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Assessing lateral stability of the hip and pelvis

Alison Grimaldi*

Physiotec Physiotherapy, 23 Weller Rd, Tarragindi, Brisbane, Queensland 4121, Australia

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ABSTRACT

Adequate function of the hip abductor mechanism has been shown to be integral to ideal lower limb function and musculoskeletal health. Clinical assessment of hip abductor muscle function may include observational assessment of postural habits, muscle bulk, and of the ability to control optimal frontal plane femoropelvic alignment during a variety of single leg tasks. Strength testing using a hand held dynamometer is perhaps our most robust clinical assessment tool but should not be considered a ‘gold standard’ in the assessment of abductor muscle function. Evidence from magnetic resonance imaging (MRI), and electromyography (EMG) studies provides a deeper understanding of specific deficits that occur within the abductor synergy. The assessment of abductor function should not be based on a single test, but a battery of tests. The findings should be interpreted together rather than independently, and in the context of a thorough understanding of function of the lateral stability mechanism. Manner and comprehensiveness of abductor assessment will have important implications for management and particularly therapeutic exercise.

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1. Introduction

Deficits in hip abductor muscle morphology, strength, activation patterns and functional control of the pelvis on the femur have been demonstrated in those with osteoarthritis (OA) of the hip (Širca and Sušec-Michieli, 1980; Long et al., 1993; Arokoski et al., 2002; Sims et al., 2002; Einre et al., 2006; Grimaldi et al., 2009a,b). Such deficits have also been linked with medial compartment tibia-femoral OA (Chang et al., 2005), patellofemoral joint pain (Ireland et al., 2003; Mascal et al., 2003; Cowan et al., 2009), and iliotibial band (ITB) syndrome (Fredericson et al., 2009a,b). The muscles in the ITB (30%) and a superficial portion of the ITB, the tensor fascia lata (TFL) muscle, whose muscle belly adheres directly to the superior joint capsule (Walters et al., 2001) enabling this muscle to augment joint stability and protect the femoral head from the femoral neck. The muscles in the ITB provide, for example, 70% of the force required to maintain the pelvis in a level state in single leg weightbearing, and the upper portion of the gluteus maximus (UGM) muscle (Grimaldi et al., 2009b). The vastus lateralis (VL) muscle could also be considered part of this superficial system due to its ‘hydraulic
amplifier’ action on the fascia lata and subsequent contribution to lateral stability at the hip and pelvis (Vleeming et al., 1997). Birnbaum et al. (2004) described the effect of the VL as an adjustable lever arm where contraction of this muscle increases the distance of the ITB from the femoral shaft, thereby increasing the tension in the ITB. The importance of this superficial system should not be underestimated. Fetto and Austin (1994) in a cadaveric study reported that sectioning of the capsule, GMIN, GMED, and gluteus maximus muscles allowed the pelvis to tilt laterally 10° reported that sectioning of the capsule, GMIN, GMED, and glutaeus
iformis (PIRI). Deep layer gluteus minimus (GMIN).

resulted in a marked 30° increase in the distance of the ITB from the femoral shaft, thereby increasing the tension in the ITB. The importance of this superficial system should not be underestimated. Fetto and Austin (1994) in a cadaveric study reported that sectioning of the capsule, GMIN, GMED, and gluteus maximus muscles allowed the pelvis to tilt laterally 10° from a horizontal start position, while sectioning of the ITB alone resulted in a marked 30° of lateral pelvic tilt. The deficiency of this mechanism is believed to underpin the apparent difficulty above knee amputees have with single leg stance. While below knee amputees have with single leg stance. While below knee amputees with single leg stance, the forces of gravity were almost entirely resisted by fascial tension of the ITB alone. In terms of energy conservation this may then seem to be a sensible postural habit, however over time there may be negative consequences.

Kendall’s widely used clinical texts describe a posturally induced ‘stretch weakness’ occurring in the hip abductor muscles in response to standing postures in which the hip is positioned in hip adduction, over time resulting in inner range weakness (Kendall et al., 1952; Kendall and McCrery, 1983). Animal studies have demonstrated that muscles immobilised in elongated positions will undergo structural change, the basis of which appears to be to shift the optimal function of the muscle to the new, lengthened position (Goldspink, 1977; Williams and Goldspink, 1978). These studies discovered increases in protein synthesis in skeletal muscle, and additions of 20% or more sarcomeres in series after 3–4 weeks of immobilisation in a lengthened position. In association with these changes, the length–tension curve shifted so that greater isometric tension was now able to be developed in lengthened positions, while less tension was developed in shortened positions, relative to a control muscle (Goldspink, 1977). This data supported Kendall’s hypothesis of ‘stretch weakness’.

Neumann et al. (1988) explored the relationship between postural habits and muscle changes in the hip abductor muscles of humans. They demonstrated a similar shift in the length–tension (hip angle–torque) relationship of hip abductor muscles held in relatively lengthened positions.

The clinical implications of this information are that postural habits such as ‘hanging on one hip’ in adduction, whereby the lateral stability mechanism is held in a lengthened position, may lead to physiological change over time within the hip abductor muscles. These changes will result in optimal muscle function in a position of relatively greater hip adduction, or a more elongated position. While postural habits in this region are difficult to measure objectively in either a clinical or research environment, assessing these habits provides information that is important for both the clinical reasoning process in terms of understanding pathomechanics, and to long term outcomes of intervention. Weightbearing in an excessively adducted hip position will result in increased joint forces (McLeish and Charnley, 1970; Kummer, 1993), and has been demonstrated to occur during the stance phase of gait in patients with early hip joint pathology (Watelain et al., 2001). While it is unknown whether such changes in abductor function are the product of, or impetus for, degenerative joint changes, the evidence provided by Kummer (1993) and McLeish and Charnley (1970) suggests that increases in postural and functional adduction will be negative for the underlying joint.

A further example of the impact of postural habits on pathomechanics and long term outcomes would be in patients with GMED tendinopathy. Compression has been well accepted as an important aetiological factor in the development of insertional tendinopathies or enthesopathies (Almekinders et al., 2003; Cook and Purdam, 2009). Birnbaum et al. (2004) have clearly demonstrated that adduction of the hip rapidly increases the compressive loading of the ITB over the greater trochanter, into which the GMED tendon inserts. Therefore, standing for prolonged periods ‘hanging on one hip’ in a position of hip adduction would represent a significant amount of compressive loading on the GMED tendon, particularly for those who have been employed in a standing

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**Fig. 1.** Layers of the lateral stability mechanism of the hip as observed on an axial magnetic resonance image through the upper pelvis. Superficial layer upper gluteus maximus (UGM), tensor fascia lata (TFL), iliotibial band (ITB). Intermediate layer gluteus medius (GMED) – anterior (A), middle (M) and posterior (P) portions, piriformis (PIRI). Deep layer gluteus minimus (GMIN).
occupation over many years. Other postural habits such as sitting cross-legged in hip adduction, and sleeping in sidelying in hip flexion/adduction will add to this cumulative compressive loading. Exercise interventions aimed at optimising hip abductor function should provide at least short term benefits from this condition. Research studies show us however that patients struggle to maintain an exercise programme for more than 12 weeks (vanBaar et al., 2001). If the postural habits involving excessive hip adduction remain, the length–tension curve will revert to optimal function in hip adduction, compressive loading of the GMED tendon will again increase, and the pain is likely to return. Assessing and retraining poor postural habits in such conditions should be an important consideration for the clinician aiming to achieve positive long term outcomes.

2.2. Resting muscle bulk and ‘stiffness’

Assessment of muscle size and tone or ‘stiffness’ as performed routinely in a clinical environment, through visual inspection and palpation, would not hold up to academic rigour. Should we then discard this part of our clinical examination? While no reliance should be placed on this examination alone, clinical assessment of muscle size, asymmetry, and stiffness can provide supplementary information, reflective of muscle usage, which may help guide, or strengthen findings from functional assessments, and more traditional strength tests. Muscle size, asymmetry and stiffness will be closely associated with activity levels, particular actions and symmetry of occupational or sporting pursuits, or a change in loading or specific muscle activity patterns related to pain or pathology. Increases in TFL bulk are often noted in clinical assessment in those with abductor dysfunction, however clinicians should also ensure there is close visual inspection of the UGM and VL, the other members of the superficial layer of the abductor synergy, as these muscles may also demonstrate relative hypertrophy. Fig. 2 is an example of hypertrophy of the VL muscle, particularly the superior portion, in a patient with GMED tendinopathy and associated hip abductor dysfunction. While much further research is required to clearly elucidate the role the VL muscle plays in the lateral stability mechanism, early links have been made in those with patellofemoral pain. This population has demonstrated both dysfunction of the VL, and of the hip abductor musculature (Ireland et al., 2003; Mascal et al., 2003; Cowan et al., 2009). Assessment of the VL muscle not only in patients with patellofemoral pain, but also in patients with hip abductor dysfunction, is suggested as part of a thorough clinical examination.

Increased tone or stiffness of muscles of the abductor synergy may also be noted on palpation during the postural assessment. Johansson et al. (1991) described two main determinants of muscle ‘stiffness’, firstly the muscles inherent visco-elastic properties including existing actin and myosin bonds, and secondly neural control mechanisms including both feedforward and feedback mechanisms, both driven by the muscle spindle unit. Background activity is maintained by the feedforward system whereby the central nervous system (CNS) provides stimulus for the muscle spindle unit. By this mechanism, activity of deeper muscles which generally have higher densities of muscle spindles (Peck et al., 1984), is characterised as tonic in nature (Richardson et al., 2004). More superficial muscles generally have better moment arms for torque production, have lower densities of muscle spindles, higher percentages of fast twitch fibres, and a more phasic pattern of activity. Surface electromyography (EMG) recording from lateral hip musculature has shown normal reciprocal phasic low level activity during bilateral standing (Nelson-Wong et al., 2008). Left and right musculature alternate their activity in an on–off strategy (Nelson-Wong et al., 2008). This is consistent with reciprocal medio-lateral shifts in centre of pressure measures that have been demonstrated as part of a normal ‘load/unload’ mechanism in symmetrical side by side stance (Winter et al., 1996). In those with hip OA, studies have shown a shift towards tonic activity (Long et al., 1993) and loss of type II phasic muscle fibres in superficial hip abductor muscles (Širca and Susić-Michieli, 1980). Furthermore, co-contraction strategies, where left and right GMED muscles activate simultaneously rather than reciprocally have been linked with the development of lower back pain (Nelson-Wong et al., 2008).

Observations of abnormal asymmetry or hypertrophy of the superficial musculature, and palpation of abnormal co-contraction, tonic activity, or stiffness of the superficial lateral musculature during quiet balanced standing, are often the first indications during the assessment process, that muscle dysfunction exists. Abnormal findings should prompt further examination, and be used in building a picture of abductor function or dysfunction.

2.3. Dynamic functional assessment

Dynamic assessment may typically involve single leg stance, single leg squat, gait, stair-climbing, running, hopping and other
higher level functional tasks specific to the level of function, or sport played by the individual. Of primary interest with respect to assessment of the lateral stability mechanism, is the ability of the individual to control femoropelvic alignment in the frontal plane. The hip abductor muscles have been shown to be primarily employed in control of medio-lateral stability in standing (Winter et al., 1996), and links with pathology have been established with respect to changes in normal control of the pelvis on the femur in the frontal plane (Krebs et al., 1998; Watelain et al., 2001).

The traditional Trendelenburg test assesses the frontal plane orientation of the pelvis and trunk. An ‘uncompensated’ positive test result is described as pelvic tilt occurring towards the non-weightbearing side and a ‘compensated’ positive test as trunk lateral flexion towards the weightbearing side during single leg stance. The modified Trendelenburg test described by Hardcastle and Nade (1985) involves maximal active elevation of the non-weightbearing side of the pelvis, while the trunk is maintained in an upright position. An abnormal test result is an inability to maximally elevate the pelvis, or to maintain maximal elevation for 30 s. In addition, these authors demonstrated that the hip flexion angle of the non-weightbearing side significantly influences test results. At 90° hip flexion, a downward pelvic tilt on this side was never observed, resulting in false negative results. Their suggestion was that the non-weightbearing leg should be held between 0° and 30° hip flexion during testing.

In both of the above versions the assessment of pelvic tilt, without consideration of lateral shift of the pelvis in the frontal plane, may underestimate abductor dysfunction. More recent versions of the Trendelenburg test have used both laboratory based 2 dimensional kinematic analysis (Asayama et al., 2002; DiMattia et al., 2005) or the simple clinical tool, the universal goniometer (Youdas et al., 2007) to study hip adduction angle as that angle produced by a line between the anterior superior iliac crests, and the line of the femur, while the trunk is maintained upright. This measurement accounts for both lateral pelvic tilt, and lateral pelvic shift.

Increase in hip adduction angle moving from double to single leg stance in normal subjects was reported as an average 5° by DiMattia et al. (2005) with values for hip adduction increasing from 10° ± 4° (mean ± standard deviation) in bilateral stance to 15° ± 4° in single leg stance. Reflective markers identifying the anterior superior iliac spines (ASIS) and the lateral femoral condyle were used for their 2 dimensional analysis. Asayama et al. (2002) using the 3SPACE magnetic sensor system with markers at both the ASISs and the tibial tuberosity reported a mean increase of 2° of hip adduction (range 2° abduction to 12° adduction) in normal healthy subjects 30 s after moving from bilateral stance (0° hip adduction) to unilateral stance. Youdas et al. (2007), using the universal goniometer, also measured hip adduction angle after standing for 30 s on one leg. One arm of the goniometer was placed along a line between the ASISs, with the other directed towards a midpoint between medial and lateral femoral condyles. Mean average values were 83° ± 3° (range 76–94°) for 90 normal subjects. As this measure was reported as the ‘inside angle’ between the 2 arms of the goniometer, rather than a true measure of hip adduction, to compare to the previous 2 results the angles need to be inverted (subtracted from 90°). Mean average angles of hip adduction therefore would be 7° ± 3° (range 4° abduction to 14° adduction). These authors reported an intratester reliability (ICC3,1) of 0.58, with a standard error of measure of 2°. Furthermore they calculated the minimally detectable change to be 4°, meaning that a change of more than 4° would be necessary to conclude that there has been a change in performance. Their conclusion was that, due to inadequate sensitivity, the usefulness of the Trendelenburg test is questionable in assessing hip abductor muscle performance and changes in that performance over time, in young healthy adults. A recent paper by the same authors (Youdas et al., 2010) examined subjects with early hip OA using this same test. The test results were not significantly different to a control population and therefore the test was not recommended as a test to identify patients with hip OA.

The use of a simple goniometer to measure a single angle does not however reflect the complexities of this task. Standing on one leg is accomplished by bringing the centre of mass over the base of support. This may result in changes not only in the angle of hip adduction, but also trunk position and even arm position. Youdas et al. (2010) attempted to eliminate trunk compensation by ‘reminding the subject to keep his or her trunk erect’. We have no assurance however that the subject did in fact achieve this, as no analysis of trunk position was reported. Shifts in the centre of mass may be achieved by trunk lateral flexion which is perhaps more obvious to visual assessment, but also subtle lateral shifts. Youdas et al. (2010) also did not standardise or control arm position. Arms were allowed to be held out away from the side, again allowing alterations of the centre of mass. These authors then have demonstrated, not that the usefulness of the Trendelenburg test is questionable, but that a simple measure of hip adduction angle during single leg standing, without assessment or proven control of other movement factors, is not sensitive enough to identify dysfunction associated with early joint pathology.

DiMattia et al. (2005) using a visual rating scale for hip adduction during performance of a single leg squat, demonstrated high specificity but low sensitivity of the investigators ability to determine if more than 10° increase of hip adduction had occurred during a single leg squat task. The low sensitivity suggests that a patient may be performing inadequately and not be detected visually. Inter-rater reliability was low to fair, with raters in agreement primarily only when they did not see excessive hip adduction. The authors suggest as a limitation of their study however that low variability inherent in their healthy active sample population may have negatively influenced these results.

DiMattia et al. (2005) also assessed the relationship between isometric hip abduction strength, and hip adduction angles measured in either the Trendelenburg test or the single leg squat task. The authors found poor correlation between hip abductor muscle strength and both static and dynamic adduction angles, and concluded these functional tests should not be used as a reflection of hip abductor strength, and that their usefulness in screening hip abductor strength is limited. No evidence is apparent at present in the literature that describes the correlation of these functional tests and abductor strength testing in patient populations.

Overall, the scientific data available to date appears to provide little support for the usefulness of clinical assessments of single leg function, and validity of these tests as a reflection of abductor muscle strength. This conclusion regarding validity however relies on two assumptions, firstly that hip adduction angle in single leg tasks is an accurate representation of abductor muscle function, and secondly that hip abductor muscle strength is the truest reflection of hip abductor function, and our ‘gold standard’ for comparison. If we examine these tests a little more closely it is apparent that these two tests provide quite different, and yet complimentary information. A strength test performed from a neutral joint position, typical of research studies (Arakoski et al., 2002; Sims et al., 2002; DiMattia et al., 2005; Youdas et al., 2007), provides unidimensional information on torque production at this hip angle, the validity of which will be impacted upon by pain in a symptomatic group (Further discussion on this test is provided in the next section.).

In contrast, the Trendelenburg test reflects the patients ‘self selected’ strategy for achieving balance in single leg function.
During motor planning, strength alone will not determine hip abduction angle selected. With the natural drive to minimise energy expenditure, an important consideration will be the optimal hip angle–torque relationship for that individual (which postural habits may strongly influence). If the optimal resting muscle length has shifted, possibly secondary to habitually resting in a lengthened position, greater hip abduction angles may be selected and therefore trunk position will be adjusted to achieve equilibrium. The amount of compressive loading abductor muscle contraction creates across a painful joint has also been suggested to be a potent modifier of segmental alignment during function in patients with hip OA. Krebs et al. (1998) demonstrated that the peak of acetabular loading occurred not at the point of maximum ground reaction force, but at the peak of GMED activity. The authors concluded that the use of trunk lateral flexion during stance phase of gait in subjects with advanced hip OA was an offloading strategy to minimise GMED contraction and therefore painful joint loading. Kapandji (1987) referred to this gait pattern with trunk compensation as Duchenne limping. During assessment of single leg function then, it will be equally important to assess both hip abduction angle, and segmental compensatory strategies such as trunk lateral flexion, and trunk lateral shift which may be subtle and missed if careful attention is not directed towards this, and shoulder abduction. Taking the ipsilateral arm out to the side will change the focus of mass towards the weightbearing leg and reduce the abductor muscle requirement.

Based on the above information, clinical approaches for optimising the value of the Trendelenburg test may include the following. Assessment of single leg stance should occur with the non-weightbearing leg between 0° and 30° of flexion. Arm position should be standardised, for example arms held against the body or crossed across the chest. Trunk translation in the frontal plane relative to the pelvis should ideally be quantified. One method may be to establish the relative positions of the sternal notch and a midway point between ASIs. A goniometer centred over this midway point with one arm aligned with the true vertical, and the other directed towards the sternal notch would provide an indication of relative trunk position. Asking the patient to then attempt to correct their position by bringing their pelvis to a horizontal position and/or their trunk to a vertical position, may provide further information regarding the mechanism for altered position. Is this a compensatory strategy related to changes in muscle function, or an antalgic strategy? Active correction that is just difficult but not painful may reflect a compensatory strategy, while a painful response to correction could reflect an antalgic ‘offloading’ mechanism. This response will have relevance to the chosen management approach regarding appropriate re-loading strategies.

2.4. Abductor muscle strength

Isometric muscle strength testing is the most commonly employed tool for assessing abductor muscle function. Hand held dynamometry has been shown to be a reliable measure of hip abductor strength in either supine or sidelying (Bohannon, 1997; DiMattia et al., 2005; Youdas et al., 2008). This test provides information on the ability of the abductor synergy as a whole to generate torque. The inherent nature of a global muscle test increases the risk of false negatives in which muscle dysfunction exists and yet is not detectable. Individual changes may occur within the abductor synergy whereby one member of the synergy is inhibited and reduces its contribution, while another member may be overactive and increases its contribution, resulting in a nil net effect. This may explain in part the considerable variability that has been reported across many studies that have used abductor strength testing to determine function in those with hip OA. While some authors have reported abductor strength deficits of up to 31% (Murray and Sepic, 1968; Jandric, 1997; Arokoski et al., 2002), others have reported no significant difference (Teshima, 1994; Sims et al., 2002). Other factors such as stage of pathology, pain, fear of pain, motivation, and neuromotor dysfunction all potentially impact upon the outcome of strength testing. All considered, the difficulty in correlating strength and the performance on the functional Trendelenburg test is not surprising (DiMattia et al., 2005).

The information gained from strength testing will be enhanced by multigait testing. As discussed earlier, ‘stretch weakness’ may be evident on a strength test performed in inner range abduction, while this same patient may be relatively stronger than their unaffected side when tested in a position of hip adduction (Kendall and McCreary, 1983; Neumann et al., 1988; Sahrmann, 2002). Optimal strength testing procedures therefore would include testing not only in neutral but also in 10° adduction (Neumann et al., 1988), and inner range abduction. Warm up and a submaximal test run may also serve to reduce fear and improve performance in patients with pain. The clinician should try to motivate the patient to perform a maximal effort, and record pain experienced by the patient prior to and during the testing procedure. A measure of perceived exertion such as the Borg CR 10 scale (Borg and Borg, 2002) can also be a useful comparison between sides for the individual and a measure of progress for that individual over time.

The manner in which a patient freely performs an active movement can also provide clinical information. The evaluation of sidelying active hip abduction has been described by Sahrmann (2002), and also recently as a screening tool for occupational low back pain by Nelson-Wong et al. (2009). These authors used a rating scale regarding the subject’s ability to maintain lower limbs, pelvis, trunk, and shoulders in the frontal plane during performance of sidelying hip abduction, with knee extended. The score ranges from 0, no loss of frontal plane position, to 3, severe loss of frontal plane alignment (Nelson-Wong et al., 2009). Lack of ability to maintain frontal plane alignment will reflect the patients level of trunk control, but also substitution strategies associated with abductor dysfunction. Active movement testing will provide additional information within a battery of tests, and may be particularly helpful in those patients who are unable, due to pain, to perform a formal resisted strength test. Similar to a strength measure, pain and exertion scores can also be gathered.

The information provided to this point has related to clinical testing procedures, each test reflecting different aspects of hip abductor muscle function and dysfunction. No single test should be relied upon, as the development of a clinical picture will be strengthened when consistencies can be appreciated across a number of tests. The sections below relate to additional scientific investigations of hip abductor function that while not generally accessible in a clinical situation, provide further valuable insight into the understanding of the lateral stability mechanism under normal and pathological conditions.

3. Laboratory based assessments

3.1. Magnetic resonance imaging (MRI) assessment of muscle function

Information from functional MRI throws a little more light on the discrepancies between functional and strength testing of the hip abductor muscles. In studying activity of the GMIN, and deep and superficial layers of the GMED muscle, Kumagai et al. (1997) demonstrated that the activity levels of these differing portions of the abductor synergy were not homogeneous, and were influenced by the degree of hip adduction in which these muscles were recruited. While GMIN was substantially active regardless of the
position of the hip in the frontal plane, the GMED was much less active if the abductors were activated in a position of hip abduction. When activated in a neutral hip position, the deeper fibres of GMED increased their activity, while the superficial fibres became most active only once the hip was in a position of 20° hip adduction. It was in this position that the GMED muscle was reported to provide maximal contribution to abduction force (Kumagai et al., 1997). Lack of adequate contribution by the deeper abductors, GMIN and the deep anterior and posterior portions of GMED could then theoretically drive increases in functional hip adduction allowing increased contribution from the more superficial fibres of GMED, and the superficial layer of the abductor synergy to reach equilibrium against gravitational loading. While specific deficits have been demonstrated in deep muscles of the trunk in association with low back pain (Hides et al., 1994, 2008), inadequate scientific evidence currently exists to elucidate specific deficits in deep hip musculature in association with hip pain. For the researcher, Kumagai et al.'s (1997) findings may assist in directing future studies, while for the clinician this information reinforces the need for close attention to femoropelvic alignment and compensatory strategies both during assessment and therapeutic exercise.

3.2. MRI assessment of muscle size

The scientific study of muscle size using MRI provides much more reliable information than an observational evaluation during a clinical assessment. Arakoski et al. (2002) demonstrated that a combined cross sectional area measure of all of the abductor synergists (TFL, UGM, PIRI, GMED, GMIN) was significantly smaller around the worst affected hip in subjects with bilateral OA of the hip. Further examination by Grimaldi et al. (2009a,b) of size of individual muscles within the synergy in subjects with hip OA, revealed heterogeneous changes. In subjects with unilateral advanced hip OA, the deeper abductor synergists GMED, PIRI, and GMIN were smaller around the affected hip (Grimaldi et al., 2009a), while the superficial synergists TFL and UGM appeared to maintain their size on the side of pathology (Grimaldi et al., 2009b). In subjects with mild unilateral hip OA, most assessments of size found no significant difference except for the finding that the GMED muscle was significantly larger on the affected side compared to the GMED of control subjects (Grimaldi et al., 2009a). As patients with early hip OA have been reported to use increased functional hip adduction (Watelain et al., 2001), the larger GMED may be explained by relatively increased activation of the superficial portion of this muscle in a position of adduction (Kumagai et al., 1997).

3.3. EMG

In support of this hypothesis, research using surface EMG has shown that subjects with earlier hip OA have increased levels of GMED EMG activity during functional weightbearing tasks (Sims et al., 2002). Surface EMG will be reflective primarily of activity in the superficial fibres of the GMED muscle. This finding of increased GMED activity is in contrast to the general clinical expectation of GMED inhibition in subjects with hip pathology. This has in fact only been demonstrated in subjects with advanced OA (Long et al., 1993), where these muscles are antagically offloaded through trunk lateral flexion over the weightbearing leg during gait (Krebs et al., 1998). This information on size and EMG changes in GMED suggests that the appropriateness of using surface EMG in a clinical situation for facilitating GMED activity should be carefully evaluated for each patient. Furthermore, pure strengthening as a rationale for development of therapeutic exercise prescription for patients with hypertrophy and increased GMED activity associated with early hip joint pathology, should be re-examined. Gossman et al. (1982) in their review of length associated changes in muscle concluded that ‘the emphasis of the correction programme should be on restoring normal length and developing tension at the appropriate point in the range rather than on just strengthening the muscle’.

4. Clinical implications and conclusions

For those with pain associated with hip abductor dysfunction, our ability as clinicians to impart both short and long term positive change will be dependent on our ability to adequately assess the lateral stability mechanism. The assessment of abductor function should not be based on a single test, but a battery of tests. The findings should be interpreted together rather than independently, and in the context of a thorough understanding of function of the lateral stability mechanism. The evidence covered in this paper builds a picture that clearly demonstrates the close association between hip abductor function and segmental alignment of the femur, pelvis and trunk. This paper has discussed the potent effect daily postural habits may have on hip abductor muscle structure and function. A postural assessment should fully explore not only how well a patient can stand on two feet, but the positions the patient uses in everyday function identifying negative postural habits such as standing ‘hanging on one hip’ in adduction, or with the legs crossed in bilateral adduction, and working with the patient to effect long term change may have significant impact not only on short term, but on long term outcomes.

Hypertrophy, or increased resting muscle tone in the superficial musculature of the lateral hip and thigh may provide impetus for further assessment, and weight to a hypothesis of abductor impairment. Assessment of single leg function requires close attention to not only lateral pelvic tilt but also lateral pelvic shift (measurable together as hip adduction angle), trunk position, arm position, and position of the non-weightbearing leg. All of these factors may strongly influence interpretation of these tests. Muscle strength tests will provide maximum information if they are undertaken as a multiangle test able to reveal ‘stretch weakness’, or weakness in specific ranges that may be otherwise missed and erroneously evaluated as ‘normal’.

Manner and comprehensiveness of abductor assessment will have important implications for management and particularly therapeutic exercise. Looking at midrange strength alone for example may result in a patient with no loss of strength here, and yet significant abductor dysfunction, receive no intervention. Similarly, consideration of lateral pelvic tilt alone in the Trendelenburg test, may result in a false negative test and no intervention, where the patient may be achieving their position of equilibrium with lateral pelvic shift, alteration in trunk position, or subtle combinations of both. Careful consideration should be given to appropriate rehabilitation strategies for a patient who uses increased functional adduction in single leg stance, has increased superficial abductor muscle bulk and activity, and tests stronger than the unaffected side in neutral and hip adduction. Therapeutic exercise based on pure strengthening, or single leg exercises where functional hip adduction is not adequately controlled, may for the short term improve the efficiency of the superficial system and control symptoms in some conditions. In the longer term however high loads in hip adduction will have negative impacts on the underlying joint, and the gluteal tendons sitting beneath the ITB.

The future will hopefully bring technological advancements that make clinical assessment of functional weightbearing tasks simple, rapid and yet comprehensive. In the meantime, the use of the battery of tests described in this paper provides us best guidance for both assessment and targeted management of abductor muscle dysfunction.

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