REVIEW ARTCLE

Functional Alterations in Gluteal Muscles due to Low Back Pain: A Qualitative Review of the Literature

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ABSTRACT

One of the biggest problem in clinical examination of the patients with LBP symptoms is the lack of a comprehensive diagnosis protocol comprising all muscular alterations responsible for LBP. Connected to lumbar pelvis region, gluteal muscles perform the important role of transferring the upper-body movements as forces to the lower-body limbs. Therefore, the gluteal muscles have received an increasing attention by clinicians and researchers diagnosing LBP. However, there has been a scattered list of studies using electromyography, image scanning and physical examination techniques for monitoring the gluteal muscles of gluteus maximus (GMax), gluteus medius (GMed). In the present research, we reviewed the literature comprehensively, discussed the advantages and disadvantages of the measurement methods. By discovering the disagreements reported by different researchers, the resultant mutual findings across all studies were identified. This study concluded a strong relationship between a dysfunction in operation of the gluteal muscles and occurrence of LBP. The functional changes in gluteal muscles include fatigability in the GMax muscles, neuromuscular alterations and a decrease in abduction strength of the GMedmuscles.

Keywords: Surface EMG; CT Scan; Physical Examination; Hip Abductor Muscle

INTRODUCTION

Low back pain (LBP) is a very common disorder and a major contributor of the health care costs targeting different age groupsand variety of the occupational categories. Approximately, 70–85% of all adults experience a significant episode of LBP at some point in their lives[1]. LBP is reported to be one of the largest cause of disability in the entire world[2]. Due to the pain and inconvenience, individuals withdeveloped LBP refrain using their back muscles properly in their daily activities. This leads to the atrophy of the back muscles and other muscles functionally coupled with the back muscles such as gluteal muscles[3,4].

The gluteal muscles include gluteus maximus (GMax), which is the largest muscle of the human body anda powerful hip extensor muscle and lateral rotator), gluteus medius (GMed), which is an abductor muscle with an important role in stabilizing the pelvis, and gluteus minimus (GMin), which is a musclewith relatively a complex function responsible for extension and locomotion of the hip. According to Joseph and Nightingale (1954) and Lyons et al. (1983)[5,6], the gluteal muscles transfer forces from the lower extremity toward the spine during upright activities and thus may develop LBP. Recent studies have shown that the lowback pathology and dysfunction of GMax and GMedmuscles are strongly associated[7,8]. For instance, the GMedmuscles accounts for 60% of the total hip abductor muscle[9]. The GMax and paraspinal muscles are activated simultaneously during back extension disturbing hip-spine interactions in patients with LBP.

Former studies indicated that the development of LBP depends on multiple factors and co-activation of the agonist-antagonist of the gluteal musclesplays an important role. However, contribution of the gluteal muscles on development of LBPhas not been envisioned as a causal versus adaptive mechanism and commensurate increase for the spine loading[10]. In fact, there are numerous studies investigating the relationship betweenLBPand activation pattern of different muscles[11,12,13,14]. But theinfluence of the gluteal muscles on development of LBP has only been investigated in a handful of studies. Moreover, there areuncertainties and discrepancies acrossfindings derived from the short list of such studies and lack of a consolidated study reviewing all previously proposed diagnostic strategies exists. To fill such a knowledge gap, this review aims to compare different clinical methods deployed by various research groups to monitor the gluteal

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muscles properties. This review may also serveas a summarized guideline in recognition of the best diagnosis and treatment strategies of the patients suffering from LBP.

Monitoring the Gluteal Muscles Functions

The diagnostic methods can be classified intothree methods of electromyography, image scanning and physical examination.Depending on the selected method, the target functional property of the gluteal muscle for measurement by the clinicianis determined. The functional property can be fatigability, strength, endurance, motor control or cross section area and offers some advantages and some disadvantages as discussed following.

Surface electromyography is a well-established and comprehensive technique widely used by clinicians to record electrical activities of different muscles[15]. However, reliability of the surface EMG signal strongly depends on the physiologic and anatomic features of the individual, positioning of the electrode, temperature of the muscle and fat layer between the muscle and the electrode. Isometric contraction is one of the most important measures when the reliability is investigated. There is a disagreement between observations by different researchers regarding the surface EMG reliability. For instance, Dankaerts et al (2004) reported a slightly greater reliability for sub maximum voluntary contraction (MVC) surfaces than that of the MVC surfaces(ICC of 0.91 vs ICC of 0.88)[16]. In contrast, Kollmitzer et al. (1999) found that the reliability of the MVC surfaces is considerably smaller than the sub MVC surfaces (ICC of 50 vs ICC of 85)[17]. In addition to the reliability, replicability of the surface EMG signals on the same patient is difficult to achieve due to the within-day and between-day variability when a certain muscle is monitored. Results of a study by Granata et al (2005) showed that intra-session variability among children subjects can be up to twice of the adults[18].

Application of image-based techniques such as computerized tomography (CT) and sonography is another mechanism for monitoring of the gluteal muscles functions.CT scan is a powerful image-based methodscombining series of X-ray images taken from different angles and therefore facilitating the real-time track of the muscle sizes and the fat content[19]. However, the cancer risk of the tissues exposed to the X-ray radiation limits application of this method[20]. In recent years, diagnostic sonography or ultrasound has gained a growing popularity compared to the other image-based techniques. Availability and low cost are two advantages of the ultrasound. Using this technique, ecodensity and echogenicity, geometry of the muscles (e.g., muscle thickness) can be determined[21].To the best of our knowledge, ultrasound-guided techniques has not been applied for measurement of the gluteal muscles yet.

In physical examination methods,the physical properties of the muscles are measured via clinical muscle tests. This class of measurement techniques offer several advantages including flexibility in the study design and simultaneous measurement of different parameters[22]. There are two major drawbacks associated with the physical examination tests. First, measurements for certain parameters may be obtained indirectly by measuring other parameters and therefore present inaccuracy. For example, muscle testing is a method for indirect measurement of the whole muscle function by only recording the muscle strength via dynamometry[23]. The second limitation is inability of performing muscular cross sectional measurements and pathophysiological information of the muscles[24].

GMAX MUSCLES

Vleeming et al. (1995) developed anelectromyography (EMG) method to measure the impact of thoracolumbar fascia on the attached muscles and bone structures when transferring the load between the spine and lower limb[25]. Later, Kankaanpaa et al. (1998) used the method and investigated the back and hip extensor fatigability in women with chronic LBP[26]. A maximal voluntary isometric back extension at 30 lumbar forward flexion was applied on the subjects and a specially designed measurement unit was used to testtheirback extensor muscle endurance. Then, a 50% MVC load was implemented while continuous raw surface EMG and corresponding endurance time were recorded. Based on the results, the GMax muscles in women with chronic LBPfatigued significantly faster than that of the control group (greater MF slope, *p*-value <0.05),though lumbar paraspinal muscles fatigability was not different in both groups. This finding supports postulation of reduced GMax activity in people with LBP[27]. Based on the median frequency of the EMG study by Kankaanpaa et al (1998), GMax is coupled with lumbar paraspinal muscles via the thoracolumbar fascia and it helps to load the area between spine and lower limb.The important role of thoracolumbar fascia with attached muscles supports the back during flexion and extension. Therefore, if patients refrain use of the back muscles, deconditioning of the hip extensor muscles in patients with chronic LBP is expected.

A couple of years later, Leinonen et al. (2000) used surface EMG in individuals with LBP to study the back and hip extensor activities during trunk flexion and extension[28]. In this study, application of the EMG was to record activities of the bilateral muscle over the lumber paraspinal (LP) muscles at the L1-L2 levels, as well as activities of the GMax and biceps femoris (BF) muscles. They observed simultaneous activities of LP and BF before the GMax, during early flexion. All of these muscles were activated in the mentioned order both at the end of the flexion and during the extension. In each flexion-extension cycle,no statistically significant differences betweenthe group of healthy subjects and the group of patients was observed(neither in the activation nor in the relaxation period of the LP and BF muscles). However, reduction in the activity of GMax muscles during trunk flexion and extension in people with chronic LBP was observed (p-value<0.05). This concludes hypoactivity of the gluteal muscles in people with LBPand it is consistent with findings by previous researchers indicating a reduced GMax muscle activity[26] and increased gluteal fatigability in people with LBP[27].

In contrast to most studies focusing solely on the multifidus muscle, Kamaz et al. (2007) utilized the CT scan imaging to study atrophy of all para-spinal muscles influential in the vertebral stability and role of the muscles in movement of the back through the thoracolumbar fascia[19]. These group of muscles included multifidus, iliocostalis, longisimus, quadratus lumbarum, psoas major and GMax in patients with chronic LBP and healthy people. Results demonstrated that cross sectional area of multifidus, psoas and quadratus lumbarum in the patients were smaller than those of in the control group. Alsocross sectional area of multifidus and paravertebral muscles at the L4 end plate level, in the patients group were smaller than that of in the control group. No significant difference in cross sectional area of the GMax between the patient and control group was observed. Large area of the muscle and less immobilization in the primary back muscles during the periods of pain were the reasons for loss of atrophy of the GMax muscles[19].

A recent study performed by Sutherlin and Hart (2015) measured the strength, fatigability and neuromuscular activation of the hip abductor muscle in people with LBP compared to a group of healthy people[29]. Relationship between alteration in the hip muscle, thigh and trunk with the hip abduction torque was also evaluated. For this purpose, five sets of 30-s consecutive isometric hip-abduction contractions were performed on 12 participants. This exercise was repeated a few times and subjects were allowed to rest for 15 minutes before recording of the surface EMG. According to the results, the GMax activation was increased during the isometric trunk rotation in individuals with LBP. They observed an increase of the hip abductor fatigability after repeated bouts of exercise in all individuals, and found no difference in the hip abductor fatigability between the groups. Change in pain level may be a reason for the difference in the outcome of this study compared to the previous studies.The average level of the pain in this study was 10.6 mm on a 100 mm (VAS) as opposed to the previous studies wherein higher pain level values in people with LBP were detected. As a result of the lower pain level in this study, they may have been able to produce the maximal force.

Another interesting finding of this study was observation of an increase in the GMax activation with no change in the GMed activation in people with a history of LBP. This is likely due to adaption mechanism resulting in the maximal hip abduction torque during task. Reduction of hip-abduction torque after a repeated exercise task in people with and without a history of LBP was also reported. This suggests no predicted hip abduction torque of specific muscles in people with LBP. Findings obtained from the study by Sutherlin and Hart (2015) wherein the hip-abduction torque was measured through physical examination and muscle activation was measured by surface EMG, were opposite to the previously mentioned study that had been reported increase of GMax in female patients with LBP[26,29]. Reason for such discrepancy may be due to the fact thatthe study by Kankaanpaa et al. focused on a seated back extension or modified Sorensen's test[30]. Increase in duration and type of exercise to fatigue the hip abductor muscle may be due to the differences in the hip abductor fatigability.

GMED MUSCLES

Nelson-Wang et al. (2008) examined thegluteal muscle activation pattern during prolonged posture focused[31]. Regarding the role of hip function in trunk and spine, they investigated differences in the trunk and hip muscles activation patterns during prolonged standing in individuals with no history of LBP. They reported discomfort level based on the VAS every 15 min for a total of 2 hr. They continuously performed a surface EMGtechnique on the hip and trunk muscles. Results of this study demonstrated that 65% of asymptomatic individuals experienced significant level of LBP during prolonged standing. Individuals with developed LBP during the prolonged standing demonstrated significant co-activation of the left and right GMed muscles (p-value of 0.002).

Nelson-Wang et al. (2010) also investigated the relationship between the muscle activation and

LBPresponses to an exercise intervention[32]. They hypothesized that exercise intervention reduces co-contraction of the muscle groups.The exercise intervention included: abdominal bracing with heel slides and straight leg raises, arm and leg extensions in quadruped, bridging in supine, standing rows with resistance band, side bridge support, ‘clamshells’ in side-lying, single leg wall-slide squat with abdominal bracing. A controlled pre-test/post-test design was used and randomly assigned to exercise intervention or control group for 4 weeks. Then, data were recorded from the trunk and hip muscle groups during 2hr of standing by surface EMG. The exercise program focused on core stabilization and exercises for the trunk and hip muscles. Based on this study, GMed co-activation is a mal-adaptive response for incapability to provide postural control at the trunk. Results of the study demonstrated that pain developing exercise had a significant change (p-value <0.0125) following the 4-week exercise intervention. There was no pain development for the control group (p-value > 0.05) based on the visual analog scale (VAS) score. Moreover, a decrease in co-contraction of GMed muscle in male subjects (in contrast to female subjects) due to exercise intervention was observed.

Core strengthening programs such as that suggested by Nadler et al. (2001) warrant some modifications for future muscular stabilization and strengthening program especially for the female subjects[33]. Any modifications should consider a higher asymmetry of the hip extensors of the female patients than that of the male patients[34]. Isolated strengthening of both hip extensors and abductors should also be included in such program to improve LBP reduction of the female patients. Based on the Nelson-Wang and Callaghan (2010) study, surface EMG may be a useful addition for screening individuals to identify the individuals at risk of developed LBP. In their study, LBP development during standing has been associated with biomechanical and clinical factors. While impact of modifying these factors through conservative intervention such as utilized exercise intervention on LBP development has not been clarified, the impact of the exercise intervention focused on the trunk and hip on the muscle activation patterns was understood from this study. This study inferred that the anthropometric differences in the pelvis between male and female are the cause of difference in the GMed muscles activation.

Another surface EMG study led by Marshall et al. (2011) focused on role of the strength and endurance of GMed in development of LBP during the standing position[35]. They selected 24 participants without history of LBP and measured strength and endurance of their GMed muscles (both sides of the body) before and after 2 hr of staying in the standing position. Results of this study indicated anassociation between individuals who developed pain with reduction of side-bridge endurance compared to non-pain developers (p-value of 0.002). Likewise, an association between reduction of side-bending endurance and hip abduction strength with increased GMed co-activation (p-value of 0.002) was concluded. However, the hip abduction strength was not different between the groups (p-value of 0.03). These findings are in line with those of previous studies[31,32], which found that the GMed co-activation was a strong predictor of acute LBP development. This study indicated that a side-bridge endurance test may be a useful clinical assessment tool to determine the endurance of the GMed. Other associated trunk musculature should be targeted in a preventative or rehabilitation context when the individual is required to stand for prolonged periods. Interestingly, they have reported no association between the pain level during standing with strength, endurance and co-activation features (p-value of 0.005). This means that GMed co-activation, endurance and hip abduction strength are not recommended for identifying the pain development in prolonged standing. This provides only a little support for the notion that the hip strength may be a successful classification tool for increased pain development in the low back due to prolonged standing. This is not surprising refer to previous research wherein no relationship between the hip abduction strength and the low back pain development in collegiate athletes was discovered (Nadler et al., 2001)[33]. An interesting finding from this study is the relationship between lower hip abduction strength and endurance measured before the standing protocol, and higher GMed co-activation measured during prolonged standing. However, these results cannot establish whether the reduced GMed strength and endurance are a cause or effect of the heightened co-activation measured during prolonged standing. Assuming reduction of the strength and endurance of GMed is a cause of the co-activation, training study for GMed strength and endurance would be very important.

Inspired from a study by Jeng et al. (1999) in which occurrence of LBP was effectively reduced by strengthening the back, legs and abdomen muscles[36], Nadler et al. (2002) designed a 3-year core strengthening program on the strength balance of the proximal hip musculature with the hope of avoiding LBP occurrence in a collegiate athletic populations[22]. Over the course of the 1999-2000, all athletes were subject to a core strengthening program with muscular stabilization of abdominal, paraspinal and hip extensor strengthening. Each participant underwent a 30-45 min examination session, 4 to 5 times per week in pre-season and 2 to 3 times per week during the season. The hip strengths of both legs were measured using a dynamometer during the physical examination, and incidence of LBP was monitored throughout each year. After the core strengthening program, the incidence of LBP in male athletes decreased but the data were not sufficient to prove the role of core strengthening in LBP reduction. Interestingly, female subjects demonstrated a slight increase in LBP occurrence (*p*-value of 0.009) after implementation of the core strengthening program. Weaker left abductors of the female athletes compared to the male athletes found to be responsible for this observation. No association between the difference of left and right hip abductors and probability of the incidence of LBP in 1998 (*p*-value of 0.72) and 1999 (*p*-value of 0.12) was concluded and maintained for the male athletes after the core strengthening program (1999-2000). Considering the left leg is mainly used for standing and posture[37], weakness of abductors increased muscular requirements of the lateral trunk stabilizer. Therefore, strengthening of the left abductors may practically help to prevent LBP occurrence. Similarly, results of the study by Nadler et al (2001) on collegiate athletes demonstrated that asymmetrical hip extensor strength was related to the progress of LBP even though that was the only measured muscle strength.

Clinical examinations by Cooper et al (2015) suggested that the hip abductor weakness is a common feature of patients with chronic LBP[38]. TFL, GMed and GMax strengths were assessed using break test as described by Hislop and Montgomery (2002) in order to functional evaluation of the GMed strength[39]. Palpation examination of the back, gluteal and hip region were performed to try and reproduce the subject's pain complaint. Friedman's test or Cochran's Q with post-hoc comparisons adjusted for multiple comparisons were implemented to compare differences between healthy controls and people with chronic LBP. Results of this study showed a significant decrease in the GMed strength for the affected side (MMT grade of 3.35 ± 0.73) compared to the unaffected side (MMT grade of 4.56 ± 0.66, *p*-value < 0.001). No significant differences within GMax strengths were observed. Also, there was a significant differences for the Trendelenburg sign between people with chronic LBP on the affected side compared to the unaffected side (7.1%, *p*-value < 0.001) or control (9.7%, *p*-value < 0.001).

In 2010, Arab and Nourbakhsh managed a cross sectional study to discoverassociation betweenthe imbalance of the hip abductor muscles weakness and iliotibal band (ITB) tightness in individuals with LBP[24]. Researchers of this study referred to previous works by Jull and Janda (1987) [40] and hypothesized that a common muscle imbalance pattern of weakness in GMed may lead to chronic LBP. The reason is that when a primary hip muscle (e.g., GMed) is weakened, a synergistic muscle is replaced and become over active[41,42]. Tensor fascia lata (TFL)/ITB is known as a postural muscle and the synergistic muscle for GMed. Since tightness of ITB in the lumbo-pelvic-hip areas occurs when the hip muscles are not balanced, tightness of the ITB is a subsequent mechanism following the weakness of the hip abduction in people with chronic LBP. Three hundred subjects were recruited and classified into 3 groups: those with LBP and ITB tightness, those with LBP but with no ITB tightness, and those with no LBP and ITB tightness.A pressure gaugesimilar to the one described by Helewa et al. (1981) was used for measurement of hip abductor muscle strength[43]. Measurement of the length of ITB was accomplished by the Ober test. Findings from this study indicated individuals with LBP had a weaker hip abductor muscles compared to those without LBP (*p*-value < 0.001). Moreover, no significant difference between LBP subjects with and without ITB tightness (*p*-value = 0.59) was concluded. Generally, results of this study was in agreement with previous studies[44,45].

Cai and Kong(2015) conducted a research on the lower limb strength in runners with and without chronic LBP[46]. Using an isokinetic dynamometer, peak concentric torque of the bilateral of the hip extensors, hip abductors, and knee extensors were measured. No difference in hip extensors (*p*-value of 0.289)and abductors(*p*-value of 0.596) strength was observed in runners with chronic LBP compared to the control group. These results were opposite to a few other studies that have reported a delay activation and reduction of the hip extensor muscles endurance in individuals with LBP[26,28].

Reason for inconsistency of the results of the study by Cai and Kong (2015) compared to those of previous researchmay be related to the fact that other studies have only aimed elderly and sedentary population whereas this study targeted solely runners. Also, the hip strength was measured only during the running activities. Functional features of the hip muscles were likely different between runners and a general population. In the contrast, physical examination study[38] revealed that theGMed weakness contributes to non-specific chronic LBP and their findings matched with previous studies (e.g., with findings of a classic study by Simons and Travell (1983) targeting the pelvic and lower muscles with myofascial origins)[47]. Considering the fact that theGMed weakness and gluteal muscle tenderness are common symptoms in people with chronic non-specific LBP, results are in the same line as those by Arab and Nourbakhsh (2010) and Kendall et al. (2010)[24,48].

CONCLUSIONS

According to the results gathered by different research groups, there is some sort of a dysfunction in operation of the gluteal muscles of LBP patients.In particular, fatigability in the GMax muscles, neuromuscular alterations in the GMed muscles and a decrease in abduction strength of both GMedmusclesof LBP patients are concluded. Further studies on significance of the gluteal muscles in the stability of the spine and spinal and lumbopelvic region of LBP patients are strongly encouraged.

Declaration of interest: The authors disclaim any conflict of interest for the present study. This research did not receive any specific grant from funding agencies in the public, commercial or not not-for-profit sectors.

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