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ORIGINAL ARTICLE

Degenerative spondylolisthesis: a prospective cross-sectional cohort study on the role of weakened anterior abdominal musculature on causation

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Abstract

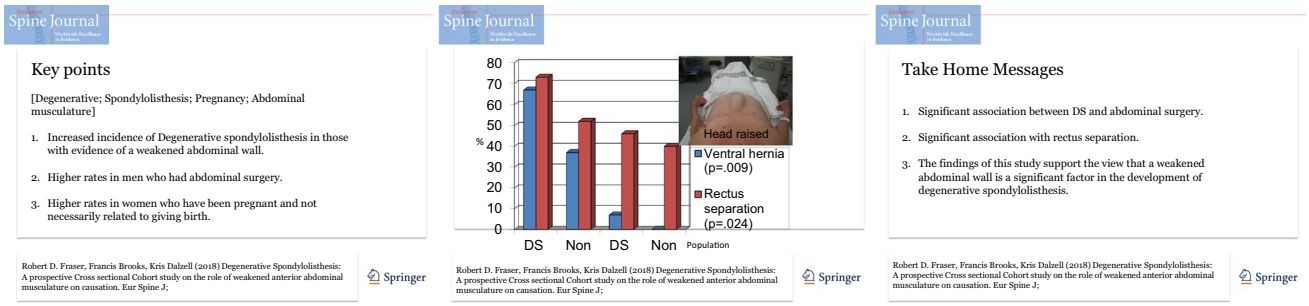
Purpose Degenerative spondylolisthesis (DS) is a degenerative condition of the spine which, unlike others, is more common in a female population. Previous studies have highlighted possible causative factors such as facet tropism and pregnancy as reasons for this. This study sets out to assess the possible link between abdominal musculature and DS.

Method A prospective cross-sectional cohort study in a single surgeon practice assessed all patients aged over 50 years attending for degenerative lumbar spinal complaints. Patient demographics, as well as the number of pregnancies, children, abdominal surgical procedures, were recorded.

Results We found 205 patients that met our inclusion criteria (98 Males/107 Females). Women with multiple pregnancies ($p=0.036$) and abdominal surgeries ($p=0.021$) were more likely to develop DS. Males with ventral hernias were more likely to have developed DS ($p=0.004$).

Conclusion This study highlights the important role that the abdominal musculature plays in stabilization of the spine and highlights its potential role as a factor in the development of DS.

Graphical abstract These slides can be retrieved under Electronic Supplementary Material.



Keywords Degenerative · Spondylolisthesis · Pregnancy · Abdominal musculature

Introduction

With an ageing population, the disability associated with degenerative conditions of the spine is producing an escalating impact on health and welfare expenditure. Foremost of such conditions afflicting the elderly is spinal stenosis which is associated with a degenerative spondylolisthesis (DS) in the majority of cases, particularly in females.

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There is no other degenerative condition of the skeleton where prevalence is up to four times greater in females than in males. In view of this disparity, surprisingly little attention has been directed at the aetiology of DS, although hormonal influences and pregnancy [1–3] have been implicated. Other suggested aetiological factors include race, soft tissue abnormalities, the influence of the lumbosacral angle, sagittal spinopelvic alignment, a lower intercrestal line, lumbosacral bony anomalies, facet tropism and alignment and diabetes [4–9].

An increased sagittal angle of the lumbar facet joints in patients with DS has been suggested to predispose patients due to an increased susceptibility to shear [4]. Although the gender difference is not explained by the morphology of the facet joints, it has been shown that sagittal orientation of facet joints in DS is due to arthritic remodelling [10].

Farfan drew attention to sex differences in bony morphology [11]. He considered DS was due to failure in torsion and that the wide pelvis and high riding L4/L5 disc in females increased their vulnerability to torsion. An analysis of loads on the spine estimated the muscles of the abdominal wall to be responsible for providing greater than 95% of resistance to torsion [12]. In keeping with this, weakening of abdominal muscles as a result of pregnancy was thought to explain the twofold increase of DS in parous patients compared with nulliparous patients [1].

This study aims to show an association between inadequate trunk muscles and the presence of DS. It is hypothesized that DS would be associated with conditions which weaken the anterior abdominal musculature.

Methods

All new patients 50 years of age or older, who presented to a single surgeon's spinal practice (RDF) for the treatment of low back pain (LBP) or sciatica, were considered for the study. Patients were excluded if they had previous lumbar surgery, or if they presented with spinal infection, neoplasm or a fracture. Using standardized data-sheets information was collected on age, height, weight, occupation, number of children, number of pregnancies and number of open abdominal operations.

All patients presenting to the practice routinely complete a questionnaire which is reviewed and expanded upon by the senior author (RDF). All the information relevant for this study was achieved via this method and standard medical history taking.

The integrity of the linea alba was assessed by asking the supine patient to lift their head and shoulders from the examination couch, and the space between the taut rectus muscles palpated. The width and length of any gap was measured and recorded. The presence of a ventral hernia was noted (Fig. 1)

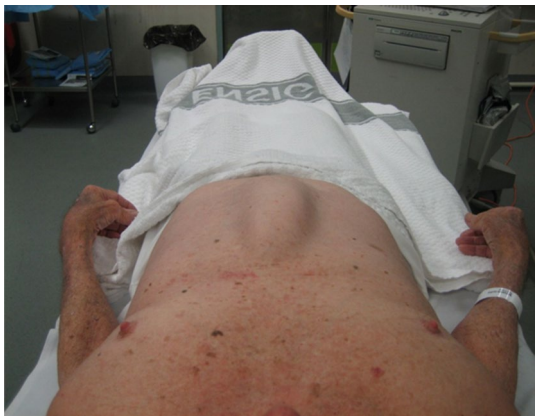

Fig. 1 Picture showing divarication of the recti with a ventral hernia on head raising

and based on its size graded as small, moderate or large. The number and location of abdominal scars was noted. Any neurological deficit was recorded. With the patient standing comfortably, the circumference of the waist at the level of the umbilicus was measured.

A MR or CT scan of the lumbar spine was examined for degenerative spondylolisthesis, using standard 2 mm slicing, and if present the level(s) and Meyerding Grade of the slip were recorded [13]. The presence of transitional anomalies was recorded. Central canal and foraminal stenosis were separately graded as mild, moderate or severe.

In selected cases, when further assessment by MRI or CT of the lumbar spine was indicated, the study included (at no additional expense) transverse scans of the anterior abdominal wall to measure the extent of diastasis recti (if present) and compare it with the clinical measurements of rectus separation.

Statistical analysis was performed using SAS version 9.2 (SAS Institute Inc., Cary, NC, USA). All data were tested for normality. Independent t tests were used for significant differences between groups. A p value of less than 0.05 was considered significant. For subgroup analysis, a logistic regression model with a single predictor was used.

Results

A total of 205 subjects were included in the study (98 males and 107 females). The average age was 68.3 years. All patients were examined by the same clinician between August 2009 and January 2010. The presence of DS was not associated with height, BMI or waist circumference in our study population. (Table 1). L4 was the most common level involved with DS (Fig. 2). A table of all variables and their results is shown in Table 2. No patient was excluded due to a lytic spondylolisthesis. The rate for lytic

Table 1 Demographic findings of the study populations

	Presence of DS males $n=28$ (SD)	Non-DS males $n=70$ (SD)	Presence of DS females $n=56$ (SD)	Non-DS females $n=51$ (SD)
Height (cm)	173 (0.09)	176 (0.08)	159 (0.05)	161 (0.06)
Weight (kg)	86.5 (19.84)	89 (14.79)	72.2 (13.67)	71.1 (13.82)
BMI	28.58 (5.05)	28.57 (3.73)	28.67 (5.4)	27.61 (5.26)
Waist (cm)	103 (14.98)	101 (9.72)	96 (11.44)	93 (11.46)
Presence of lytic spondylolisthesis at adjacent levels	2	5	2	5

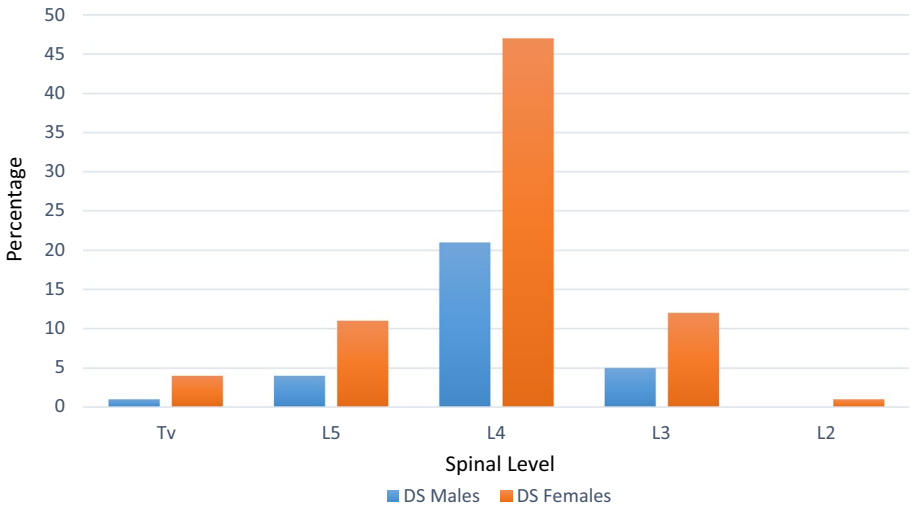

Fig. 2 Bar chart showing the levels involved in DS

Table 2 Subgroup analysis by gender: logistic regression model with single predictor

	Males ($n=98$)		Females ($n=107$)	
	Odds ratio	p value*	Odds ratio	p value*
Age	1.06	**0.02531**	1.08	0.000508
Height (cm)	0.955	0.117	0.946	0.108
Weight (kg)	0.99	0.484	1.005	0.690
BMI	1.00	0.987	1.038	0.303
Children (ave)	–	–	1.314	0.064
Pregnancies (ave)	–	–	1.311	0.036
Central stenosis (0–4)	3.01	**4.41e−05**	3.195	2.85e−07
Foraminal stenosis (0–4)	1.29	0.185186	1.149	0.397
Diastasis (0–4)	2.170	**0.000314**	11.113	0.021
Abd scars/patient	0.785	0.5247	1.491	0.021
Max girth (cm)	1.01	0.456	1.030	0.087
Rectus sep (cm)	2.046	**0.00434**	1.753	0.060
F flexion (cm)	0.947	**0.00528**	0.985	0.302
Extension (cm)	0.943	**0.0181**	0.975	0.196
SLR	1.05	**0.00713**	1.002	0.881
Hip flexion SLR deg	1.048	**0.00871**	0.999	0.963

Bold indicates statistical significance

*p values are found after fitting logistic model with DS and non-DS subjects and the single predictor

spondylolisthesis in the DS was 4.8% compared with 8.3% for the non-DS patients.

DS and gender

As is previously reported, there is a strong association with females and DS. This study found an increased risk of DS in females in all subgroups when compared to males. This reached significance with a $p=0.005$. There was a significant difference between the sexes for multilevel slips with 30% of females having multilevel DS compared with 7% in males ($p=0.017$)

DS and pregnancies

We performed subgroup analysis on the female cohort and asked the number of pregnancies they had and how many children they had. We found that females with DS were statistically more likely to have been pregnant ($p=0.036$). This was more significant than having children $p=0.064$ (Fig. 3).

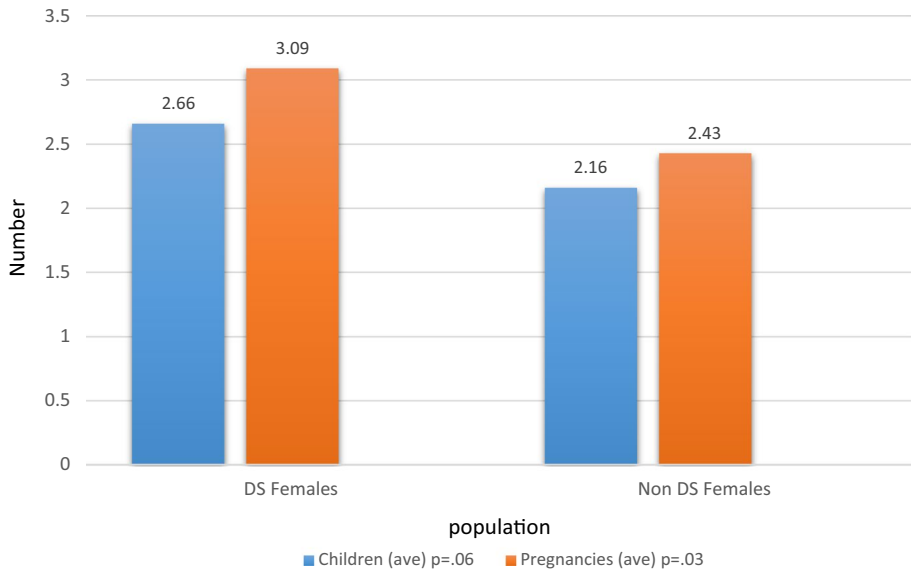

Fig. 3 Bar chart showing the association with pregnancy and DS

DS and abdominal surgery

The presence of scars from previous abdominal surgery was statistically significant in females compared to males ($p = 0.021$). Over 70% of females with DS had undergone previous abdominal surgery. Thirty per cent of patients who had DS had multiple abdominal surgical procedures performed previous, in females with DS this rose to 41%.

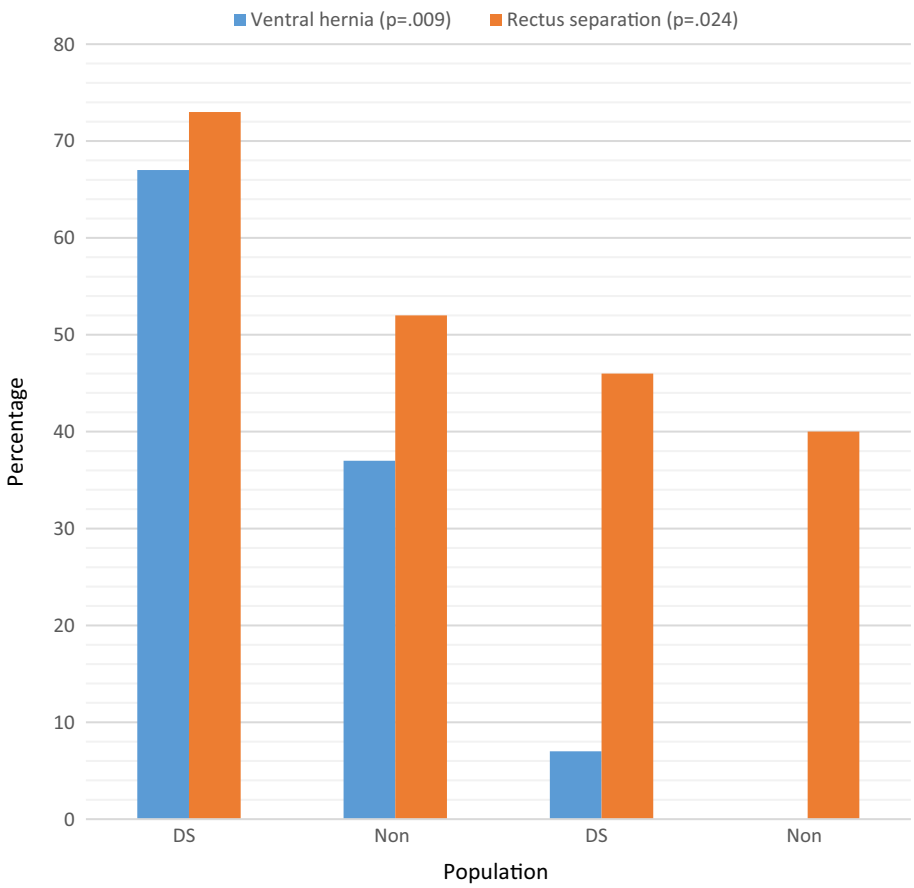

Fig. 4 Bar chart showing the presence of DS and its association with rectus dissociation in our study

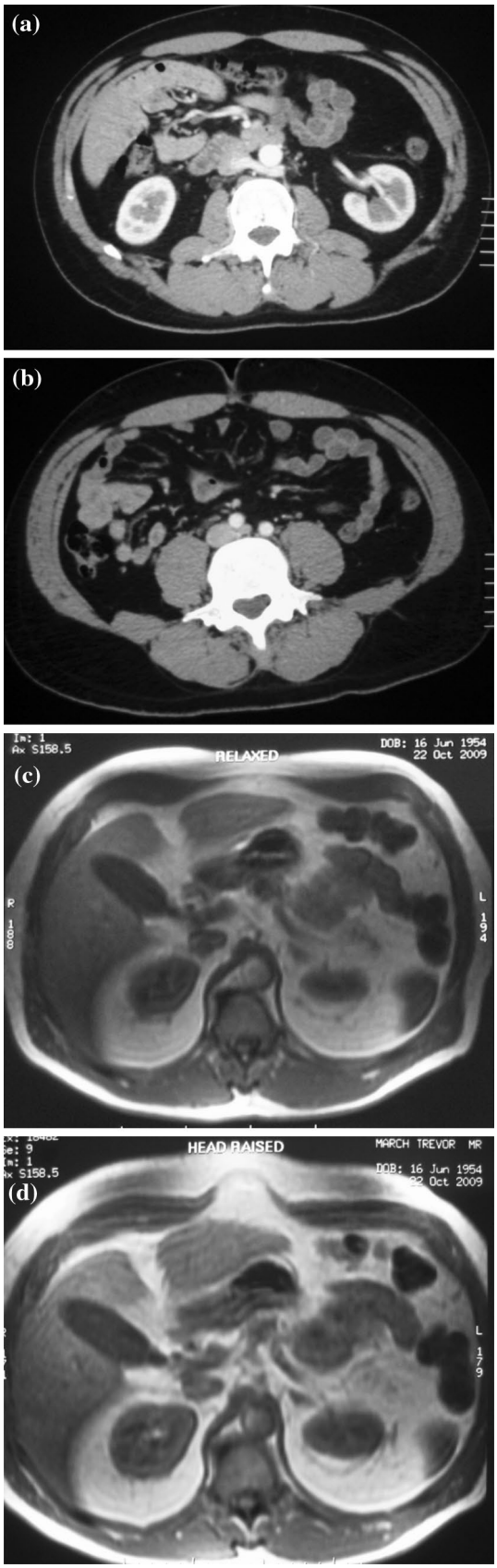

Fig. 5 **a** Abdominal CT scan of 40-year-old male with no rectus separation. **b** Abdominal CT scan of 40-year-old male with head raised showing no rectus separation. **c** Abdominal MRI of 55-year-old male with head relaxed showing thinning of abdominal wall due to rectus separation. **d** Abdominal MRI of 55-year-old male with head raised showing separation of the recti and ventral herniation ▶

DS and rectus dissociation

Weakness of the linea alba leads to rectus dissociation and a ventral hernia. We analysed the results and found that rectus dissociation was highly significant in males with DS ($p = 0.0003$) and this reached significance in females ($p = 0.021$) (Fig. 4). Ventral herniation was found to be statistically more likely in DS ($p = 0.009$) compared to rectus separation ($p = 0.024$).

Discussion

Our study highlights an association between the possible weakness of the abdominal wall and the presence of DS. We believe it suggests that weakness in the abdominal muscles may decrease the ability to withstand torsional forces leading to degenerate changes of the lumbar spine.

This study builds on work by the senior author looking at the aetiology of DS [1]. This work showed the positive relationship between pregnancy and DS. It suggests that the hormones associated with pregnancy rather than the childbirth may be associated with the development of DS. A recent publication by Cholewicki seems to add further credence to this opinion [3]. Despite this, a longitudinal study from the Copenhagen Osteoarthritis Study Group failed to find any significant differences between age of menopause or childbirth in their female cohort [14]. These results differ from those in this study and Cholewicki's where an association between parity and DS was shown. Reasons for this difference are not clear.

Our study suggests that the abdominal muscles have an association in the development of spondylolisthesis. The abdominal musculature is an important stabilizer of the spine [15, 16] particularly in torsion [17]. Biomechanical studies have highlighted the negative impact that torsional forces have on the disc and joints of the lumbar spine [6]. The weakness and imbalance in the trunk muscles has been suggested as potentially one of many factors in contributing to low back pain [18, 19]. Furthermore, back pain is an indication for abdominal hernia repair [20]. It appears reasonable to assume that weakness of these muscles would have a significant role in the development of DS, given the association with rectus dissociation in our study. We performed dynamic MRI scans on patients who had a ventral hernia

with their head raised and flat. This showed significant thinning of the abdominal wall in comparison with those who did not have this (Fig. 5).

Farfan proposed a rotatory force involvement in the development of DS [21]. Evidence supports the role of torsion in disc prolapses [22, 23]. Drake's study highlighted that facet joints also failed under axial torque [24]. These studies differ from previous work which has suggested that torsion has no role in the cause of lumbar spine disorders [25]. The aforementioned studies support our belief that torsion and failure of the abdominal muscles may have a role in DS development.

The role of the posterior spine muscles was not assessed in this study. Previous research has suggested that weakness in the paraspinal muscles may lead to anterior and lateral movement which could be a cause of DS [26]. Further evidence to support this as a possible cause is provided by laboratory studies which showed that weakness in the posterior muscles rather than the abdomen might lead to DS [27]. Whilst these studies are certainly worthy of note, they fail to answer why the rate of DS is higher in females, in particular those who have been pregnant.

Other factors have been assessed as a cause of DS. Facet joint orientation has been highlighted as a possible cause for spondylolisthesis [3, 28]. This was not found in a finite element analysis by Kim et al. [29]. They found that facet orientation did not increase stress in either the disc or the facet joints. However, there is evidence that the change in orientation is more a remodelling process rather than a cause [8]. Another theory is that sacralization predisposes to DS due to increased forces at L4–L5 level. This is debated [30, 31]. Other risk factors are thought to be increased BMI, shorter stature, advanced age and degenerative arthritis [32]. We believe our results suggest that the weakened anterior abdominal muscles may be associated with DS.

Weaknesses of this study are the use of a single institute and single clinician (RDF). This may introduce observational bias. The large number of patients in the study and the statistical significance we have shown may counteract this. The MRI scan slices of 2 mm do allow for the possibility of missed lytic spondylolisthesis. We did not feel it appropriate to change the standard of care for these patients. By not including abdominal MRI scans on all patients, it is possible that more diastasis existed than we identified. We only included scans on patients who were having further imaging to limit the financial burden on them.

To our knowledge, this is the first study which has highlighted the role that the abdominal muscles play in the development of DS. This is important as it may lead to prevention or reduction by appropriate post-partum and post-surgical physiotherapy.

Conclusion

This study suggests that a weakness in the abdominal muscles and the inability to withstand torsional forces has an important role in the development of DS. It highlights the key role that the abdominal muscles play in spinal stabilization and the role that pregnancy may play in DS.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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