Gluteus Maximus and Gluteus Medius in pelvic and hip stability: isolation or synergistic activation?

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Summary

Gluteal muscle dysfunction has been implicated in a variety of pelvic and lower limb disorders, particularly where there is a deficit in pelvic and hip stability. Rehabilitation of gluteus medius has been much advocated in the physiotherapy management of these disorders. The literature however suggests that synergistic activation of multiple muscles, and not just gluteus medius, is critical in the control of frontal plane stability. The evidence suggests the presence of functional subdivisions within these muscles, with function being dependent on appropriate synergistic activation of multiple muscles, including gluteus maximus and gluteus medius. In addition, musculoskeletal disorders appear to adversely affect many different muscles, in terms of muscle strength, size or activation pattern. The synergistic activation of these muscles, rather than isolated activation of one particular muscle, may be an important consideration in the assessment and rehabilitation of gluteal dysfunction. Further research, both laboratory-based and in the clinical environment, is required to help our understanding of how to best recruit these muscle groups and facilitate return to full function.

Keywords

Physiotherapy, gluteus maximus, gluteus medius, rehabilitation, exercise.

Background

Gluteal muscle dysfunction has been implicated in many musculoskeletal pain disorders related to reduced frontal plane stability and control of the pelvis and lower limb. Gluteus medius is considered the primary frontal plane stabiliser. Strengthening of gluteus medius, especially the posterior portion of gluteus medius, has been advocated in the rehabilitation of numerous lower limb disorders including hip osteoarthritis, patellofemoral pain syndrome, iliotibial band syndrome and patients who present with a ‘Trendelenburg’ gait. In particular, there has been a recent emphasis on the role of ‘isolated’ gluteus medius exercises in rehabilitation programmes. In contrast, some authors have suggested that the proposed importance of gluteus medius in frontal plane stability does not correlate with its small size. Furthermore, it has been proposed that the greater size of gluteus maximus, and the strength of its attachment to the iliotibial band (ITB), indicates it also contributes significantly to frontal plane stability. Despite ongoing research, there is still much debate regarding the exact function and role of the gluteal muscles. In particular, deficits of gluteal muscle function, in terms of strength, activation or co-ordinated function, in symptomatic populations are still not fully understood. In order to address deficits in hip frontal plane stability in clinical practice, rehabilitation programmes provided by physiotherapists should be evidence-based. Improved awareness of the underlying anatomy and the functional activation of these muscle groups can play a part in enhancing our understanding in this regard. The purpose of this paper is to examine the functional anatomy of gluteus maximus and gluteus medius, and how it may relate to assessment and rehabilitation of dynamic frontal plane stability and control.

Anatomy

Gluteus maximus is attached to the posterior layer of the thoracolumbar fascia, posterior superior iliac spine, posterior gluteal line, posterior sacrum and coccyx, sacrotuberous ligament and the overlying gluteal fascia. Anatomical textbooks describe the muscle as being one homogenous muscle, however functionally this muscle is divided into superior and inferior portions. There does not appear to be a structural boundary between each subdivision however, with the division being based on variations in functional activation, muscle fascicle orientation, muscle thickness and insertion pattern. Therefore they are referred to as ‘functional’ subdivisions similar to other muscle groups e.g. trapezius, quadriceps.

The muscle fascicles pass inferolaterally, at an angle varying between 60° (inferior fascicles) and 45° (superior fascicles) (Figure 1). The superior fibres of gluteus maximus, together with the superficial fibres of the inferior portion of gluteus maximus, insert into the superficial layer of the ITB. The deeper inferior fibres have a fibrous insertion, via the deep layer of the ITB, into the gluteal tuberosity. The attachment of gluteus maximus to the ITB is particularly strong and fibrous.

Gluteus medius attaches...
Significant variations in thickness within each muscle, average thickness of both muscles is similar, there are surface area than gluteus medius. The orientation of gluteus medius has a broadly similar fascicles of gluteus medius have a similarly similar orientation to TFL, and the anterior fascicles are attached via fascia to that muscle. In contrast to gluteus maximus, gluteus medius has only a weak connection to the ITB. It consists of three portions; anterior, middle and posterior. Similar to gluteus maximus, this division is based on variations in muscle fascicle orientation, muscle thickness, innervation and insertion pattern, rather than a clear structural boundary.

Gluteus medius inserts onto the greater trochanter of the femur, although the insertion is described in the literature as varying between anterosuperior or posterosuperior. It appears that the anterior and middle portions insert onto the posterosuperior surface of the trochanter, while the posterior portion converges to a pointed insertion on its superomedial aspect. The posterior portion of gluteus medius has a more horizontal orientation than the more vertical middle and anterior portions. The orientation of these posterior fascicles actually more closely resembles the orientation of gluteus maximus than its own anterior and middle fascicles. Both the anterior and middle fascicles of gluteus medius have a broadly similar orientation to TFL, and the anterior fascicles are attached via fascia to that muscle.

Gluteus maximus is approximately 40 percent larger in surface area than gluteus medius (Figure 3). While the average thickness of both muscles is similar, there are significant variations in thickness within each muscle, with gluteus maximus being thickest inferiorly and gluteus medius being thickest posteriorly.

**Function**

Many methods of quantifying the functional role of gluteus maximus and gluteus medius have been described in the literature. These include assessment of muscle activation by electromyography (EMG) using surface or fine-wire electrodes. Surface EMG (sEMG) is prone to errors including crosstalk from other nearby muscle groups, and cannot measure the muscle activation of deep muscles, however it has been more commonly used in research due to the somewhat invasive nature of fine-wire EMG. Many other trials have used biomechanical models to estimate the timing and amount of muscle activation during functional tasks e.g. during gait. Unfortunately, little research has been carried out looking at the function of gluteus maximus and gluteus medius using 3D motion analysis. Gluteus maximus has been described as an extensor, lateral rotator and adductor of the hip joint. While this appears to represent the action of the muscle as a whole, the orientation of the superior portion above the axis of rotation of the hip explains how it acts to abduct, rather than adduct, the hip. The role of the inferior portion of gluteus maximus as a hip extensor is supported by its vertical orientation and its attachment to the gluteal tuberosity. Finally, the orientation and attachment of superior gluteus maximus supports its proposed function as a hip lateral rotator and abductor, as indicated on EMG studies.

All three portions of gluteus medius have previously been described as acting to abduct the hip. Previous research has reported however, that in some subjects gluteus medius activity, as measured by EMG, in abduction is minimal or even absent. This is in direct contrast with other EMG studies showing significant gluteus medius activation in abduction. These conflicting research findings are possibly related to the varying contributions of each subdivision to hip abduction. The more vertical anterior and middle portions of gluteus medius appear better positioned to abduct the hip, than the more horizontal posterior portion. This is further substantiated by the fact that the trials demonstrating significant gluteus medius activation in abduction examined the middle portion, while those demonstrating poor gluteus medius activation on abduction examined the posterior portion.

There has also been controversy over whether gluteus medius is primarily activated during medial rotation or lateral rotation. Ireland et al. demonstrated significant weakness of hip abduction and lateral rotation in female subjects with patellofemoral pain, when compared to matched controls. They assessed muscle strength isometrically using hand-held dynamometry, and did not actually measure muscle activation. However, the weakness of lateral rotation observed in the injured population was attributed to gluteus medius dysfunction based on descriptions of the function of gluteus medius in textbooks. In contrast, Earl observed the highest activation of gluteus medius using sEMG when combining an abduction and medial rotation task.
Once again however, these studies appear to have examined different portions of gluteus medius, indicating how it may be inappropriate to extrapolate the activation of one portion of these muscles to the muscle as a whole\textsuperscript{24,33}, owing to the functional subdivisions within each muscle. The orientation of the anterior and posterior portions appears to reflect their proposed actions as medial and lateral rotators respectively, in line with the findings from EMG studies\textsuperscript{19,24,33}. Finally, the insertion pattern and orientation of muscle fascicles on dissection\textsuperscript{19} indicates the anterior portion flexes the hip, while the posterior portion extends the hip, in agreement with descriptions in the literature\textsuperscript{24,34}

Contribution to pelvic and hip stability
Gluteus medius is typically described as the primary frontal plane stabiliser\textsuperscript{1}. This is supported by the fact that its insertion envelopes the greater trochanter and the thicker, posterior portion has an orientation similar to that commonly described for the femoral angle of inclination\textsuperscript{10,11,19}. Gluteus maximus stabilises the pelvis in the sagittal plane with its superior portion also suggested to contribute to frontal plane stability, by acting together with TFL, as the ‘pelvic detoid’\textsuperscript{10,12,16}. A similar pattern of synergistic activation of these muscles is seen in the gait cycle\textsuperscript{16,27}.

During the early-stance phase of gait, gluteus maximus and medius act to eccentrically control femoral flexion, internal rotation and adduction\textsuperscript{1,38}. Both muscles display high levels of activity from terminal swing to mid-stance, with most activity in early-stance. This similarity of activation is particularly true between the posterior portion of gluteus medius and the superior portion of gluteus maximus\textsuperscript{16,27}. The posterior fibres of gluteus medius remain active until mid-stance, with the anterior and middle fibres displaying most EMG activity at the end of mid-stance. The superior portion of gluteus maximus remains active until mid-stance, similar to the posterior portion of gluteus medius, while the inferior portion of gluteus maximus is active only until early-stance\textsuperscript{16,27,36}.

It is of course true that many other muscles contribute to frontal plane stability, for example TFL, the adductors and the deeper hip muscles\textsuperscript{4,35}. The essential point remains the same however; frontal plane stability is dependent on coordinated, synergistic activation of multiple muscles rather than any individual muscle.

Clinical implications
Gluteal muscle weakness and/or abnormal patterns of muscle activation have been reported in subjects with numerous disorders, including anterior knee pain\textsuperscript{1,3,38}, hip osteoarthritis\textsuperscript{39}, iliotibial band syndrome\textsuperscript{50}, sacroiliac joint pain\textsuperscript{40,41} and low back pain\textsuperscript{42}. Most of this research has focussed on gluteus medius, and changes in activation have been seen in the presence of pain\textsuperscript{2,38}. However, clear changes in gluteus maximus activation have also been observed\textsuperscript{41}. In particular, recent research indicates that the timing of gluteus maximus activation in single-leg standing is significantly more delayed than that of other muscles, including gluteus medius, in the presence of pain\textsuperscript{41}. It has also been demonstrated that hip muscle weakness, if present, is not necessarily isolated to one particular muscle or muscle group\textsuperscript{1,3}. In addition, the amount of gluteal muscle atrophy varies with the severity of the disorder, as well as varying between muscle subdivisions\textsuperscript{37}. Grimaldi et al\textsuperscript{37} observed significant atrophy of the inferior portion, but not the superior portion, of gluteus maximus in subjects with severe hip osteoarthritis. Therefore it can be said that hip muscle dysfunction appears to be neither isolated to one muscle nor indicative of general deconditioning, as not all muscles or muscle portions are affected equally\textsuperscript{37}.

The diagnostic usefulness of resisted unidirectional hip movement tests has been questioned, as they appear to have poor sensitivity and specificity in the diagnosis of gluteal tendon pathologies, including tendon tears, tendinitis and bursal distension in symptomatic subjects\textsuperscript{43}. These sensitivity and specificity values were determined by their ability to reproduce a pain response in the symptomatic subjects. Instead, the evaluation of the pain response associated with the ‘Trendelenburg’ sign appears to be more reliable, sensitive and specific at detecting pathology\textsuperscript{43}. The presence of the observed ‘functional’ subdivisions within each of these muscles may explain this, since unidirectional tests are unlikely to test all portions of the muscle. In contrast, the positive results for the ‘trendelenburg’ sign may reflect the need for simultaneous activation of multiple muscular subdivisions in functional, weightbearing tasks\textsuperscript{5}.

Rehabilitation programmes aimed at improving gluteal muscle activation and strength are advocated for many pelvic and lower limb musculoskeletal disorders, with some of these demonstrating improvements in pain, strength and function\textsuperscript{1,9}. There is still however much debate regarding optimal assessment and rehabilitation of gluteal dysfunction and/or ‘Trendelenburg’ gait\textsuperscript{24,25,38,43-45}. At the moment, it is hard to justify ‘isolation’ of any particular muscle as a rehabilitation approach if it does not reflect function, and has no evidence of improved outcomes over other treatment approaches (Figure 4). In addition, even in the area of low back pain where there has been much talk about teaching ‘isolation’ of muscles\textsuperscript{46}, there is recent evidence that it may not be possible to do this\textsuperscript{47}. Until further research indicates that we can confidently predict that certain movements or exercises specifically target a muscle or muscle portion, it seems more appropriate to re-educate movement and motor control strategies rather than prescribing any particular ‘muscle’ exercise (Figures 5-7). This would be consistent with current trends in other regions of the body e.g. low back pain (LBP), such that treatment is addressed at modifying abnormal motor control patterns, rather than

\textbf{Figure 4}
Illustration of a commonly used non-weight-bearing exercise, which is suggested to recruit the posterior fibres of gluteus medius.
any particular ‘sign’ (e.g. weakness, muscle hypo- or hyper-activity) of the abnormal pattern. Following on from this, there are ongoing attempts being made to identify patterns of hip muscle dysfunction in many of these disorders, particularly with respect to the recent emphasis in LBP on ‘deep’ and ‘superficial’ muscle groups. It remains to be seen if the changes seen in superficial muscles such as gluteus maximus and gluteus medius reflect dysfunction of the deeper hip muscles, although this has been proposed by many.

Recommendations

While the role of the gluteal muscles has been investigated in many musculoskeletal disorders, there may be a need to reexamine some of these with greater differentiation between the relative contributions of each subdivision of the gluteal muscles. Further research is required to evaluate the effect of other factors that may affect muscle activation, such as trunk angle, hip joint position, innervation, underlying bony architecture and weight-bearing status. Ideally, these studies should evaluate the activation of each portion of these muscles in functional activities. It is hoped that future research will also examine multiple parameters, rather than any one in isolation (e.g. motion analysis, EMG, strength, muscle size). A further complication is the fact that most EMG and biomechanical modelling studies assume the muscles to be homogenous, which will hopefully be addressed in future trials.

Conclusion

In conclusion, there appear to be distinct ‘functional’ subdivisions within gluteus medius and gluteus maximus. These differences may reflect the various roles of each portion of both muscles. The literature suggests that synergistic activation of multiple muscles is required for the control of dynamic pelvic and hip frontal plane stability. It is proposed that analysis of motor control or movement strategies may be more relevant than specific ‘isolated’ muscle tests. This may have implications for the optimal functional assessment and rehabilitation of gluteal muscle dysfunction. However, further research, both laboratory-based and in the clinical environment, are needed to support and validate this hypothesis.

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References
