A structured review of the role of gluteus maximus in rehabilitation

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ABSTRACT

Gluteus maximus is the largest muscle in the body and is important in many functional activities such as walking, running and lifting. The aim of this structured review was to investigate the role of gluteus maximus in functional rehabilitation. A computerised literature search of five electronic databases was conducted to seek papers which reported investigations of function, altered function and rehabilitation of gluteus maximus. A total of 34 articles were identified for inclusion in the present structured review. Gluteus maximus has a role in walking and lifting activities as well as providing stability to the sacroiliac joint. The function and properties of gluteus maximus may be altered when changes to the kinetic chain of the lower limb occur as a result of injury or altered biomechanics. The activation level of gluteus maximus was found to be highest when a full squat exercise was performed. Incline running, the use of balance shoes and, to a lesser extent, level running are also effective methods of increasing the activity of gluteus maximus. While research has identified which exercises most effectively activate gluteus maximus, it is still unknown whether the neuro-muscular activation during these particular exercises is high enough to bring about a training effect within the normal population.


Key words: Gluteus maximus, function, rehabilitation

INTRODUCTION

Gluteus maximus is superficially the largest muscle of the body. This important muscle is distinctive in comparison with other primates due to evolutionary postural changes from quadrupeds to bipeds. In the human, gluteus maximus has increased leverage due to its superior attachment on to the dorsal ilium (Marzke et al., 1988) and in a morphological study comparing baboon hind legs with human legs, it was found that gluteus maximus has a larger relative weight in humans (Ito et al., 2000). This single joint muscle allows for increased force production to maintain an upright position needed for bipedalism. Jenkins (1998) describes the insertion of gluteus maximus proximally into the sacrum, the dorsal sacral ligaments, the posterior portion of the crest of the ilium and the sacrotuberous ligament. The muscle fibres run inferiorly and laterally to the distal insertion, where it splits in two components. The upper half of the muscle inserts into the iliotibial tract of the fascia lata and the lower half into the gluteal tuberosity of the femur.

Due to its attachments, gluteus maximus is primarily involved in hip extension and lateral rotation (Kendall et al., 1993). In addition to these latter actions, the upper fibres abduct and the lower fibres adduct the thigh. It is also thought that, due to its attachment into the iliotibial tract, gluteus maximus may play a role in stabilising the knee in extension. Fischer & Houtz (1968) found in an electromyographic (EMG) study that the strongest contractions of gluteus maximus occurred with muscle setting by isometric contraction, external rotation, abduction with resistance and vigorous hyperextension exercises of the thigh and trunk in an erect posture. To obtain a significant strengthening effect, it was suggested by Atha (1981), that the level of activity required must exceed 66% of maximum voluntary isometric contraction (MVIC).

Gluteus maximus is important in many daily activities such as lifting, walking and running, and plays a role in pelvis stability. It is appropriate to investigate, therefore, not only the manner in which gluteus maximus functions during these daily activities, but also how its function is altered due to pathology or altered biomechanics. Treatment of impairment needs to be incorporated into activities that can be repeated on a daily basis in order to have a carry over effect from physiotherapy to function. The purpose of this structured review was to synthesize the information on the role of gluteus maximus in functional rehabilitation and to identify areas of further research. At the time of undertaking this work no other structured review addressing the role of gluteus maximus in functional rehabilitation...
was able to be identified. Although a wide variety of different exercises are advocated to train and condition gluteus maximus and surrounding musculature, there are no specific guidelines for rehabilitation using best evidence based practice. A critical review of the literature, therefore, with an emphasis on functional rehabilitation would seem timely and appropriate.

**Search Strategy**

A computerized literature search of five electronic databases was conducted: Medline (Index Medicus), CINAHL (Cumulative Index to Nursing and Allied Health Literature), EMBASE (Excerpta Medica), AMED (Allied and Complementary Medicine) and PubMed (National Center for Biotechnology Information). Using these databases the search strategy was based on the key words: gluteus maximus, function and rehabilitation. The search was expanded by using the related terms: gluteal muscles, anatomy, structure, treatment, strengthening, impairment, exercise, training protocol and hip extension.

Articles were retrieved from the University of Otago Dunedin Medical Library, Electronic Journals, Document Delivery and Remote Services both within New Zealand and overseas. On obtaining the articles their reference lists were searched for further articles to be included in our research. Only articles written in the English language were included in any of the searches. The selected articles examined a broad range of functions associated with gluteus maximus. There were limited studies on the gluteus maximus muscle specific to the topic of rehabilitation and no randomized controlled trials were reported. Therefore the scope was widened to include a range of papers that addressed the function of gluteus maximus in healthy subjects. Articles were excluded if mention was only made to gluteus maximus in the abstract or the introduction but without further reference to the muscle.

Thirty four articles were included in this study and were allocated into three categories; function, altered function and rehabilitation. Of the studies reporting clinical trials the following outcome measures had been used: EMG, MVIC, speed of lift, biomedical models, video analysis, sacroiliac joint (SIJ) stiffness, force displacement, electromagnetic sensor, ground reaction force, electro-goniometer and isokinetic dynamometer measures. As only six papers specifically addressed the role of gluteus maximus in functional rehabilitation, papers discussing function in both normal and altered biomechanics were included. These two aspects were considered to be fundamental to understanding the functional role of gluteus maximus and therefore its importance in rehabilitation.

**The Role of Gluteus Maximus in Normal Function**

Gluteus maximus has many different functions such as providing sacroiliac joint (SIJ) stability, strength for lifting and control of gait. Stability to the SIJ is provided by compression thus creating a self-bracing mechanism. There is very little movement at the SIJ which is important for the primary function of load transfer from the trunk to legs. If excess movement occurs at the joint, a positional change may occur between the ilia and sacrum thus compromising the L5-S1 intervertebral joints and disc, SIJ and pubic symphysis and could lead to SIJ dysfunction and low back pain. Due to its proximal attachment on to the sacrotuberous ligament, gluteus maximus is thought to cause tightening of the ligament, giving dynamic joint stability and thereby reducing mobility (Vleeming et al., 1989). Snijders et al (1993) also examined SIJ stability using a biomedical model and hypothesized that the large shear forces caused by the body weight above the sacrum would be counteracted by the self-bracing and compressive mechanism of a gluteus maximus contraction. In a study on male weight lifters, Lafond et al (1998) found that hip extensor contraction reduced sacral mobility significantly. This appreciation of the role of gluteus maximus in the control of the SIJ may have a practical application in the treatment of SIJ dysfunction.

During the task of lifting gluteus gluteus maximus has also been shown to have an important role in extending the hips and stabilising the pelvis. Research has shown that emphasis should be placed on contraction during the early phase of the lift to provide pelvic stability, enabling a safe and effective movement to occur (Noe et al., 1992; Vakos et al., 1994).

Gluteus maximus also makes a large contribution to gait, and ineffective functioning can compromise many aspects of the gait cycle. The muscle contributes most significantly to support the lower limb via the vertical ground reaction force during the early stance phase from foot flat to just after contralateral toe off (Anderson & Pandy, 2003). Gluteus maximus initiates foot rotation in the rocker action, and also has a role in the amplitude of the second rocker (Jonkers et al, 2003a). In addition, knee extension during stance is partially controlled by gluteus maximus working as an antagonist. During the stance and swing phases, gluteus maximus contributes to hip extension and controls the rate of hip flexion. Jonkers et al (2003a) also found that when gluteus maximus was excluded from the stance limb, hip flexion was prolonged. This was found to prevent initiation of hip extension and of the 3rd rocker stage thereby inducing prolonged stance-phase knee flexion. The action of the gluteus maximus, therefore, is not confined to the proximal hip joint which it directly spans, but also to the control of the more distal joints.

**Role of Gluteus Maximus in Abnormal Function**

Alterations in function and properties of gluteus maximus have been found in association with
kinetic chain changes of the lower limb due to pain or injury. For example, patients (n=20) suffering from ankle sprain injuries have been shown to have reduced activation levels of gluteus maximus (Bullock-Saxton et al., 1994). Freeman et al (1965) proposed that damage to the proprioceptive feedback loop via a lateral ankle sprain may alter postural control by changing muscle firing patterns in lower limb muscles. Bullock-Saxton et al (1994) investigated altered hip muscle function in patients with a Grade II or III ankle sprain and found that in the injured subjects, the activation patterns of gluteus maximus during hip extension were significantly delayed (p<0.01) compared with the controls. Notably, this delay was not only isolated to the injured limb but affected hip extension bilaterally. These findings suggest there is a need to focus on muscle activation and co-ordination of more proximal muscles during the rehabilitation process even with injuries in the distal part of the limb.

The changes in muscle firing patterns identified in gluteus maximus have implications for rehabilitation of lower limb dysfunction. For example, an antalgic gait at the time of injury may lead to muscle inhibition or atrophy and if the activation of gluteus maximus is delayed, pelvic stability may become compromised. Potentially, this could result in compensation by the lower back and other structures round the SIJ leading to further altered firing patterns and function. The finding of altered firing patterns in gluteus maximus in more distal lower limb problems also demonstrates the clinical significance of examining beyond the immediate site of injury. In the case of ankle injuries, rehabilitation may need to focus more on muscle activation and co-ordination of proximal muscles such as gluteus maximus.

Altered activation patterns in gluteus maximus are not limited to acute trauma. It has been found that in patients with single above-knee amputations, gluteus maximus has slower activation patterns along with increased atrophy on the amputated side in comparison with the other side (Burger et al., 1996). These authors also found that gait dysfunction when walking with a prosthesis was due to imbalance of the muscles around the hip following the removal of major muscles such as hamstrings, adductors and quadriceps. The associated change in muscle activation patterns in gluteus maximus emphasizes the need for above-knee amputees to undertake strengthening exercises for this muscle to help control the prosthesis during gait.

Patients who suffer from low back pain often avoid painful movements and subsequently have reduced activity of gluteus maximus and decreased muscle endurance through disuse. Low back pain has been associated with changes in the hip extensor recruitment pattern and disturbed lumbo-pelvic rhythm, both to which the gluteus maximus muscle contributes (Leinonen et al., 2000; Vogt et al., 2003). Gluteus maximus has also been found to fatigue faster in subjects with low back pain (Kankaanpää et al., 1998) with avoidance of aggravating movements of the lumbar spine leading to subsequent deconditioning of the back and hip extensor muscles. The finding of increased fatigue levels in gluteus maximus highlights the need to incorporate this muscle in low back pain rehabilitation as a strategy to minimize the potential cycle of pain avoidance behaviour.

Analysis of Gluteus Maximus in Task Specific Exercise

The literature suggests rehabilitation of gluteus maximus is an important strategy in the correction of lower limb biomechanics following injury or dysfunction. While a wide variety of different exercises are used clinically to strengthen gluteus maximus, however, little is known about their effectiveness in specifically targeting this muscle.

Konrad et al (2001) investigated the activation and co-activation patterns of the main trunk and hip muscles, including that of gluteus maximus, in various positions of hip flexion and extension, trunk flexion, extension and lateral flexion. These investigators found that in a diagonal hip and shoulder extension exercise gluteus maximus showed a low mean activation in comparison with the other exercises. Further, in the bridging exercise, which is commonly used in the rehabilitation setting, the activation level was found to be less than 14% of MVIC thus demonstrating that gluteus maximus was not the primary force generating muscle in this particular set of exercise (Konrad et al., 2001).

In yet another exercise Worrell et al (1998) found that gluteus maximus displayed relatively consistent levels of activation during the lateral step-up without resistance with small increases in activation when holding weights. Both exercises, however, showed low levels of EMG activity with less than 25% of MVIC. On the basis of these latter findings the lateral step-up exercise, therefore, cannot be recommended as a specific exercise to strengthen gluteus maximus.

Clark et al (2002) evaluated the effect of increased resistance and repetitions on EMG activity of the gluteus maximus, biceps femoris and lumbar extensor muscles during dynamic trunk extension. Their results showed that EMG activity of gluteus maximus increased significantly in comparison to that of the lumbar extensor muscles. With an increase in resistance there was a corresponding significant increase in EMG activity of gluteus maximus Clark et al (2002). Hypothetically, this would suggest gluteus maximus is responsible for accommodating the increased resistance.

Souza et al (2001) compared the EMG activity of the trunk flexors and extensors during two different spine stabilisation exercises, dying bug and quadruped exercises (the dying bug exercise performed in supine and that of the quadruped
exercise in the four point kneeling, both with reciprocal arm and leg movements). The quadruped exercise, in the four point kneeling position, showed gluteus maximus was the most active muscle during leg raise phase on the ipsilateral side. During the leg lowering phase of this exercise the ipsilateral gluteus maximus activity dropped to less than 6% MVIC. During contralateral leg raising and lowering, gluteus maximus activity was greatly reduced implying that this muscle does not contribute to stability of the pelvis during these phases. As exercise intensity increased there was also an increase in EMG activity of the gluteus maximus muscle. In the dying bug exercise, gluteus maximus showed no functionally significant activity during any phase and did not vary with exercise intensity. The results showed that even though gluteus maximus muscle was active in the quadruped exercise, it did not give a strengthening effect in the healthy subjects as the EMG activity was less than 32% (Souza et al., 2001).

The influence of unilateral hip extension exercise in prone with flexed knees on the gluteus maximus activation pattern has also been examined (Arokoski et al. 1999). Again it was found, however, that with this task EMG activity was less than 30% MVIC indicating that in a normal population, these exercises performed in this way would not give a strengthening effect. When knee and hip extension were combined, gluteus maximus force production was reduced (Yamashita 1988), indicating that combined hip and knee extension is another unsuitable exercise for strengthening gluteus maximus.

**Analysis of Gluteus Maximus in Closed Kinetic Chain Exercise**

Closed kinetic chain exercises allow functional muscle recruitment patterns to occur throughout multiple joints and are frequently used in strengthening and functional rehabilitation of the lower limb. The squat is a closed kinetic chain exercise and is a complex movement involving the ankle, knee and hip joints. Analysis of EMG activity in the unloaded squat, has demonstrated that, while gluteus maximus is active throughout the entire squat, it is most active from 90-60º of hip flexion during the ascent phase. Furthermore it was estimated that during the ascent phase gluteus maximus worked at an average of 16.9% of the MVIC. (Isear et al., 1997). Schwab & Worrell (1995) have also measured the EMG activity of gluteus maximus during an isometric squat and found that the isometric squat EMG values for gluteus maximus were equal to or less than 40% of the MVIC.

Altering positions of body segments and support during a squat may change the way in which these exercises are performed and the muscles which are targeted (Blanpied, 1999). McCaw & Melrose (1999) analyzed the EMG activity of gluteus maximus during a squat of narrow stance (75% of shoulder width) and wide stance (140% of shoulder width), with low resistance (60% of 1 Repetition Maximum) and high resistance (75% of 1 Repetition Maximum). The EMG values showed a significant

**Analysis of Gluteus Maximus During Running**

To improve sprint performance, training programmes have been designed to enhance muscle loading at the hip, knee and ankle by including incline treadmill running. Swanson & Caudwell (2000) compared incline treadmill running with that of level running with two different conditions using EMG. Gluteus maximus was significantly more active during the incline running at 4.5ms⁻¹ at 30% incline in comparison with level running. The activity of gluteus maximus during the swing phase also increased in response to the level running with the same higher stride frequency as the incline condition. Therefore this finding suggests that incline running and, to a lesser extent, level running with a high stride frequency, are effective methods of increasing the activity of gluteus maximus.

An unstable base of support creates the need for increased postural activity inducing heightened proprioceptive flow via the cerebellovestibular regulatory circuits of motor control. Bullock-Saxton et al (1993) found a significant increase in the EMG activity of gluteus maximus in subjects wearing balance shoes during gait compared with barefoot on the first day. There was also a significant decrease in the time taken for gluteus maximus to reach 50%, 75% and 90% of maximum activation during a gait cycle following one week of training with balance shoes. These results demonstrate the immediate response of the body to sensorimotor stimulation and the need for an establishment of...
a motor programme for gait that incorporates a more effective activation of the gluteus maximus muscle (Bullock-Saxton et al 1993). Sensorimotor stimulation in the form of balance shoes offers a form of rehabilitation that automatically facilitates gluteus maximus, which may otherwise be difficult to activate effectively with conscious control during complex activities such as gait.

The Response of Gluteus Maximus to Strength Training

Mooney et al (2001) carried out a study using a rotary strengthening exercise program for training gluteus maximus on patients with sacroiliac dysfunction (N=5) and found all patients returned to normal function with no need for further pain medication. It needs to be noted, however, that the MedX torso machine which has been used in this research project is not widely used in New Zealand.

CONCLUSIONS AND IMPLICATIONS FOR CLINICAL PRACTICE

Gluteus maximus has many different functions such as providing SIJ stability, strength for lifting and control of gait and it is hypothesised that it provides stability to the SIJ by creating a self-bracing mechanism. Gluteus maximus has also been shown to be an important muscle during lifting activities. Research has shown that emphasis should be placed on contraction during the early phase of the lift to provide pelvic stability thus enabling a safe and effective movement to occur. Gluteus maximus also makes a large contribution to gait and ineffective functioning can compromise many aspects of the gait cycle. Weakness of this muscle may affect not only movement at the hip joint during gait, but also the distal joints.

Changes to the kinetic chain of the lower limb via pain or injury has shown to cause alterations to the function and properties of gluteus maximus in conditions such as ankle sprains, above knee amputations and low back pain. The findings would suggest that re-education and/or strengthening of gluteus maximus should be considered in many conditions involving lower limb dysfunction including that of the lumbar spine.

In comparison with other exercises both the quadruped exercise and full squat exercise achieve high levels of activation specific to gluteus maximus. It is recommended, however, that the full squat exercise should be performed with a wide stance and high loads to target gluteus maximus optimally. In addition a squat machine with scapular support and with feet placed forward is the preferred protocol compared with a wall squat. Incline running and to a lesser extent, level running with a high stride frequency, are also effective methods of increasing the activity of gluteus maximus. Rehabilitation of gluteus maximus may also be performed using sensorimotor stimulation in the form of balance shoes designed to reflexly recruit contraction of gluteus maximus. A reservation regarding these recommended exercises is made if effectiveness is defined in terms of strength improvement, as the neuromuscular activation of these exercises is probably not high enough to bring about a training effect in the normal population. Further research is needed to investigate a training programme which incorporates exercises such as the full squat in order to identify the relevant parameters required to bring about a training effect in gluteus maximus.

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