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Review

The lumbar multifidus: Does the evidence support clinical beliefs?

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Abstract

The contribution of the trunk muscles to spinal stability is well established. There is convincing evidence for the role of multifidus in spinal stability. Recently, emphasis has shifted to the deep fibres of this muscle (DM) and five key clinical beliefs have arisen: (i) that DM stabilizes the lumbar spine whereas the superficial fibres of lumbar multifidus (SM) and the erector spinae (ES) extend and/or rotate the lumbar spine, (ii) that DM has a greater percentage of type I (slow twitch) muscle fibres than SM and ES, (iii) that DM is tonically active during movements of the trunk and gait, whereas SM and ES are phasically active, (iv) that DM and the transversus abdominis (TrA) co-contract during function, and (v) that changes in the lumbar paraspinal muscles associated with LBP affect DM more than SM or ES. This paper reviews the biomechanical, electromyographic, histochemical and morphological data that underpin these beliefs. Although there is support for the importance of the lumbar multifidus and the specific contribution of this muscle to intervertebral control, several of the clinical beliefs have little or no support and require further evaluation. These findings have implications for clinical practice.

Keywords: Exercise therapy; Low back pain; Review; Rehabilitation; Lumbar multifidus

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1. Introduction

Exercise programmes that aim to improve the "stability" of the lumbar spine are widely utilized in the management of patients with low back pain (LBP) (Grieve, 1982; Saal and Saal, 1989; Porterfield and DeRosa, 1991a, b; Norris, 1995a, b; Richardson and Jull, 1995, 2000; O'Sullivan et al., 1997; Pool-Goudzwaard et al., 1998; Porterfield and DeRosa, 1998a, b; Richardson et al., 1999a; Taylor and O'Sullivan, 2000; McGill, 2001; Richardson et al., 2004). These programmes target a variety of trunk muscles and aim to optimize the control of segmental motion, spinal stability, spinal stiffness, spinal orientation, or a combination of these characteristics.

Two fundamental principles that underpin these exercise programmes are that trunk muscle activity is necessary to control and stabilize the lumbar spine (Panjabi, 1992a, b) and that this activity must be restored, optimized, or enhanced in LBP (Richardson et al., 1999e; McGill, 2001; Hides, 2004a, b). In vitro studies have demonstrated that the osseoligamentous lumbar spine is inherently unstable (Lucas and Bresler, 1961; Panjabi, et al., 1989) and is dependent on the integrated function of the active, passive and neural subsystems to control stability and movement (Panjabi, 1992a, b). Therefore, exercise programmes which train trunk muscles to control spinal motion in patients with LBP seem logical (Norris, 1995a, b; O'Sullivan et al., 1997; Richardson et al., 1999a; Hides et al., 2004), and have been argued to reduce stress on injured osseoligamentous structures, which in turn leads to pain reduction and enhanced function. (Saal and Saal, 1989; Panjabi, 1992a, b; Norris, 1995a, b; O'Sullivan et al., 1997; Hides et al., 2001).

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Although it is agreed that exercise should be part of the management of LBP, there is significant variation in the type of exercise and the proposed mechanisms of effect of each type. Some authors advocate exercises which activate the entire paraspinal muscle group in order to control spinal motion (Grieve, 1982; Porterfield and DeRosa, 1991a, b, 1998a, b; McGill, 2001). These authors propose that the effectiveness of these exercises is due to increased power of the trunk muscles both segmentally and regionally (Grieve, 1982), increased tension in the thoracolumbar fascia through multifidus hypertrophy (Porterfield and DeRosa, 1998a, b), increased segmental compression (Porterfield and DeRosa, 1998a, b), and facilitation of co-contraction of the trunk flexors and extensors to optimize control of buckling (Euler stability) (McGill, 2001).

Other authors suggest that rather than increasing the strength or hypertrophy of the trunk muscles, the aim of therapeutic exercise in LBP should be to enhance the function of trunk muscles which are thought to be preferentially suited to stabilizing the lumbar spine (Richardson and Jull, 1995). In contrast to the general approach, this strategy aims to activate the lumbar multifidus independent of the other paraspinal muscles in the initial stages of rehabilitation, and to then integrate appropriate multifidus activation into functional activities (Richardson and Jull, 1995; O'Sullivan et al., 1997; Richardson et al., 1999a, c). Specific exercises have been designed to activate the lumbar multifidus in an isometric, low load, tonic manner, while maintaining a neutral lumbar spine, to restore the proposed function of the lumbar multifidus and its contribution to spinal control (Saal and Saal, 1989; Richardson and Jull, 1995; O'Sullivan et al., 1997; Richardson et al., 1999e; Hides, 2004a, b). Recently, this selective activation of the lumbar multifidus from the other paraspinal muscles has been further refined. The clinical literature has focussed on the deep segmental fibres of the lumbar multifidus (DM) as the target of exercise interventions (Richardson et al., 1999e; Richardson and Jull, 2000; Taylor and O'Sullivan, 2000; Hides, 2004a, b). This specific type of exercise approach has been demonstrated to reduce recurrence following acute LBP (Hides et al., 2001), and to reduce pain and disability in patients with chronic LBP (O'Sullivan et al., 1997).

The recent focus on DM in therapeutic exercise, rather than the superficial fibres of the lumbar multifidus (SM) or the erector spinae (ES), appears to be based on five common beliefs: (i) DM stabilizes the lumbar spine whereas SM, like ES, function as extensors/rotators of the lumbar spine (Richardson and Jull, 1995; Richardson et al., 1999f); (ii) DM has a greater percentage of type I (slow twitch) muscle fibres than SM and the ES (Porterfield and DeRosa, 1991a, b; Richardson et al., 1999f); (iii) DM is tonically active during movements of the trunk and gait while SM and the ES are phasically active (O'Sullivan et al., 1997; Richardson et al., 1999f; Taylor and O'Sullivan, 2000; Hides, 2004a, b); (iv) DM and transversus abdominis (TrA) co-contract during function (Richardson and Jull, 1995; O'Sullivan et al., 1997; Pool-Goudzwaard et al., 1998; Richardson et al., 1999b; Richardson et al., 2000; Taylor and O'Sullivan, 2000; Arokoski et al., 2001; Hides et al., 2004); and (v) changes in the lumbar paraspinal muscles associated with LBP affect DM more than SM or ES (Norris, 1995a, b; Pool-Goudzwaard et al., 1998; Richardson et al., 1999d; Arokoski et al., 2001; Hides 2004a, b).

The purpose of this review is to critically evaluate the literature to determine whether neurophysiological, biomechanical and histological data support these clinical beliefs. A further aim is to consider the implications of this evidence for clinical practice.

2. Differential contribution of DM, SM and ES to mechanical control of the spine

It has been argued that therapeutic exercise for the paraspinal muscles should focus on DM because these fibres are anatomically and biomechanically suited to the control of segmental motion, whereas SM and ES are not (Richardson and Jull, 1995; Arokoski et al., 2001). Do the anatomical and biomechanical data support this argument?

The lumbar multifidus consists of multiple fascicles that originate from the caudal tip and inferolateral aspect of the spinous process and lamina at one vertebral level and insert between two and five spinal levels caudal onto the zygapophyseal joint capsule (Lewin et al., 1962), mamillary process, lamina, medial posterior superior iliac spine and dorsal sacrum (Macintosh et al., 1986). The fibres of multifidus that cross just two spinal levels and insert onto the lamina, mamillary process (Macintosh et al., 1986) and zygapophyseal joint capsule (Lewin et al., 1962; Jemmett et al., 2004) are referred to as DM. The lumbar ES consist of two separate muscles: longissimus thoracis pars lumborum and iliocostalis lumborum pars lumborum. The longissimus thoracis pars lumborum originate from the lumbar transverse and accessory processes, and insert onto the ventral surface of the posterior superior iliac spine. The iliocostalis lumborum pars lumborum originate from the tips of the lumbar transverse processes and adjacent middle layer of the thoracolumbar fascia and insert onto the ventral edge of the iliac crest (Macintosh and Bogduk, 1987).

Biomechanical models, based on those anatomical data, suggest that SM and ES produce sufficient torque to create a posterior sagittal rotation (extension) of the lumbar spine, in addition to intervertebral compression

(Macintosh and Bogduk, 1986; Bogduk et al., 1992). DM, due to its proximity to the predicted instantaneous axis of rotation of the lumbar segments, primarily generates compressive forces, with minimal associated torque (Bogduk et al., 1992). Further, the length of DM remains unchanged during three planes of spinal motion suggesting that DM does not rotate the lumbar vertebra (McGill, 1991).

There is strong evidence that the lumbar multifidus controls spinal motion. Of the muscles examined, multifidus contributes ~2/3 to the stiffness at L4/5 (Wilke et al., 1995), and in vitro studies (Panjabi et al., 1989; Kaigle et al., 1995) demonstrate contraction increases intervertebral stiffness at an injured lumbar segment. Thus, multifidus has the capacity to control motion of an uninjured lumbar motion segment and restore control of segmental motion following injury. However, it is important to consider that all lumbar muscles contribute to stability of the lumbar spine (Crisco and Panjabi, 1991; McGill, 1991; Wilke et al., 1995; Cholewicki et al., 1997; Granata and Marras, 2000; Cholewicki and VanVliet, 2002; McGill et al., 2003). Notably, co-contraction of the superficial flexors and extensors is required to control spinal buckling (Euler stability), and can also impart control of intervertebral motion via compression. However, the resulting increase in spinal load, if sustained, has been argued to have detrimental effects on the spine (Nachemson and Morris, 1964).

The anatomical and biomechanical evidence supports the clinical belief that DM stabilizes the lumbar spine and that SM and ES extends/rotates the lumbar spine. However, in addition to their extensor function, when co-contracted with the trunk flexors, SM and ES increase Euler stability and control of intervertebral motion. However, selective training of DM has theoretical justification in that data suggest that this muscle can control a single segment without generating associated torque which, if present, would require co-contraction of the abdominal flexors. Consequently, activation of this muscle has the potential to provide a strategy to control intervertebral motion without restricting movement of the spine.

3. Fibre type percentage in DM, SM, and ES

A fundamental belief underpinning the rehabilitation of lumbar multifidus is that DM has a greater percentage of type I muscle fibres than SM or ES (Porterfield and DeRosa, 1991a, b). Type I (slow twitch) muscle fibres, while being fatigue resistant and ideally suited to low load tonic activity, have been argued to be more susceptible to the adverse effects of pain and immobilization than type II (fast twitch) muscle fibres (Appell, 1990). The proposed fibre type composition has formed, in conjunction with the proposed tonic activation of DM, the justification for low load, tonic exercise in LBP rehabilitation (Richardson et al., 1999e; Arokoski et al., 2001) as well as providing a possible explanation for changes in multifidus in LBP (Hides, 2004b).

A number of studies evaluated the fibre type composition of DM, SM and ES (Fidler et al., 1975; Jowett et al., 1975; Ford et al., 1983; Bagnall et al., 1984; Sirca and Kostevc, 1985; Mattila et al., 1986; Thorstensson and Carlson, 1987; Jorgensen et al., 1993; Rantanen et al., 1993; Mannion et al., 1997a, b). It is important to note that all DM samples have been harvested from cadavers or people undergoing spinal surgery. Therefore, these results may not represent healthy tissue (Johnson et al., 1973; Fidler et al., 1975; Jowett et al., 1975; Ford et al., 1983; Bagnall et al., 1984; Sirca and Kostevc, 1985; Mattila et al., 1986; Rantanen et al., 1993). Samples from individuals without LBP have been restricted to SM and ES (Thorstensson and Carlson, 1987; Jorgensen et al., 1993; Mannion et al., 1997a, b), which limits discussion of DM fibre type composition in pain-free individuals.

The pooled results (Table 1) from these studies indicate that DM, SM and ES each have a greater percentage of type I than type II muscle fibres. There is only limited evidence to support the presence of a greater percentage of type I fibres in the deep, compared to the superficial, paraspinal muscles (Sirca and Kostevc, 1985). Further, the evidence does not appear to support the argument that fibre type composition is responsible for the specific changes seen in multifidus in LBP. However, the predominance of type I muscle fibres in the lumbar multifidus supports the use of low load exercise, at least initially. Direct, within-subject comparisons of DM, SM and ES histology in normals is required to clarify the issue of relative proportions of fibre types.

4. Activation of DM, SM and ES during functional movements

The argument that multifidus has a tonic postural role is based on reports of continuous activity reported during standing, and tonic activation during gait (Richardson et al., 1999f; Hides, 2004a). It has also been argued that absence of electrical silence in multifidus at the end of trunk flexion constitutes evidence that this muscle has a stabilization role (Richardson et al., 1999f; Hides, 2004a). The proposed tonic activation of multifidus and the fibre composition of this muscle, form the basis for training tonic holding of this muscle in the rehabilitation of LBP patients. As tonic retraining of multifidus has been directed to the segmental portions of this muscle (Hides, 2004a), the clinical belief has

Table 1
Percentage of type I muscle fibres in DM, SM and ES

Authors	Population sampled	Sample site	% Type I fibres DM	% Type I fibres SM	% Type I fibres ES	Comments by authors
Johnson et al. (1973)	6 male cadavers (aged 17–30)	1 cm^3 blocks were taken from the deep and superficial ES. No other information provided			Superficial ES ranged from 100–26.7% Deep ES ranged from 88.6–34.0%	
Fidler et al. (1975)	17 subjects (aged 34–80) undergoing surgery for lumbar derangement	Patients with spinal derangements: lumbar multifidus samples taken at the time of surgery. Superficial procedure described		Patients with spinal derangements and cadaver results combined: 60–66%		The results suggest that multifidus adopts an increasingly postural role with advancing age and with disabling lesions of the lumbar spine
	2 male and 1 female cadaver (aged 19–51)	Cadavers: L5 spinal level				
Jowett et al. (1975)	5 male and 12 female patients with spinal derangements (aged 15–58), 2 male cadavers and 1 female cadaver (aged 19–51), and 4 male and 6 female patients with idiopathic scoliosis (aged 12–17)	Cadavers: lumbar only. No other information provided. Patients with spinal derangements: between L3 and L 5. No other information provided		Cadavers: between 43% and 69% Patients with spinal derangements: between 36% and 93%. With an average of 72% at the L5 level samples		
		Patients with idiopathic scoliosis: apex of concave and convex curves and in 2 subjects the top and bottom of the concave and convex curves. No other information provided		Patients with idiopathic scoliosis: varied between 36% and 97%. With a greater percentage being present on the apex of the convex side of the curve		
Ford et al. (1983)	18 patients undergoing lumbar IVD surgery (aged 28–73)	1 cm lateral to the tip of the L5 spinous process and 1 cm from the inferior border of the L5 lamina bilaterally	Affected side: 53% Non—affected side:49%	Affected side: 59% Non—affected side: 53%		*Wide variation in muscle characteristics between sides, not related to side of dysfunction
Bagnall et al. (1984)	19 patients undergoing lumbar IVD surgery (aged 26–73)	Multifidus sampled 1 cm from the inferior border of the L5 lamina and 1 cm lateral to the L5 spinous process just below the TLF bilaterally	Males: R 53% L 41% Females: R 58% L 58%	Males: R 48% L 60% Females: R 54% L 65%		*At any one level of the vertebral column, large differences in muscle fibre characteristics can exist
Sirca and Kostevc (1985)	21 male cadavers (aged 22–46)	Multifidus and longissimus at the L2 spinal level	Cadavers: 63% (deep muscle)		Cadavers: 57% (superficial muscle)	* More type I fibres in deep than superficial muscle
	12 male and 5 female patients undergoing lumbar IVD surgery (aged 28–50)	*samples divided into deep and superficial muscle	Surgical patients: 63% (deep muscle)		Surgical patients: 56% (superficial muscle)	

Table 1 (*continued*)

Authors	Population sampled	Sample site	% Type I fibres DM	% Type I fibres SM	% Type I fibres ES	Comments by authors
Thorstensson and Carlson (1987)	9 males and 7 females with no history of LBP (aged 20–30)	Superficial longissimus and multifidus at the left side of the L3 spinal level		62% (average across all subjects)	57% (average across all subjects)	*No significant differences in the relative number of different fiber types between multifidus and longissimus
Jorgensen et al. (1993)	6 male cadavers with no known history of LBP (aged 17–29)	Superficial and central portions of multifidus, longissimus, and iliocostalis at the upper level of L3 spinal level bilaterally		54.0% multifidus (superficial and central samples pooled)	70.5% longissimus (superficial and central samples pooled) 55.0% iliocostalis (superficial and central samples pooled)	*Longissimus significantly greater percentage of type I fibers than multifidus and iliocostalis ($P < 0.001$)
Rantanen et al., (1993)	14 male and 7 female cadavers with no known history of LBP (aged 23–65)	DM at the right side of the L4/5 spinal level in all cadavers and the right L3/4 and right L5/S1 spinal levels in the last 12 cadavers	62.6% at L4/5	57.4% at L4/5	66.6% deep	*A slight predominance of type 1 fibers
		SM, deep and superficial illiocostalis lumborum at the right L4/5 spinal level in last 12 cadavers	69.6% at L3/4 61.7% at L5/S1		66.55% superficial illiocostalis lumborum	
Mattila et al. (1996)	22 males and 19 females undergoing lumbar IVD surgery at L4/5 or L5/S1 under the age of 55 9 male and 3 female cadavers with no known history of LBP (aged 21–58)	Multifidus at the transversospinal corner at L4/5 and L5/S1	Cadavers: 60.8% (male) 62.5% (female) Surgical patients: 57.7% (male) 61.5% (female)			
Mannion et al. (1997a)	17 male and 14 female subjects with no history of LBP (mean age for men 23±4.3 years and for females 29±10.6 years)	Left erector spinae approximately 3–4 cm from the midline at the 10th thoracic and 3rd lumbar spinal levels		65.0% (male)	62.0% (male)	
				63.6% (female)	67.8% (female)	
Mannion et al. (1997b))	12 male and 9 female subjects with no history of low back pain 12 male and 9 female subjects about to undergo lumbar spinal surgery	Control group: Left ES at the level of the 3rd lumbar vertebrae Surgical patients: superficial multifidus from the level of L3 or L4 taken during surgery		Surgical Patients: 51.0±12.9% (male) 50.1±7.7% (female)	Controls: 66.1±7.7% (male) 66.5±12.0% (female)	

Note: DM, deep fibres of lumbar multifidus; SM, superficial fibres of lumbar multifidus; ES, erector spinae; IVD, intervertebral disc.

arisen that DM is active tonically whereas SM and ES are active phasically. Is this argument supported?

Electromyographic activity (EMG) of multifidus has been evaluated during a variety of tasks and postural perturbations with surface and intramuscular electrodes inserted with and without visual guidance (Floyd and Silver, 1951; Joseph and McColl, 1961; Morris et al., 1962; Joseph, 1963; Pauly, 1966; Jonsson, 1970; Donisch and Basmajian, 1972; Waters and Morris, 1972; Dofferhof and Vink, 1985; Valencia and Munro, 1985; Lindgren et al., 1993; Leinonen et al., 2001; Andersson et al., 2002; Moseley et al., 2002, 2003; White and McNair, 2002; Saunders et al., 2004). Unfortunately, recordings made with surface electrodes over multifidus correlate better with activity of lumbar longissimus than that of multifidus (Stokes et al., 2003). Furthermore, intramuscular EMG recordings indicate that activity of the deep back muscles can be different to that of the superficial components, and this difference is unlikely to be detected with surface electrodes (Wolf et al., 1989). Therefore, it is difficult to interpret the results of studies of multifidus in which surface electrodes have been used (Joseph and McColl, 1961; Joseph, 1963; Dofferhof and Vink, 1985; Arokoski et al., 2001; Leinonen et al., 2001).

In most studies using intramuscular electrodes, suggestions of tonic activation during trunk movements have been based on qualitative judgments in a few subjects (Morris et al., 1962; Pauly, 1966; Jonsson, 1970; Donisch and Basmajian, 1972; Valencia and Munro, 1985). For instance, in a trunk rotation task, Donisch and Basmajian (1972) reported that 7 out of their 25 subjects had activity in the lumbar multifidus that was not related to the direction of movement. However, this activity was described by the authors as "burst like" or phasic in nature. During trunk flexion, Valencia and Munro (1985) reported that 10–15 subjects did not decrease multifidus activity at the end of range of trunk flexion (Valencia and Munro, 1985). However, 9 of those subjects were reported to be apprehensive to move and did not achieve full flexion with intramuscular electrodes. In 5 subjects who were not apprehensive and reached full flexion, electrical silence was demonstrated. It was concluded that the "flexion–relaxation phenomenon" was not as characteristic a feature of multifidus as that of ES. However, an alternative explanation is that activity of multifidus was altered by apprehension to move, rather than reflecting a normal feature of multifidus activity.

Multifidus EMG has been shown to vary in static postures. Valencia and Munro (1985) reported slight intermittent activity of multifidus whilst standing in 14 subjects and no activity in three subjects. Donisch and Basmajian (1972) demonstrated either slight or no multifidus activity in quiet standing. Jonsson (1970) reported slight multifidus activity in more than half of their recordings, and activity was varied in intensity more often than not. This activity has been shown to be affected by posture, slight changes in standing position (Floyd and Silver, 1955; Morris et al., 1962; Joseph, 1963; Waters and Morris, 1972), and to vary between spinal levels (Joseph and McColl, 1961). In general, ES and the lumbar multifidus have been shown to be active in any posture that requires lumbar extension. In addition, ipsilateral ES is active during lateral flexion and rotation, and contralateral ES is active when carrying a load in a hand (Jonsson, 1970).

Multifidus and ES are phasically active during gait (Pauly, 1966; Waters and Morris, 1972; Dofferhof and Vink, 1985; White and McNair, 2002). A recent study by Saunders et al. (2004) was the first to simultaneously record activity from DM and SM with intramuscular electrodes during gait. Phasic bursts of DM and SM activity occurred with ipsilateral and contralateral heel strike.

Recent quantitative EMG studies have investigated the possibility that, although not tonically active, DM and SM may be differentially active. Moseley et al. (2002) reported that, unlike SM and ES, DM is active in a non-direction-specific feedforward manner in association with rapid arm movements. Differential activity of DM and SM has also been demonstrated during expected, but not in unexpected, trunk loading (Moseley et al., 2003). This suggests that DM and SM are differentially active in loading tasks, and that differential activity is dependent on input from higher centres. Such differentiation may serve to fine tune spinal control.

In summary, these data suggest that the nervous system does not simply maintain tonic multifidus activity. Rather, it matches the spatial and temporal features of multifidus activity to the demands of spinal control, which vary with constantly changing internal and external forces. As such, the clinical belief regarding tonic activation of DM and phasic activation of SM and ES is not supported. However, it is apparent that DM, SM and ES are differentially active in functional tasks, which should be considered in the design of therapeutic exercise interventions.

5. Co-contraction of DM and TrA

It has been proposed that DM and TrA may co-contract during an abdominal hollowing manoeuvre (Richardson et al., 2000). Furthermore, it has been proposed that co-contraction of DM and TrA is required for lumbar stability and must be retrained in patients with LBP (Richardson et al., 1990, 1992, 2000; O'Sullivan, 2000; Taylor and O'Sullivan, 2000). Is there evidence to support those proposals?

Several studies have demonstrated activity of the abdominal and paraspinal muscles during an abdominal hollowing manoeuvre (Richardson et al., 1990, 1992; Vezina and Hubley-Kozey, 2000; Arokoski et al., 2001) but none have recorded TrA or DM EMG. Furthermore, whether abdominal hollowing preferentially activates DM compared to SM or ES has not been tested.

During function it is unlikely that co-contraction of DM and TrA is obligatory. Although there is evidence that TrA is continuously active (with amplitude modulation) during gait (Saunders et al., 2004) and in static postures (Cresswell et al., 1992), DM is active with phasic bursts as outlined above. Thus, while periods of co-contraction will occur it is not necessary for stability. However, there is evidence that suggests similarities in activity of TrA and DM. For instance, DM (Moseley et al., 2002) and TrA (Hodges and Richardson, 1997) are both active in a non-direction-specific feedforward manner in preparation for the perturbation to the spine from arm movement. Although contraction of these muscles is not simultaneous, it is possible that the mechanical effects occur more or less simultaneously because the electromechanical delay of TrA is likely to be longer than that for DM due to its long elastic anterior fascias. Earlier activity of TrA may compensate for this delay.

Although there is no evidence that DM and TrA co-contract during abdominal hollowing, there is no evidence that they do not. Although DM and TrA do not co-contract tonically in function, further investigation of whether such co-contraction needs to be trained in patients with LBP is required.

6. Dysfunction of DM in LBP

Changes in the lumbar paraspinal muscles associated with LBP have been suggested to affect DM more than SM or ES (Norris, 1995a, b; Pool-Goudzwaard et al., 1998; Richardson et al., 1999d; Arokoski et al., 2001; Hides, 2004b). Changes in activation patterns and cross sectional area (CSA) of the segmental portion of the lumbar multifidus (Hides, 2004b) have been suggested, and therapeutic exercise programmes that target multifidus have been tailored to address these issues.

Several studies have demonstrated morphological changes in the lumbar multifidus in LBP. The CSA of multifidus has been shown to decrease on the painful side, and at the clinically determined level of symptom provocation (Hides et al., 1994). In chronic LBP the CSA of multifidus measured with CT (but not psoas) is reduced (Danneels et al., 2000). Furthermore, intramuscular fat in multifidus has been shown to be increased in chronic LBP (Parkkola et al., 1993; Kader et al., 2000) and following spinal surgery (Laasonen, 1984). Increased intramuscular fat has been argued to be greatest in DM (Kader et al., 2000).

Histochemical changes in multifidus have also been identified in LBP. Degeneration of type I muscle fibres (Jowett et al., 1975; Bagnall et al., 1984; Mattila et al., 1986; Rantanen et al., 1993) and atrophy of type II fibres (Rantanen et al., 1993) have been demonstrated. Furthermore, the decreased CSA of type I and II muscle fibres and other structural changes in multifidus have been identified at the level of intervertebral disc herniation (Yoshihara et al., 2001).

In terms of activity, both denervation and re-innervation have been shown in multifidus in long-term LBP with leg pain (Sihvonen, 1997). Evidence of specific denervation of DM was demonstrated in one subject who was about to undergo repeat microdiscectomy (Zoidl et al., 2003). Lindgren et al. (1993), using intramuscular electrodes at an unspecified location, demonstrated a reduction in the number of functional motor units in multifidus ipsilateral to the patients symptoms at a segment determined radiographically to be unstable. The temporal characteristics of multifidus activity have been investigated with surface electrodes in response to expected trunk loading (Leinonen et al., 2001). Unlike controls, subjects with LBP did not reduce the latency of the multifidus response when the loading was predictable. However, as surface electrodes were used to record multifidus activity these data are difficult to interpret. No studies have specifically investigated the control of DM in LBP, acute or chronic.

Evidence supports the clinical belief that changes specific to the lumbar multifidus occur in LBP. These changes have been demonstrated to be confined to a single segment and to the side of pain in some (Lindgren et al., 1993; Hides et al., 1994; Zhao et al., 2000; Yoshihara et al., 2001) but not all cases (Kader et al., 2000). However, the evidence for specific changes in DM in LBP is limited (Zoidl et al., 2003) or based on qualitative judgements in a limited number of subjects (Laasonen, 1984; Hides et al., 1994; Kader et al., 2000). Investigation of DM activity in LBP is required.

7. Summary and clinical implications

The neurophysiological, biomechanical and histological data considered in this review provide a detailed examination of the evidence that underpins the clinical beliefs regarding lumbar multifidus. Although some beliefs are supported by the literature, a range of questions remain unanswered.

Anatomical and biomechanical studies convincingly argue that DM, SM and ES control segmental motion. Although studies refute the clinical belief that SM and ES are solely extensors/rotators of the lumbar spine, data suggest that DM has an advantage for the nervous system in that this muscle can control intervertebral shear and torsion without generating torque. Thus, activity of this muscle does not require co-contraction of antagonists. This supports the use of therapeutic exercise programmes which target DM in the rehabilitation of patients with LBP. Consistent with biomechanical data, is the evidence of differential activation of DM and SM with postural perturbations. This has been argued to indicate that DM fine tunes intervertebral control whereas SM functions to counteract flexion torque to maintain spinal orientation. This differential activation of DM and SM supports the use of specific motor learning strategies in the design of therapeutic exercise programmes that target multifidus.

EMG studies refute the belief that DM is tonically active during static postures, trunk movements and gait. It is, therefore, unlikely that training tonic activity of multifidus restores the normal function of this muscle. However, tonic DM activity may still be a necessary and beneficial characteristic of therapeutic exercise as it may be required to compensate for osseoligamentous deficiency.

DM and TrA do not maintain tonic co-contraction. However, these muscles do share functional similarities. As with tonic activation of DM, training co-contraction of DM and TrA as part of therapeutic exercise programmes is unlikely to restore typical activation patterns, but may be required to compensate for an underlying osseoligamentous deficit to restore intervertebral control.

DM, SM and ES all have a predominance of type I muscle fibres. Unfortunately, biopsy samples for DM have only been harvested in cadaveric and surgical specimens. It remains unknown whether there are any differences in fibre types between DM, SM and ES in healthy individuals. Thus, the implication of muscle fibre characteristics for clinical practice remains unclear.

Morphological, histochemical and neurophysiological changes have been shown in the lumbar multifidus in subjects with LBP. However, findings demonstrating specific dysfunction in DM are limited. Furthermore, whether postural activity of DM is affected or not in LBP remains to be investigated.

Although the evidence which underpins clinical beliefs regarding lumbar multifidus is incomplete, there is good evidence that exercises which target DM, at least in the early phases of management, are effective to reduce the recurrence rate of LBP following a first episode of acute LBP (Hides et al., 2001), in the treatment of patients with radiological evidence of spondylolysis and spondylolisthesis (O'Sullivan et al., 1997) and as a component of the multimodal management of moderately disabled patients with chronic LBP (Moseley, 2002). Evaluation of the literature has raised a number of implications for the design of therapeutic exercises targeting DM and SM in the management of the LBP, which may improve these already positive results.

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