear prior to walking across the GaitRITE pressure sensitive walkway (CIR Systems, USA) at a self-selected speed.

Surface EMG was completed using standard guidelines [11]. Skin was shaved and cleaned with alcohol wipes and 10 mm diameter electrodes (Ag/AgCl, 30 mm inter-electrode distance, 3M Healthcare, USA) were affixed bilaterally on LH and MH. Surface EMG was recorded at 2000 Hz (AMT-8 EMG system, Bortec Inc., Canada) via Qualisys Track Manager V2.10 (Qualisys, Sweden).

Participants walked barefoot, at the speed calculated from the GaitRITE walkway, for at least 5-minutes on a treadmill. A 20-second measurement was made after familiarization. Following, a supine resting muscle bias was recorded.

**3. Processing**

Custom programs, written in MATLAB 2017b (The Mathworks Inc., USA), were used to correct signals for subject bias and gains. Ipsilateral and contralateral hamstring activation was assessed for the knee OA group whereas a random limb was selected from the asymptomatic older adults. Using a kinematic heel strike detection method [12], the gait cycle was determined using reflective markers placed on the sacrum and posterior calcaneus tracked using a Qualisys® motion capture system. The first eight full strides of the 20-second data collection were used for analysis. Root mean squared amplitudes from the entire gait cycle were calculated for LH and MH. The LH:MH activation ratio was computed.

**4. Statistical analysis**

Normality and heteroscedasticity were assessed prior to analyses. To address the first objective, an independent *t*-test was performed; both corrected and not corrected for walking velocity. A paired *t*-test was used to test the second objective. All statistical testing was completed in Minitab V18 (Minitab Inc., USA). Alpha was set to 0.05 and effect sizes were calculated (Cohens *d*).

**Table 1**  
Mean (Standard deviation) participant characteristics for the asymptomatic and knee OA groups. Radiographic grade distribution for the Knee OA group also shown.

Variable	ASYM	Knee OA
n	42	40
Age (years)	62 (6)	62 (6)
Height (m)	1.70 (0.08)	1.70 (0.09)
Mass (kg)	71.8 (15.5)	85.3 (17.8)
BMI (kg/m <sup>2</sup> )	24.6 (4.2)	29.5 (5.1)
Walk Velocity (m/s)	1.33 (0.22)	1.04 (0.12)

Kellgren Lawrence (#)	Ipsilateral	Contralateral <sup>*</sup>
KL 0	0	7
KL 1	0	12
KL 2	31	17
KL 3	9	2
KL 4	0	0

\* two individuals did not have contralateral radiographs.

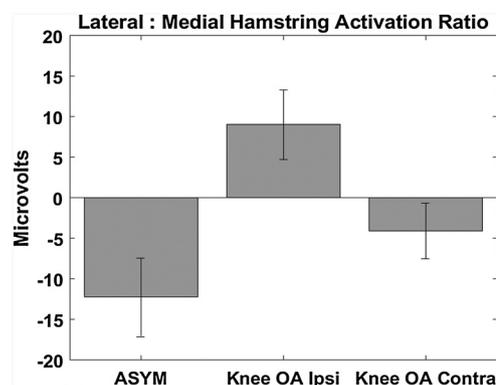
**5. Results**

Participant characteristics are found in Table 1. The LH:MH activation ratio was greater in the knee OA group in both models; corrected for walking velocity (*p* < 0.001) and not corrected for walking velocity (*p* = 0.004). The effect size was moderate (Cohens *d* = 0.73). The ipsilateral LH:MH ratio was also greater than the contralateral (*p* = 0.006) in the knee OA group, showing a low to moderate effect size (Cohens *d* = 0.53). Ratios are shown in Fig. 1.

**6. Discussion**

The findings support that LH activation is greater than MH in the knee OA group (symptomatic leg) compared to a similarly matched group of older adults with no OA with moderate effect size (Objective 1). Secondly, the symptomatic ipsilateral LH:MH activation ratio was greater than the contralateral. Together, the results support the primary hypotheses of the study where using raw, unprocessed LH and MH EMG, a differential activation can be detected in the hamstrings during gait in individuals with medial compartment knee OA.

Previous knee OA gait EMG literature has consistently shown a higher level of LH activation compared to MH, thought to be a neuromuscular response to either medial compartment loading or lateral compartment tensile stress [5,13]. This greater activation has been linked with radiographic severity, where by a greater radiographic severity of medial compartment knee OA experienced greater LH activation [14]. A limitation in these previous conclusions was that the



**Fig. 1.** Mean LH:MH activation ratios (with standard error bars) for the asymptomatic group (ASYM), ipsilateral (Knee OA Ipsi) and contralateral (Knee OA Contra) for the asymptomatic older adults and participants with unilateral symptomatic medial compartment knee OA.

MVIC outcomes, given the amplitude normalization methodology, could impact the interpretation of gait results. The negative ratio found for both the older adults and contralateral knee in this current study suggests gait cycle MH activity was greater than LH activity. On the contrary, the greater activation ratio on the symptomatic knee OA suggests the LH is in fact being activated to a greater degree, evidenced by a greater RMS over the gait cycle. These findings have implications for EMG methodologies, given that MVIC procedures may influence LH/MH activation [9], that are designed to understand activation patterns at the OA knee during walking.

Study findings support the use of LH and MH activation during gait as a tool to understand joint function in those suggesting symptoms of knee osteoarthritis in a clinical context. MVIC-normalized procedures require equipment and time that are not always available in clinical settings. Computationally, RMS signals provide a less demanding analysis procedure compared to MVIC methods; providing clinicians with attainable objective measurements of joint function during walking.

A limitation of using raw EMG signals (non-amplitude normalized) in EMG analyses, is the possible influence of tissue characteristics between the active muscle and the electrode skin interface, which can vary between muscle sites within a person and across people. This effect was thought to be minimized in the current study, given the potential for relatively low levels of subcutaneous tissue located in this region and across hamstring sites [15] and the close approximation of the MH and LH electrode sites. When subcutaneous tissue depth is greater, hamstring activation ratios may not represent the underlying muscular activity and this technique should be interpreted with caution as it is based on raw EMG signals.

In conclusion, the symptomatic leg of individuals with medial compartment knee OA demonstrate an altered LH:MH activation ratio using unprocessed signals obtained during gait, biasing a greater lateral hamstring, compared to the contralateral knee and compared to the ratio of asymptomatic older adults.

#### Conflict of interest

Authors have no competing interests pertaining to this manuscript.

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