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Do Neuromuscular Alterations exist for Patients with Acetabular Labral Tears during Function?*

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Abstract

Purpose—The purpose of our study was to determine if contact forces and electromyography (EMG) muscle amplitudes were altered during the lunge for patients with symptomatic labral tears compared to asymptomatic control subjects.

Methods—Surface electromyography electrodes were placed over the gluteus medius, gluteus maximus, adductor longus, and rectus femoris muscles of the patients' involved limb and matched limb of asymptomatic controls. Subjects performed three trials of the lunge on a clinical force platform. An electrogoniometer tracked knee flexion motion during testing. Average root-mean squared EMG muscle amplitudes for each muscle were calculated for the descent and ascent phases of the lunge, represented as a percent of maximum activity (%MVIC). Peak knee flexion was calculated from the goniometer(°). The dependent variables from the force platform were lunge distance(%height), contact time(seconds), vertical impact force(%BW), and force impulse(%BW*seconds). Dependent variables were compared between groups using either independent samples t-tests or Mann-Whitney U tests. Relationships between dependent variables were assessed with Spearman Rho correlation coefficients. The level of significance was set at $p = 0.05$.

Results—Twenty-one patients with symptomatic unilateral labral tears (14 females, 7 males) and 17 asymptomatic control subjects (11 females, 6 males) participated in this study. Average gluteus maximus EMG muscle amplitudes were reduced for symptomatic labral patients compared to asymptomatic controls during lunge ascent (51.6 ± 31.1 vs. 71.7 ± 36.3 ; [MD: 20.1% (–2.4%, 42.6%)]; $p=0.042$). Average vertical impact force was reduced (21.8 ± 5.5 vs. 26.8 ± 7.3 ; [MD: 5.1%BW (0.84%BW, 9.3%BW)]; $p=0.02$) and average contact time (1.8 ± 0.4 vs. 1.5 ± 0.4 ; [MD: 0.27s (0.006sec, 0.54sec)]; $p=0.045$) and force impulse (188.4 ± 42.4 vs. 162.6 ± 33.3 ; [MD: 25.8%BW*s (0.3%BW*s, 51.4%BW*s)]; $p=0.042$) were increased for symptomatic labral patients compared to asymptomatic controls. Vertical impact force was inversely correlated with

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gluteus medius muscle amplitudes during lunge descent for symptomatic labral patients ($r = -0.452$; $p=0.045$).

Conclusions—Our study demonstrates that contact forces and EMG muscle amplitudes are altered during the lunge for patients with symptomatic labral tears. The presence of a relationship between muscle amplitudes and contact forces suggests that targeting muscle impairments may restore function in these patients.

Introduction

Acetabular labral tears are a common source of intractable hip pain. Improvements in our understanding of the clinical presentation of patients, along with advancements in imaging techniques, has allowed for earlier detection and treatment of intra-articular hip conditions. For patients with intra-articular hip pathology, pain and mechanical symptoms are commonly reported^{1–3}, which limit their ability to perform their desired activities^{4,5}. However, identification of the specific functional impairments experienced by these patients is limited. Quantifying muscle and joint function in patients who have acetabular labral tears is critical to determining appropriate treatment plans and assessing the ability of surgical intervention to restore function in this population.

Traditionally, quantifying function in patients with labral pathology has been limited to the use of patient reported outcome measures^{6–11}. While these measures are invaluable to providing an overall assessment of subjective pain and function in these patients^{12–15}, the use of outcome scores for such measures has limited our ability to identify the specific muscle impairments which contribute to the functional limitations reported by patients and, more importantly, determine the causes of these limitations. Recently, measures of hip muscle strength in patients undergoing hip arthroscopy were reported^{16,17}. Specific deficits in hip flexion and abduction strength were noted in patients, and the reduction in hip flexion strength was found to be associated with a decrease in both flexion range of motion and patient reported function, as measured by the modified Harris Hip Score. While these initial reports provide valuable initial insight into a potential contributor to poor function in these patients, the specific impact that muscle impairment has on joint function in patients with labral pathology is unknown. Identification of the specific muscle impairments present during function in patients with labral tears is imperative to developing appropriate, evidence-based treatment programs.

The aim of our study was to compare electromyographic (EMG) muscle activation patterns and clinical force measures during the performance of the lunge between patients with symptomatic unilateral acetabular labral tears and asymptomatic control subjects. We hypothesized that patients with symptomatic acetabular labral tears would demonstrate alterations in average EMG amplitudes of the periarticular muscles of the hip and altered force and timing variables during the lunge compared to asymptomatic control subjects. In addition, we hypothesized that the alterations in EMG muscle amplitudes would correlate to the observed changes in lower extremity movement patterns and loading.

Methods

Between May 2014 and May 2015, we assessed EMG muscle activation patterns and clinical force measures during a lunge in patients with symptomatic unilateral acetabular labral tears and asymptomatic control subjects. Our study was retrospective with prospectively collected data. Individuals with a tear of the acetabular labrum were recruited from the patient population of our center. Patients were included if they presented with current unilateral hip pain; positive clinical symptoms, including anterior groin pain and mechanical symptoms of clicking and/or locking in the hip; positive clinical tests, including flexion-adduction-internal rotation (FADDIR), McCarthy sign¹⁸; a tear of the acetabular labrum, as confirmed by MRI arthrography; were between 18 and 60 years of age, and presented with no major co-morbidities. Patients were recruited consecutively and included if they met the exclusion criteria and agreed to participate. Subjects were excluded if they had symptomatic bilateral hip pain, had undergone a previous hip arthroscopy, had a history of previous major knee or ankle surgery, had current back, knee or ankle pain, had any history of muscle impairment, or had an adhesive allergy. Asymptomatic control subjects were recruited from the local area via word of mouth. Subjects were considered for the asymptomatic control group if they were between 18 and 60 years of age; had no previous history of hip pain or injury, had normal ranges of hip motion, specifically into internal rotation; had no positive clinical findings during the impingement test or FADDIR test; had no current pain in any lower extremity joint; and had no history of major lower extremity injury or surgery. This research study was approved by the institutional review board at our institution. All participants signed a written informed consent form prior to participation.

A 16-lead EMG system (Biopac Systems, Inc., Santa Barbara, CA, USA) was used to record muscle activity. Unit specifications include an amplifier gain of 2000Hz, an input impedance of 2M Ω , and a CMRR of 110dB. Muscle activation of the gluteus medius (GMD), gluteus maximus (GMX), adductor longus (ADD), and rectus femoris (RF) muscles were collected unilaterally for each subject using bi-polar Ag-AgCl surface electrodes (Ambu Inc., Glen Burnie, MD, USA) measuring 5mm in diameter with a center-to-center distance of approximately 2.0cm. Data were collected from muscles on the involved limb of the patients and a matched limb of the asymptomatic control subjects. The asymptomatic control subjects were matched to a symptomatic labral patient of equal sex and similar age. Prior to electrode placement, the skin was prepared by dry shaving the area, abrading the area with sandpaper, and cleansing it with alcohol to reduce impedance. Electrodes were placed in parallel arrangement over the muscle belly for each muscle, as described by Cram et al¹⁹. Electrodes were secured to the skin using Cover-Roll (Beiersdorf-Jobst, Charlotte, NC, USA). To determine accurate electrode placement, the subject was instructed to contract each muscle being tested while EMG activity was observed using the oscilloscope. EMG data were sampled at 1000Hz and analyzed using AcqKnowledge software (Biopac Systems, Inc., Santa Barbara, CA, USA). A dual-axis goniometer (Biopac Systems, Inc., Santa Barbara, CA, USA) was calibrated and attached to the testing limb to assess sagittal plane knee motion during the activities. Goniometer data were collected at 1000 Hz and synchronized with the EMG data using AcqKnowledge software.

Impact force data were collected during the lunge using the long force platform of the Neurocom Balance Master® (Neurocom Inc, Clackamas, OR) connected to a desktop computer. The computer receives the input regarding forces, timing, and distance from the force plate, analyzes the data, and generates a screen display and printed report. Dependent variables calculated during the lunge were lunge distance, contact time, vertical impact force, and force impulse. Lunge distance was defined as the average length of the forward step, expressed as a percentage of each subject's height. Contact time was defined as the average duration of contact with the force platform during the forward step, expressed as seconds. Vertical impact force was defined as the average maximum force transmitted through the lunging leg as it lands on the force platform, expressed as a percentage of body weight. Force impulse was defined as average amount of work performed by the lunging leg during the contact phase, represented as a percentage of body weight (force) multiplied by the time the force is exerted in seconds.

All testing was performed in a controlled laboratory setting. A member of the research team instructed each subject on the performance of the lunge on the force platform. All subjects were given time to practice the lunge until they felt comfortable performing it. Investigators did not provide feedback or correct lunge mechanics for any subject, as the goal was to assess functional ability. The EMG sensors were then placed on the four muscles as described above. Following electrode placement, subjects were asked to perform three maximum voluntary isometric contractions (MVIC) for each muscle using standardized positions – standing hip abduction (GMD)²⁰, prone hip extension (GMX), seated knee extension (RF), and standing hip adduction (ADD)²⁰. Standing position during hip adduction and abduction was utilized instead of a sidelying position due to the report of pain experienced by our patients while lying on their symptomatic hip. Resistance to movement during MVIC testing was provided by a mobilization strap. Each MVIC trial lasted 3-seconds with a 30-second break in between trials and a 2-minute rest between muscles. Following MVIC data collection, each subject performed the lunge. The lunging leg for all subjects was the limb instrumented with electrodes. Subjects were instructed to step out to a comfortable distance, lunge down as far as they can, and then come back to the starting position. All subjects performed three trials of the lunge, with a 30-second rest between trials.

Data Processing and Analysis

For EMG data collected during MVIC testing, raw signals obtained during the 3-second trials were band passed filtered from 20–500ms and full wave rectified using Datapac software. Each trial was analyzed by dividing the data into 500ms windows, with each window overlapping by 100ms. The 500 ms window with the highest mean amplitude represented 100% activation. The peak mean amplitude of the three trials for each muscle was used for normalization.

For EMG data obtained during the lunge, raw signals were band passed filtered at 20 to 500Hz, stored on a personal computer, and analyzed using the AcqKnowledge software. In order to determine the appropriate data smoothing parameters, the fidelity of the muscle amplitude after signal smoothing was evaluated using time constants from 5ms–50ms at 5ms

time increments. Based on the results of this analysis, filtered EMG signals were processed using root-mean squared (RMS) smoothing with a 50ms time constant. Average RMS muscle amplitudes were calculated for two phases of the lunge – lunge descent and lunge ascent. For analysis purposes, the phases of the lunge were defined using the goniometer data. Lunge descent was defined as the period of time from peak knee extension at the start of the contact phase to peak knee flexion during the contact phase (Figure 1). Lunge ascent was defined as the period of time from peak knee flexion during the contact phase to peak knee extension at the end of the contact phase. The phases did not include the time before lunge contact or after lunge contact, when the limb was non-weight bearing and in flight. Average RMS muscle amplitudes for each muscle were averaged across the three trials during both lunge descent and lunge ascent for each subject and normalized to the 100% peak mean amplitude measured during MVIC testing to allow for comparison between subjects (%MVIC).

Each of the dependent variables obtained from the force platform were averaged across the three trials. Dependent variables during the lunge were average vertical impact force (% body weight (BW)), lunge distance (% body height), contact time (sec), and force impulse (%BW * s). Peak knee flexion during the lunge was calculated from the goniometer and averaged across the three trials for each subject (°).

All dependent variables were expressed with a sample mean and standard deviation and examined for deviation from normality using the Shapiro-Wilk test. To compare data between the patients with symptomatic labral tears (LT) and asymptomatic control subjects (CON), separate independent t-tests were conducted for dependent variables that were normally distributed, and separate Mann-Whitney U tests were conducted for those variables which were not normally distributed. Mean difference and 95% confidence intervals were calculated for all comparisons and presented along with the p-value in the results section (mean difference [95% confidence intervals]; p value). The presence of relationships between the dependent variables was assessed with Spearman Rho correlation coefficients. All statistical analyses were performed using IBM SPSS v.20.0. The level of statistical significance was set at $p = 0.05$.

Results

The study sample consisted of 21 patients in the LT group (14 females, 7 males) and 17 subjects in the CON group (11 females, 6 males). The LT group did not differ from CON in terms of average age (33.0 ± 9.1 y vs. 33.9 ± 12.6 y; $p = 0.79$), height (169.8 ± 8.5 cm vs. 171.1 ± 7.9 cm; $p = 0.63$), or mass (75.0 ± 14.1 kg vs. 74.7 ± 11.8 kg; $p = 0.96$). Patients in the LT group reported the presence of anterior, inguinal, or trochanteric pain, along with mechanical symptoms, which had begun an average of 3.1 ± 3.1 years prior to examination. MRI arthrography images revealed the presence of a labral disruption isolated to the anterior region in 7 patients, posterior region in 1 patient, and superior region in 1 patient, and damage in both the anterior and superior regions in 12 patients. The tear was focal, non-displaced in 16 patients, partial thickness in 3 patients, and full thickness in 2 patients. Three patients had mild chondromalacia on MRA, and no patient had evidence of potential extra-articular causes of pain. The alpha angle averaged 49.6° (range: $44^\circ - 54^\circ$) for our labral

patients, indicating normal femoral morphology for this group of patients^{21,22}. None of the patients had radiographic evidence of degenerative joint changes. All patients in the labral tear group had participated in at least one cycle of physical therapy for their hip pain prior to seeking treatment at our clinic; however, none of the patients was currently in physical therapy nor had been in physical therapy in at least 2 months prior to testing. All subjects were asked about the presence of pain following each trial for each muscle during testing. Pain was reported by 5 subjects during hip adduction testing and 2 patients during hip abduction testing. On average, pain was rated between a 1 and 3 out of 10; however, one patient rated their pain a 7/10 for one trial of adductor testing. None of the patients who reported pain felt the pain prevented them from giving maximal effort. Pain also did not seem to be a factor in the performance of the lunge. All patients were asked to rate their pain following each trial, and no patient reported an increase in pain compared to their daily level. Ten patients reported no pain at all during lunging, while 7 described the pain as an “uncomfortable” feeling and were unable to give it an accurate rating. No asymptomatic control subject reported any pain during either MVIC testing or lunge testing when asked.

Patients with a symptomatic acetabular labral tear exhibited altered EMG muscle amplitudes during the performance of the lunge (Table 1). Average RMS EMG muscle amplitudes for the GMX were reduced for the LT group when compared to CON (MD: 20.1% [−2.4%, 42.6%]; $p=0.042$) during the ascent phase of the lunge. No other EMG differences were observed (lunge ascent- GMD MD: 16.1% [−1.9%, 34.1%], $p = 0.09$; RF MD: 16.2% [−25.4%, 57.9%], $p = 0.78$; ADD MD: 6.5% [−7.5%, 20.4%], $p = 0.16$) (lunge descent- GMD MD: 9.6% [−3.1%, 22.3%], $p = 0.28$; GMX MD: 6.4% [−6.4%, 19.3%], $p = 0.48$; RF MD: 10.5% [−12.8%, 33.8%], $p = 0.71$; ADD MD: 5.8% [−4.0%, 15.6%], $p = 0.16$). Peak knee flexion angle achieved during the contact phase of the lunge also did not differ between LT and CON groups ($91.0 \pm 15.8^\circ$ vs. $95.3 \pm 9.1^\circ$, respectively; MD: 4.7° [−5.3°, 13.8°]; $p = 0.37$).

Patients with a symptomatic acetabular labral tear exhibited altered timing, impact forces, and force impulse during the lunge (Table 2). Patients in the LT group exhibited reduced average vertical impact force during lunge contact compared to the CON group (MD: 5.1%BW [0.84%BW, 9.3%BW]; $p = 0.02$). Average contact time during the lunge (MD: 0.27s [0.006sec, 0.54sec]; $p = 0.045$) and average force impulse during lunge contact (MD: 25.8%BW*s [0.3%BW*s, 51.4%BW*s]; $p = 0.042$) were increased for the LT group when compared to CON. Average lunge distance did not differ between groups (MD: 2.5% [−1.4%, 6.4%]; $p = 0.21$). For the LT group, GMD muscle amplitudes during lunge descent ($r = -.452$; $p = 0.045$) were inversely correlated with average vertical impact force. Average vertical impact force was positively correlated with peak knee flexion for the LT group ($r = .488$; $p = 0.029$) and lunge distance for the CON group ($r = .526$; $p = 0.030$).

Discussion

Our study demonstrated that reductions in gluteus maximus EMG muscle amplitudes exist for patients with symptomatic labral tears during the ascent phase of the lunge when compared to asymptomatic control subjects. In addition, the labral tear patients exhibited decreased impact forces and greater contact times and force impulse during the lunge.

Impact forces were positively correlated with peak knee flexion and inversely correlated with average gluteus medius muscle amplitudes during lunge descent for patients with symptomatic labral tears. Thus, our findings revealed the existence of muscle impairments and alterations in lower extremity movement and loading patterns during function for patients with symptomatic labral pathology. The presence of a relationship between muscle amplitudes and alterations in the performance of functional activities suggests that addressing muscle impairments through treatment programs that target the observed impairments may restore normal function in these patients.

The reduction in gluteus maximus muscle amplitudes for the labral patients was observed during the ascent phase of the lunge. During lunge ascent, forward momentum of the body over a flexed knee must be reversed, such that the body weight is pushed backward into a standing position. In doing so, the gluteus maximus muscle must produce a concentric muscle contraction to move the hip into extension. A reduction in the amount of motor units recruited to achieve hip extension, as observed with the labral patients, would be expected if the degree of forward momentum to overcome was less, due to changes in forces or quantity of movement. However, given that no differences were observed in the depth of knee flexion to which the symptomatic patients and asymptomatic controls lunged nor the distance to which either group stepped forward, it does not appear that less muscle activity would be required; therefore, the reduced gluteus maximus muscle activity is most likely the result of an impaired ability of the labral patients to utilize the muscle to the same extent as the asymptomatic control subjects. While muscle activation levels during functional activities have not been previously assessed in patients with hip pathology, reductions in gluteus maximus EMG amplitudes during active hip extension were reported for patients with suspected labral injury following experimental joint effusion²³. The authors theorized that the reduction in gluteus maximus EMG was indicative of an extensor muscle inhibition in the presence of intra-articular fluid increases, similar to the arthrogenic inhibition observed for the quadriceps muscles during effusion experiments in the knee²⁴. While knowledge regarding the presence of fluid in the joint for our patients at the time of testing is unknown, synovitis is a common finding in patients with labral pathology^{25,26}. Given that our patients had been experiencing hip-related pain and symptoms for an average of 3 years prior to testing, reduced gluteus maximus EMG during the concentric phase of the lunge may represent the presence of an extensor inhibition during function. Biomechanical modeling has demonstrated that decreasing the contribution of the gluteus maximus muscle during hip extension results in increased anterior hip joint forces²⁷. Thus, restoration of extensor muscle activation levels during function may be protective of the joint and should be a focus of rehabilitation programs for these patients.

Despite the lack of group differences in muscle amplitudes during the descent phase of the lunge, the symptomatic labral patients loaded less body weight onto the lunging limb at foot contact. The amount of impact force on the lunging leg is an indicator of eccentric muscle control. As such, lower impact forces would suggest improved control. However, given that the patients in our study had been experiencing hip pain for over 3 years, the reduction in forces applied to the lunging limb is most likely a compensatory behavior to protect the injured limb from increased loading. Similar reductions in loading of the knee during lunging were observed for patients who were deemed non-copers following anterior cruciate

ligament (ACL) deficiency²⁸. Thus, it appears that protective unloading of the limb during functional exercises may be a common compensation for patients with lower extremity pathologies.

Impact forces were positively correlated with measures of movement during the lunge for both the asymptomatic control subjects and patients with symptomatic labral tears. For asymptomatic control subjects, impact index increased concurrently with increases in lunge distance. This is to be expected as the further one steps out, the more out of balance the center of mass becomes. As a result, contact at further distances would be more difficult to control, resulting in greater impact. This relationship was not observed for patients with symptomatic labral tears; however, greater impact forces were positively correlated with increases in peak knee flexion angles for this group. This suggests that those patients who did load the lunging limb to a greater extent were able to lunge to greater depths, possibly supporting the theory that higher impact forces are indicative of better functional ability. Interestingly, for the labral patient group, a significant negative correlation existed between the amount of impact forces and gluteus medius muscle amplitudes during lunge descent. Given that impact forces are an indicator of eccentric muscle control and that lower impact indices represent a compensatory unloading of the limb for these patients, the increased gluteus medius muscle amplitudes associated with lower impact forces may indicate that these patients are recruiting the gluteus medius muscle to a greater extent to control loading of the limb at contact. Advanced biomechanical studies of these patients during lunging are required to further assess this relationship.

In addition to lower impact forces, patients with symptomatic labral tears also exhibited longer contact time and greater force impulse during lunging. Contact time would be extended if either eccentric control of weight acceptance (lunge descent) or concentric control of momentum reversal (lunge ascent) were deficient. Given that reductions in gluteus maximus muscle amplitudes were observed for labral patients during lunge ascent, the increased contact time is most likely the result of deficient concentric muscle control, such that the labral patients were unable to recruit the necessary hip extensor muscle forces to reverse momentum quickly and extend the hip. Similar increases in time to complete the lunge were observed for patients who were deemed non-copers following ACL tear²⁸. The increases in contact time resulted in greater force impulse for the labral patients, an indicator that these patients performed more work during the lunge. Restoration of normal gluteus maximus muscle amplitudes may improve the muscle efficiency with which patients with labral tears perform the lunge.

Limitations

Our study is not without limitations. First, a major limitation of our study was the lack of imaging to rule out labral tears in our control group. Due to the absence of any history of hip pain or positive clinical findings suggestive of a labral tear or impingement, i.e. reduced internal rotation or positive FADDIR test, subjecting these subjects to radiation was not allowed. We have indicated the strict exclusion criteria we applied when selecting these subjects in the methods section and have referred to these subjects as ‘asymptomatic controls’ throughout the manuscript. Second, we did not control for the speed at which the

participants performed the lunge. We chose not to control for this factor, as contact time was a variable of interest. Therefore, we could not determine the effect that speed had on muscle amplitudes; however, we believe that our results can be better generalized to a clinical setting. We also did not control the distance to which the subjects stepped nor the depth to which they lunged, as these were also variables of interest for our study. Third, it is possible that MVIC testing performed during our study for the labral patients was influenced by pain. While 7 subjects did report pain during MVIC testing, none felt the pain prevented them from giving maximal effort. Pain also did not seem to be a factor in the performance of the lunge. For the 7 patients who reported an “uncomfortable” feeling during the lunge, their data did not show observable, marked differences when examined with the data from the 14 patients who reported no symptoms during lunging. Thus, while we cannot rule any influence as a result of pain, we do not suspect that it was a factor in our results. Fourth, we did not collect measures of muscle strength from our patients. We recognize that the addition of strength measures may have reinforced our findings, and we are conducting future studies in which strength and EMG values are being collected for each patient. Fifth, all our labral tear patients had previously participated in at least one cycle of structured physical therapy for their hip pain prior to testing, but no patient was currently in physical therapy or had been participating in physical therapy for at least the 2 months prior to testing. Therefore, while we cannot rule out some effects, physical therapy for hip pain is rarely homogenous and is unlikely to result in consistent and prolonged changes, especially in those with continued pain. All of our patients had continued pain. Finally, we recognize that the observed power for many of our measures was low due to the large variability within our EMG data (see Table 1). The lunge is a demanding task, which requires coordination of multiple groups of muscles, and the pattern of coordination may differ between individuals and groups of subjects. Previous studies examining hip muscle EMG patterns during functional tasks in patients with lower extremity pathology have also reported large variability^{23,29}. However, we did have statistical significance with a number of our variables, along with moderate to large effect sizes; thus, we feel our findings are meaningful.

Conclusions

Our study demonstrates that contact forces and EMG muscle amplitudes are altered during the lunge for patients with symptomatic labral tears. The presence of a relationship between muscle amplitudes and contact forces suggests that treatment programs which target muscle impairments may restore function in these patients.

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Figure 1. Lunge descent was defined as the time between full knee extension (A) and peak knee flexion (B), while lunge ascent was defined as the time between peak knee flexion (B) back to full knee extension (A).

Table 1

Average RMS EMG Muscle Amplitudes during the Lunge (% MVIC)

	Lunge Descent			Lunge Ascent		
	LT	CON	p-value	LT	CON	p-value
GM	25.3 ± 14.0	34.9 ± 23.5	0.28	39.5 ± 20.1	55.7 ± 33.2	0.09
GX	23.5 ± 15.8	29.9 ± 22.6	0.48	51.6 ± 31.1	71.7 ± 36.3	0.042 *
AD	26.5 ± 14.9	32.2 ± 14.3	0.16	35.4 ± 21.2	41.9 ± 20.5	0.16
RF	45.6 ± 25.9	56.1 ± 42.9	0.71	82.0 ± 50.8	98.2 ± 73.5	0.78

* Significant at the p = 0.05 level

MVIC – maximum voluntary isometric contraction; LT- symptomatic labral tear group; CON- asymptomatic control group
 GM – gluteus medius muscle; GX- gluteus maximus muscle; AD- adductor longus muscle; RF – rectus femoris muscle

Table 2

Average Clinical Forceplate Measures during the Lunge

	LT	CON	p-value
Lunge Distance (%H)	42.6 ± 6.5	45.1 ± 5.1	0.21
Contact Time (s)	1.8 ± 0.4	1.5 ± 0.36	0.045 *
Impact Force (%BW)	21.8 ± 5.5	26.8 ± 7.3	0.02 *
Force Impulse (%BW-s)	188.4 ± 42.4	162.6 ± 33.3	0.042 *

* Significant at the p = 0.05 level

LT- symptomatic labral tear group; CON- asymptomatic control group

%H - % height; s - seconds; %BW - % body weight; %BW-s - % body weight - seconds