Int J Clin Exp Med 2018;11(10):10667-10672
www.ijcem.com /ISSN:1940-5901/IJCEM0069500

Original Article

Effect of functional leg length inequality on the quadratus lumborum muscle by using EMG signal on asymptomatic population

Sevim Eryigit[1], Abdullah al Kafee[2], Aydin Akan[3]

[1]Istanbul University, Institute of Science, Department of Biomedical Engineering, Istanbul, Turkey; [2]Istanbul University, Institute of Science, Department of Biomedical Engineering, Istanbul, Turkey; [3]Izmir Katip Çelebi University, Faculty of Engineering and Architecture, Department of Biomedical Engineering, Izmir, Turkey

Received November 20, 2017; Accepted May 3, 2018; Epub October 15, 2018; Published October 30, 2018

Abstract: Objectives: The objective of the study was to analyze the electromyography signals of quadratus lumborum muscle activity on pelvic asymmetry and leg length inequality as this might cause serious injuries in lumbar spine and lower extremity. Subjects and Methods: This was a randomized control trial with a total of 60 participants that were all are right handed and that were assessed manually and by tape measurement for leg length inequality then by electromyography (EMG) in two positions to determine the activity of quadratus lumborum muscle. Results: In the resting position, the power spectral density to analyze the EMG signals results showed that the right side upper pelvis crista iliac position EMG signals were higher in the right than the left side of the quadratus lumborum muscle. The left side upper pelvis crista iliac position had higher EMG signals on the left side than on the right side of the quadratus lumborum muscle activity. Moreover 98% of participants who have up right iliac crista also had short LLI. Additionally, 96% of participants who had up left iliac crista also had short LLI. Conclusions: In conclusion the present study shows that asymmetry in pelvis or QL activity can be caused by LLI which might cause serious injuries in the lower extremities or lumbar spine.

Keywords: Pelvic asymmetry, leg lenght inequality, quadratus lumborum, electromyography signal

Introduction

Evaluation of pelvic asymmetry constitutes one of the common diagnostic methods used by clinicians in cases of lumbo pelvic and lower extremity dysfunction [1]. The human body is one unit, and biomechanically attached parts can affect each other. If there is any alteration in activity or alignment of any structure this can cause problems or injuries to the human body [2]. This study will focus on the QL, leg length inequality, and pelvic asymmetry as pelvis is the fulcrum of the body, its unique location between the upper body and lower body gives it important functions and great effects on the mechanical and pathological issues. Knowing of pelvic functions can clarify how it can have a great effect on these regions. The functions of pelvic region are as a key structure for posture. The pelvis is the suspension of upper trunk and lower limbs so any pelvic deviation affects the posture causing deformities and postural imbalance [1, 3]. The pelvis provides a site for muscle attachments and there are 45 muscles attached to it. The pelvis has great impact on locomotion as increased or decreased pelvic rotation may alter gait cycle causing gait abnormalities [4]. Clinically, the pelvis is occupied by several systems. It is closely related to the gastrointestinal, urogenital, peripheral nervous also the vascular system. When we look at the functions of the pelvis, we can say that this region has a very important role for the body because it change in the position of the pelvis can lead not only to musculoskeletal problems, but also to organ problems [5, 6].

By knowing the functions of the pelvic we can know its vital role on the body and how any asymmetry in its position can cause not only musculoskeletal problems but also genital, nervous or gastrointestinal problems. In this article

Figure 1. EMG Electrode placement.

Table 1. Demographic characteristics of the cases

	Total (n=60) Mean ± **SD	****P* value
Age (year)	20.20 ± 0.14	0.56
Weight (kg)	65.78 ± 6.12	0.57
Height (m)	1.64 ± 0.18	0.08
*BMI (kg/m^2)	20.11 ± 2.45	0.75

*BMI: Body Mass Index, **SD: Standard deviation. ***p<0.05.

we will discuss effect of QL activity on functional leg length inequality and pelvic asymmetry. There are three types of pelvic asymmetry that can happen separated or combined, which are tilt, shift, and upslip. Tilt: is the rotation of the hip bone anteriorly or posteriorly around transverse axis. Shift: is the movement of hip bone anteriorly or posteriorly along sagittal axis. Upslip pelvis: is the movement of the hip bone upward (elevation of pelvis). All these asymmetries can cause leg length inequality [7, 8]. Leg length inequality is inequality of lower limbs length and its classified into two types structural and functional, structural is inequality of limbs because of inequality of bony structures while functional is asymmetry of lower limbs without any inequality of bony structures.

The effect of leg length inequality on physiological function has been explored, and can shed some light on a possible range of clinical significance. Leg length inequality causes muscular hypertonicity and changes in strength and/or coordination [7, 9]. Expected leg length inequality, (because of presumed stressful mechanical effects on the lumbar spine by virtue of the asymmetrical loading) would cause earlier and greater fatigue of trunk muscles.

Many studies have shown that Electromyography (EMG) is an invaluable tool in verifying the actual involvement of muscles in certain position. In EMG measurement myoelectric signals are generated by physiological variations in the condition of muscle fiber membranes. EMG allows for directly looking into the muscle, measurement of muscular performance, analysis to progress and detects muscle response in different musculoskeletal disorders [10, 11].

Our aim in this study was to determine the relationship between the pelvic asymmetry and leg length inequality by measuring the EMG signals of the quadratus lumborum muscle. Therefore, it was aimed to investigate whether the pelvic asymmetry caused any pathology.

Material and method

The study was approved by the Bakırköy Sadi Konuk Training and Research Hospital local ethics committee and informed consent was obtained from all participants. A randomized control trial conducted on 60 healthy Istanbul Gelisim University of Health Sciences School students, their age ranged between 19-24 years. Participants were invited to participate in this study by announcement in their classroom and they signed informed consent form and agreement to participate in the study. The inclusive criteria were: age between 19 and 24 years must be a student in the university. The exclusive criteria were: any student with scoliosis, back pain, rheumatic disease, structural leg length inequality, any neurological disorder, fracture or musculoskeletal pain.

The medical measurements of this study were performed by an expert physiotherapist. The measurements in this study were done by three methods:

A. Leg length measurement method

The first method was by measuring firstly the participants leg length by tape measurement

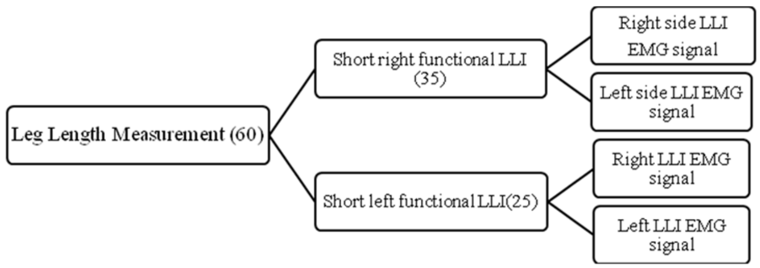

Figure 2. Leg Length Measurement procedure.

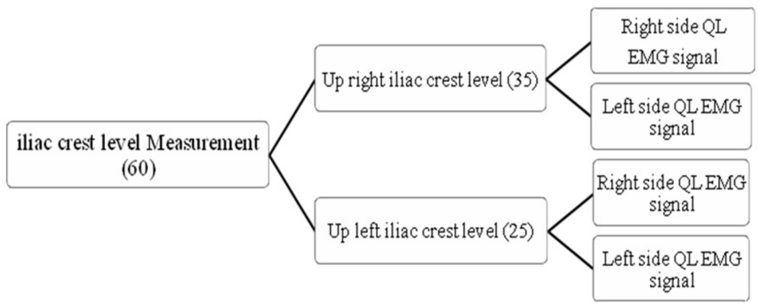

Figure 3. Iliac crest level Measurement procedure.

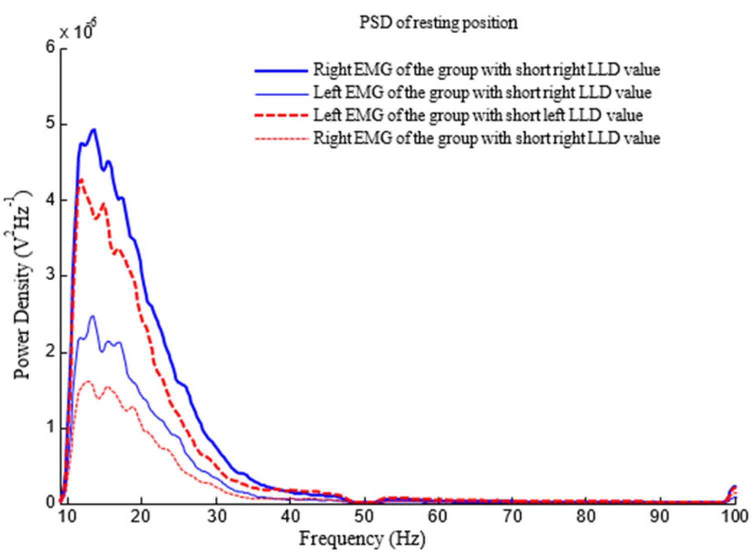

Figure 4. Leg length inequality resting position EMG signal analysis.

from umbilicus to medial malleolus if the legs are equal measurement is done from anterior superior iliac spine to medial malleolus [12, 13].

B. Pelvic position measurement method

The second method was by manual measurement of iliac crest level. The iliac crest position on the measurement paper was recorded as upward or downward each other [9, 14].

C. Electromyographic measurement method

The third method was by using surface electrode EMG on QL muscle, two cables with three electrodes were used each cable on each side, the three electrodes were active, passive and ground electrodes. Active electrode was put below the 12th rib, and passive electrode was put under the 2 cm of active electrode also the ground electrode was put on the olecranon process. Signals were taken in resting prone position and participant on table containing head hole to avoid any neck rotation as it might affect the readings, lower extremities were in neutral position side by side (**Figure 1**). Myoelectric activity from QL was measured using a Biopac (Goleta, California) instrument. EMG signals were recorded when the patient was lying in the prone position while the arms were in the free resting position also legs were in the neutral resting position and did not perform any muscle activity [10, 15-18].

D. Electromyography (EMG) signal processing

A high-pass FIR filter of 10 Hz and form and a notch filter at 50 Hz were applied to the data. The power spectral density was then calculated using the Welch method. Parameters for Welch's method were as follows: The signals were overlapped by 50% and the data were divided into 8 segments and a hamming window was applied to each segment. Each segment was subjected to a 256 point DFT (Discrete Fourier Transform). The amplitude was then squared. Finally, a single power spectral density was obtained as the

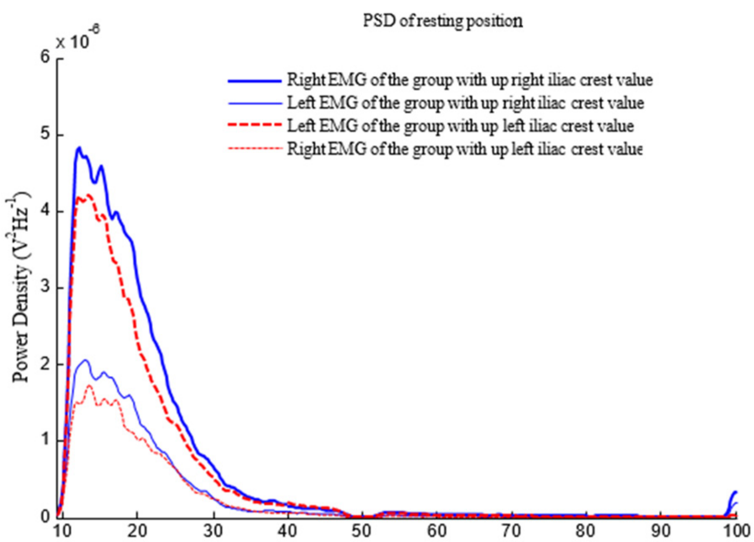

Figure 5. Iliac crest resting position EMG signal analysis.

average of all these parts. All the signal processing and statistical analysis were carried out using MATLAB software (Math Works Inc., Natick MA, USA).

Results

The physical characteristics of the 60 healthy university students (age, height, body weight, and BMI) are shown in (**Table 1**). In Leg Length Measurement out of 60 subjects we found that 35 subjects had short right functional LLI and 25 had short left functional LLI. After that both short right functional LLI and short left functional LLI subject's right and left side EMG signals were compared (**Figure 2**).

For pelvis measurement we found that 32 subjects had up right iliac crest and 28 subjects had up left iliac crest. After that both up right iliac crest and up left iliac crest subjects right and left side EMG signals were compared (**Figure 3**).

The EMG activity in the resting position, participants who had short right LLI had higher PSD of EMG signals on the right LLI than the left LLI, while participants who had short left LLI had higher PSD of EMG signals on left compared to the right LLI. Comparing the two group's short right LLI and short left LLI it was found that short right LLI group had generally high EMG values than the short left LLI group (**Figure 4**).

Moreover in the resting position participants who had up right iliac crest had higher PSD of EMG signals on the right QL than the left QL. Also, participants who had up left iliac crest have higher PSD of EMG signals on the left QL than the right QL. Comparing the two groups up right iliac crest and up left iliac crest, it was found that up right iliac crest group had generally high EMG values than the up left iliac crest (**Figure 5**).

Furthermore, in 98% of the cases with lower extremities short on the left, the iliac crest level was found to be in the elevation position on the left side. It was also found that 94% of the cases with shortened right lower extremity were in the elevation position on the right side of the iliac crest.

Discussion

Studies in the literature have shown that leg length inequality (LLI) and QL muscles cause skeletal problems in the spine, pelvis and lower extremities. In this study the EMG signals of the QL muscle were analyzed and investigated the relationship between functional leg inequality and pelvic asymmetry. According to the results of this study, it was determined that there is an important relation between leg length inequality and pelvic position and quadratus lumborum muscles.

The results found that the right side upper pelvic iliac crest position EMG signals were higher in the right than the left side of the quadratus lumborum muscle. The left side upper pelvis crista iliac position had higher EMG signals on the left side than on the right side of the quadratus lumborum muscle activity. Moreover 98% of participants who have upward right iliac crest also have short LLI. At the same time 94% of participants who have upward left iliac crest also have short LLI. When we look at all results together, we can say that there is a strong relationship between QL, pelvis position, and LLD. Since all of our cases are right, so according to our results, we can say that right handed dominancy makes same side QL muscles more active. In right handed people QL muscles caused an imbalance in the lumber region, this imbalance causes some people to develop functional scoliosis.

A study was done about incidence of foot rotation, pelvic crest unleveling, and supine leg length alignment asymmetry and their relationship to self-reported back pain and was found that there is relationship between the supine leg length inequality and recurrent back pain. The pain intensity of those who demonstrated supine LLI was significantly higher than those without such asymmetry [19]. Another study was found that QL muscle ipsilateral to the supine short leg had significantly decreased endurance times over the same-side QL fatigue times in the no leg-length asymmetry [20]. Another study proved that the relation between leg length inequality and runner's injury is related to lower extremity stress fractures, low back pain, hip pain, and vertebral disk problems of runners [21].

In order to measure the maximal activity of the QL muscle, analysis of the EMG signals from the QL muscle revealed that the activity of the QL muscle on the same side reached the level of the body lateral flexion and supported the posture by isometric contraction [22]. In another study, the QL muscle was found to be the most important stabilizer fragment of lumbar vertebrae [23]. According to these results when hyperton is present it can be said that QL may cause lumbar vertebral and postural problems. Moreover it can be said that the QL muscle is the important effect of pelvic asymmetry and LLI.

In conclusion, pelvic asymmetry and/or QL activity can cause LLI, which can result in serious injury to the lower extremities and lumbar vertebrae. After standardization of some parameters, our joint methodology may become an essential and irreplaceable test to diagnose and follow up QL muscle activity in clinical populations. When functional LLI is found, even in asymptomatic patients, it is thus very important to advise them that the shorter leg can lead to secondary symptoms in the future which need to be corrected.

Acknowledgements

We thank the students of the School of Health Sciences, Istanbul Gelişim University for their dedication to this study.

Disclosure of conflict of interest

None.

Address correspondence to: Sevim Eryigit, Istanbul University, Institute of Science, Department of Biomedical Engineering, Avcılar 34320, Istanbul, Turkey. Tel: +90 505 826 50 21; E-mail: fztsevimeryigit@gmail.com

References

[1] Rafael gnat and maciej biały. A new approach to the measurement of pelvic asymmetry: proposed methods and reliability. J Manipulative Physiol Ther 2015; 38: 295-301.
[2] Donald A. Neuman. Kinesiology of the musculoskeletal system. Foundations for rehabilitation. Mosby Elsevier, Third Edition 2002.
[3] Al-Eisa E, Egan D, Deluzio K, Wassersug R. Effects of pelvic asymmetry and low back pain on trunk kinematics during sitting: a comparison with standing. Spine 2006; 31: 135-143.
[4] Staszkiewicz R, Chawla W, Forczek W, Laska J. Three-dimensional analysis of the pelvic and hip mobility during gait on a treadmill and on the ground. Acta Bioeng Biomech 2012; 14: 83-89.
[5] Herschorn S. Female pelvic floor anatomy: the pelvic floor, supporting structures, and pelvic organs. Rev Urol 2004; 6: 2-10.
[6] Snell RS. Klinik Anatomi. T. Marur, Çev.M. Yıldırım, Third Edition, Nobel Kitabevi, 2004. pp. 49-108.
[7] Castellano BD. Significance of Minor Leg Length Discrepancy. Chapter 35. Georgia: Podiatry Institue; 2011 pp. 182.
[8] Qureshi Y, Kusienski A, Bemski JL, Luksch JR, Knowles LG. Effects of somatic dysfunction on leg length and weight bearing. J Am Osteopath Assoc 2014; 114: 620-630.
[9] Boulay C, Tardieu C, Bénaim C, Hecquet J, Marty C, Prat-Pradal D, Legaye J, Duval-Beaupère G, Pélissier J. Three-dimensional study of pelvic asymmetry on anatomical specimens and its clinical perspectives. J Anat 2006; 208: 21-33.
[10] Park KM, Kim SY, Oh DW. Effects of the pelvic compression belt on gluteus medius, quadratus lumborum, and lumbar multifidus activities during side-lying hip abduction. J Electromyogr Kinesiol 2010; 20: 1141-5.

[11] Edwards L, Dixon J, Kent JR, Hodgson D, Whittaker VJ. Effect of shoe heel height on vastus medialis and vastus lateralis electromyographic activity during sit to stand. J Orthop Surg 2008; 3: 2-10.
[12] Jamaluddin S, Sulaiman AR, Imran MK, Juhara H, Ezane MA, Nordin S. Reliability and accuracy of the tape measurement method with a nearest reading of 5 mm in the assessment of leg length discrepancy. Singapore Med J 2011; 52: 681-684.
[13] Neelly K, Wallmann HW and Backus CJ. Validity of measuring leg length with a tape measure compared to a computed tomography scan. Physiother Theory Pract 2013; 29: 487-492.
[14] Hanada E, Kirby RL, Mitchell M, Swuste JM. Measuring leg-length discrepancy by the iliac crest palpation and book correction method: reliability and validity. Arch Phys Med Rehabil 2001; 82: 938-942.
[15] Kim HU, Kwon OY, Yi CH, Cynn HS, Choi HS. Effect of contralateral hip adduction on activity of lumbar stabilizers and pelvic lateral tilting during hip abduction in side-lying. Physical Therapy Korea 2013; 20: 16-21.
[16] Monteiro RL, Facchin JH, de Freitas DG, Callegari B, João SM. Hip rotations influence electromyographic activity of gluteus medius muscle during pelvic drop exercise. J Sport Rehabil 2015; 26: 65-71.
[17] McGill S, Juker D, Kropf P. Appropriately placed surface EMG electrodes reflect deep muscle activity (psoas, quadratus lumborum, abdominal wall) in the lumbar spine. J Biomech 1996; 29: 1503-1507.
[18] Cynn HS, Oh JS, Kwon OY, Yi CH. Effects of lumbar stabilization using a pressure biofeedback unit on muscle activity and lateral pelvic tilt during his abduction in sidelying. Arch Phys Med Rehabil 2006; 87: 1454-1458.
[19] Knutson GA. Incidence of foot rotation, pelvic crest unleveling, and supine leg length alignment asymmetry and their relationship to self-reported back pain. J Manipulative Physiol Ther 2002; 25: 110-115.
[20] Murray KJ and Azari MF. Leg length discrepancy and osteoarthritis in the knee, hip and lumbar spine. J Can Chiropr Assoc 2015; 59: 226-237.
[21] McCaw ST and Bates BT. Biomechanical implications of mild leg length inequality. Br J Sports Med 1999; 25: 10-13.
[22] Andersson EA, Oddsson LI, Grundström H, Nilsson J, Thorstensson A. EMG activities ofthe quadratus lumborum and erector spinae muscles during flexion relaxation and other motor tasks. Clin Biomech 1996; 11: 392-400.
[23] McGill S, Juker D, Kropf P. Quantitative intramuscular myoelectric activity of quadratus lumborum during a wide variety of tasks. Clin Biomech 1996; 11: 170-172.