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The relationship beween posture and back muscle endurance in industrial workers with flexion-related low back pain

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Abstract

This preliminary cross-sectional study was undertaken to determine if there were measurable relationships between posture, back muscle endurance and low back pain (LBP) in industrial workers with a reported history of flexion strain injury and flexion pain provocation.

Clinical reports state that subjects with flexion pain disorders of the lumbar spine commonly adopt passive flexed postures such as slump sitting and present with associated dysfunction of the spinal postural stabilising musculature. However, to date there is little empirical evidence to support that patients with back pain, posture their spines differently than pain-free subjects.

Subjects included 21 healthy industrial workers and 24 industrial workers with flexion-provoked LBP. Lifestyle information, lumbo-pelvic posture in sitting, standing and lifting, and back muscle endurance were measured.

LBP subjects had significantly reduced back muscle endurance ($P<0.01$). LBP subjects sat with less hip flexion, ($P=0.05$), suggesting increased posterior pelvic tilt in sitting. LBP subjects postured their spines significantly closer to their end of range lumbar flexion in 'usual' sitting than the healthy controls ($P<0.05$).

Correlations between increased time spent sitting, physical inactivity and poorer back muscle endurance were also identified. There were no significant differences found between the groups for the standing and lifting posture measures.

These preliminary results support that a relationship may exist between flexed spinal postures, reduced back muscle endurance, physical inactivity and LBP in subjects with a history of flexion injury and pain.

Keywords: Posture; Low back pain; Back muscle endurance; Activity levels

1. Introduction

Epidemiological studies report the lifetime incidence of low back pain (LBP) in industrial workers to be approximately 60% (Svensson and Andersson, 1983; Lee et al., 2001). Yearly incidence has been reported as high as 31% (Svensson and Andersson, 1983; Poppel et al., 1998). A number of studies have investigated potential predictors of LBP including physical risk, psychosocial and physiologic factors. A study investigating various physical and psychosocial risk factors over a 1 year period could account for only 12% of serious LBP (Adams et al., 1999). Risk has been identified with prolonged sitting (Balague et al., 1988), prolonged standing (Macfarlane et al., 1997) and lifting (Lee et al., 2001), although the exact basis for the risk for sitting is still contentious.

A reduction in back muscle endurance has been found to be significantly predictive for new episodes of LBP (Biering-Sorensen, 1984; Luoto et al., 1995; Stevenson

Abbreviations: LBP, Low back pain; BMI, Body mass index; ASIS, Anterior superior iliac spine

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Keypoints

- LBP subjects with a history of a flexion-provoked pain sit with their lumbar spine closer to end of range flexion, and with a greater degree of posterior pelvic tilt than healthy controls.
- LBP subjects with flexion-provoked pain have lower back muscle endurance than healthy controls, even when matched for physical conditioning.
- Decreased back muscle endurance is associated with habitually adopting passive sitting posture, reduced activity levels and LBP.
- The findings provide evidence for a relationship between passive sitting postures, inactivity, reduced back muscle endurance and LBP in subjects with flexion-provoked pain.

et al., 2001). This may be explained by the evidence that the back muscles, which are known to reduce load on passive structures (Goel et al., 1993), act to maintain the erect posture of the spine throughout the day, as well as being active during many manual handling procedures including lifting and load carrying (Nicolaisen and Jorgensen, 1985). Increased spinal mobility (Biering-Sorensen, 1984), and decreased lumbar side flexion (Adams et al., 1999) have also been found to be predictors of LBP in men in single studies. Other studies have found no significance in spinal range of movement (Battie et al., 1990; Luoto et al., 1995). With regards to spinal posture, Adams et al., (1999), reported a loss of lumbar lordosis as a predictor of LBP. Otherwise, to date there is little evidence that lumbar spine posture plays a significant role in the presence or development of LBP.

Recent research has established a relationship between the level of trunk muscle activity and different standing and sitting postures (O'Sullivan et al., 2002). Adopting "passive" postures such as sway standing and slump sitting results in lower muscle activity in the transverse abdominal wall and back muscles, when compared to more upright standing and sitting postures. It was hypothesised on the basis of this research that subjects who habitually adopt "passive" spinal postures may decondition their lumbar stabilising muscles (O'Sullivan et al., 2002), leading to increased passive system loading, injury and pain (Cholewicki and McGill, 1996).

Specific trunk muscle dysfunction (Hides et al., 1994; Hodges and Richardson, 1996) and impaired spinal proprioception (Brumagne et al., 2000), have been reported in LBP populations. Recent research has documented a loss of lumbar spine neutral zone position sense in chronic LBP subjects with signs of clinical instability with a flexion pain pattern (O'Sullivan et al., 2003). It was hypothesised that these findings may represent a motor control deficit, secondary to pain and motor dysfunction of the spinal stabilising muscles, which in turn may result in increased passive system loading from repeated end range stress to the spine (O'Sullivan et al., 2003).

To date, the relationship between spinal posture, trunk muscle dysfunction and LBP has not been proven in clinical studies (Dieck et al., 1985; Raine and Twomey, 1994; Hartvigsen et al., 2000). Most postural studies are difficult to compare due to the lack of standardisation of postural assessment, and the difficulty in reproducing some assessment tools in the clinical setting (During et al., 1985; Wrigley et al., 1991). Furthermore, few studies have looked at a specific LBP population, which may explain the lack of significant findings.

The aim of this preliminary study was to examine whether a relationship exists between spinal posture, back muscle endurance, activity levels and LBP in a specific sub-group of industrial workers who reported flexion-provoked pain.

2. Materials and methods

2.1. Subjects

A cross-sectional study of industrial workers involving a control group and a specific LBP population group was conducted. Twenty-one control subjects with mean age 38.24 years (SD 9.33) and mean BMI 25.05 kg/m^2 (SD 3.32), and 24 LBP subjects with mean age 38.79 years (SD 9.24) and mean BMI 26.43 kg/m^2 (SD 2.86) were volunteers from an industrial work setting. All1200 employees from a bauxite refinery were contacted via email and invited to volunteer for the study if they fitted into the inclusion criteria for either the control or LBP group. Volunteers were screened for exclusion criteria, and then allocated to the appropriate group according to their LBP history. All subjects were manual workers, engaged in similar work activities at the time of testing. Ethical approval and written informed consent were obtained.

The control subjects were male industrial workers with a minimum of 2 years continuous employment in an industrial workplace. They had no history of significant LBP requiring medical intervention or time off work, and no history of low back ache in the preceding 3 months. Subjects in the control group were matched to the LBP subjects on the basis that they engaged in the same kind of work activity.

The LBP subjects reported a flexion injury to the lumbar spine, with ongoing pain over the preceding 18 months related to flexion activities and/or postures related to their work. All LBP subjects were performing their pre-injury duties for at least 3 months prior to testing to ensure physical work conditioning matched with the control group.

Subjects who reported the onset of back pain secondary to trauma (such as from a motor vehicle accident) or pain provoked by lumbar spine extension postures/activities were excluded. Subjects were also excluded who had radicular symptoms, or had undergone spinal surgery or posture retraining or specific stabilising muscle training as part of treatment for their LBP, to limit potential bias in the posture measures. Subjects with pain greater than 3/10 on a visual analogue scale during testing were excluded to limit the influence of pain impacting on the test results. Subjects who had a pending worker's compensation claim were also excluded.

2.2. Measures and procedures

Estimates of subject's activity levels and commonly adopted postures, both at work and home were obtained by a questionnaire designed for this study. The authors were unable to locate a previously validated questionnaire, which enabled the required information, at the time of testing. Subjects were asked in an interview format to estimate how much time they spent at work and home engaged in activities that involved sitting, standing, lifting and strenuous physical activity. Each activity was given an individual rating. The number of hours per week spent sitting (watching television, computer use, driving/travel and sitting at work) and standing (walking, standing at work and light general activity), was classified into 0–12 h (low), 13–24 h (moderate) and 25 + h (high). Lifting hours per week (at work and home) was broken down into 0–5h (low), 6–10h (moderate) and 11 + h (high). Activity levels were based on time spent doing vigorous outdoor activities (brisk walking, sport and strenuous outdoor tasks) over an average week, and was broken down into 0–3h (low), 4–7h (moderate) and 8 + h (high). From this information, subjects were given ratings of "low", "moderate" or "high" for amounts of time spent in each category.

2.3. Posture measures

Photo-reflective balls were taped to the bony landmarks of each subject's left anterior superior iliac spine (ASIS), greater trochanter midpoint, lateral femoral condyle, lateral malleolus, and the spinous processes of T10, L2, L4 and S2. Subjects were photographed in their natural sitting and maximal slumped sitting postures (Fig. 1), natural standing and maximal sway standing postures, and lifting and maximal standing lumbar flexion postures. In the sitting postures, subjects' knee and ankle position was standardised with an adjustable stool to allow for subject height variances to ensure the knees were at a 90° angle. Natural sitting posture was determined in a blind manner, whereby the subjects' sitting posture was photographed when they first sat on the stool without them being aware of the role of the initial photograph. Subjects were then guided into their full slump sitting posture and another photograph was taken. For standing, subjects were asked to stand on a mark on the floor looking forwards, with no instruction how they stood. They were then positioned into their maximal sway standing posture by a consistent examiner

The lifting posture involved a 12 kg box with handles being lifted 5 cm off the floor. Subjects were asked to lift using their 'usual' technique. The lift was below the recognised safe single lift limit for risk of low back injury (Waters et al., 1993). Measures of lumbar, hip and knee angles were recorded.

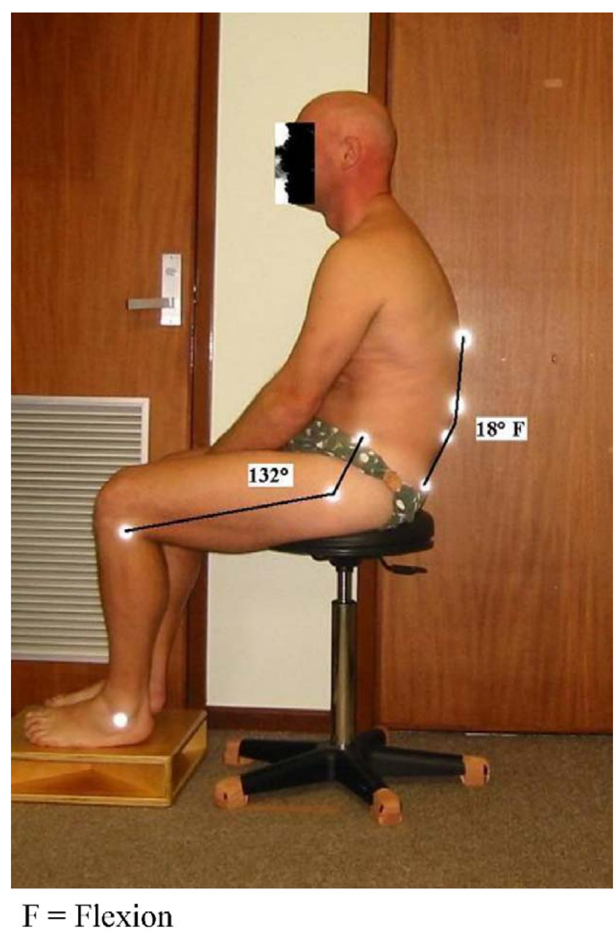

Fig. 1. Slumped sitting measure. Lumbar and hip angles shown.

Digital photographs were taken with a Canon Digital IXUS V camera (2.1 mega pixels). The posture photos were imported into Scion Image (Scion Corporation, Fredrick, USA), an image-processing programme that measures angles between manually marked positions on a digital image.

The hip angle was calculated as the angle formed between the points of the ASIS, greater trochanter and lateral femoral condyle. The knee angle was the angle formed between the points of the greater trochanter, lateral femoral condyle and lateral malleolus. The lumbar angle was measured as the angle between the intersection of the tangents drawn through the T10/L2 markers and the L4/S2 markers, as shown in Fig. 1.

To validate the measures of lumbar flexion and extension using anatomical markers, digital photography and Scion Image analysis software, a pilot study was conducted. Five subjects were measured in end of range lumbar flexion and sway standing. Lumbar angles were taken using the previously validated 'two inclinometer' method (Rainville et al., 1994), and compared to the digital photograph measures taken from the same position. Intraclass correlations revealed high levels of correlation between the two measures in sitting and standing postures ($\text{ICC} = 0.93-0.98$). Reliability testing of the angles produced using the Scion Image Software programme was also conducted on 5 subjects repeating the measures three times. Intraclass correlations showed high levels of both inter-tester ($\text{ICC} = 0.94-0.99$), and intra-tester reliability ($\text{ICC} = 0.99-1.00$).

2.4. Back muscle endurance

The Biering-Sorensen test was used to measure back muscle endurance (Moreau et al., 2001). Subjects lay prone over the edge of a couch, with the trunk unsupported. They were instructed to maintain a horizontal position of the trunk for as long as possible. Endurance time was recorded when the subjects deviated more than 10° from the lumbar neutral position. This angle was determined using a hand-held inclinometer (Cimed, Switzerland), at the thoraco-lumbar junction.

The investigators taking the postural photographs and lumbar muscle endurance scores were blinded to the group allocation of the subjects during both testing and data management.

2.5. Statistical analysis

A sample of 20 subjects was determined from previous lumbar muscle endurance data to be sufficient to detect an effect of moderate size with an alpha level of 0.05 and power level of 80%. No prior data was available for the posture measures, and 20 subjects was considered to be sufficient for this preliminary study. All data were coded and input into SPSS Student Version 10.0 (SPSS, Chicago USA). Data were analysed for normality. Paired t-tests were used to compare the difference between lumbar and hip angles in 'usual' and slump sitting postures and 'usual' and sway standing lumbar spine postures. Independent t-tests were used to compare hip angles, lumbar spine angles, and muscle endurance scores between the pain and control groups. Mann–Whitney U test were performed on the activity level data. Spearman's correlations were used to test for relationships between lumbar muscle endurance, posture, activity level, sitting time data and LBP.

3. Results

The mean, standard deviation and "P" values of the endurance scores, and the lumbar, hip, and knee angles in the test positions are shown in Table 1. The results showed normal distributions using the Shapiro–Wilk test.

The LBP group showed significantly lower back muscle endurance compared to the pain-free controls, ($t(43) = -3.98$, $P = <0.001$).

No difference was observed between the two groups when comparing their 'usual' sitting, standing and lifting lumbar flexion angles. However, the LBP subjects sat in greater posterior pelvic tilt than control subjects when assuming their 'usual' sitting posture, ($t(43) = 2.00$, $P = 0.05$).

When comparing the lumbar angle difference between 'usual' sitting and maximal slumped sitting, the back pain group sat significantly closer to their end of range lumbar flexion in their 'usual' sitting posture ($t(43) = 0.32$, $P = 0.02$).

There were significant correlations between decreased low back muscle endurance scores and increased posterior pelvic tilt during 'usual' sitting ($\rho(43) = -0.32$, $P = 0.03$), as well as between decreased low back muscle endurance and smaller differences in lumbar angles between 'usual' sitting and maximal slumped sitting ($\rho(43) = 0.36$, $P = 0.01$).

The results from the activity questionnaires regarding sitting, standing, lifting and activity periods are shown in Table 2. When comparing the questionnaire results between the two groups, no significant difference was found, although LBP subjects sitting longer than the pain-free controls demonstrated a trend towards a statistical significance ($P = 0.057$). Significant correlations did exist however, across all subjects, between lower back muscle endurance scores and higher sitting periods ($\rho(43) = -0.31$, $P = 0.04$). Correlation was also observed between low back muscle endurance scores and low activity levels ($\rho(43) = 0.31$, $P = 0.04$).

Table 1
Lumbar, hip and knee angles and endurance scores

	Low back pain group			Control group			
	N	Mean[a]	SD	N	Mean[a]	SD	P-values[b]
Stand (Lx)	24	154.18	7.43	21	153.32	5.90	0.67
Sway (Lx)	24	148.98	10.36	21	148.25	5.27	0.76
Stand (hip)	24	154.83	12.65	21	149.61	9.01	0.12
Sway (hip)	24	158.26	12.59	21	152.20	10.61	0.90
Sit (Lx)	24	187.13	7.61	21	183.92	10.87	0.25
Slump (Lx)	24	192.80	5.90	21	193.83	7.97	0.62
Sit–slump Difference (Lx)	24	5.67	5.29	21	9.91	6.08	0.02
Sit (hip)	24	109.09	19.32	21	98.57	15.32	0.05
Slump (hip)	24	111.90	17.11	21	103.00	13.68	0.06
Flexion (Lx)	24	200.42	5.94	21	202.22	6.31	0.33
Lift (Lx)	24	189.86	12.20	21	192.17	13.93	0.56
Flexion (hip)	24	110.73	15.88	21	104.81	15.10	0.16
Lift (hip)	24	90.81	27.73	21	88.51	22.22	0.76
Flexion (knee)	24	176.37	6.51	21	178.84	6.56	0.21
Lift (knee)	24	106.55	45.08	21	109.42	44.85	0.83
Endurance[c]	24	121.12	43.69	21	167.76	33.27	<0.001

Lx = Lumbar.
Difference = angles subtracted to give difference between 2 stated measures.
[a]Mean = Degrees.
[b]P—values of LBP vs Control groups.
[c]Endurance = Seconds.

Table 2
Activity questionnaire time ratings

	Low back pain group			Control group		
	Low (%)	Medium (%)	High (%)	Low (%)	Medium (%)	High (%)
Sitting	0.0	20.8	79.2	0.0	47.6	52.4
Standing	8.3	45.8	45.8	0.0	47.6	52.4
Lifting	25.0	70.8	4.2	28.6	61.9	9.5
Active	20.8	50.0	29.2	4.8	57.1	38.1

% of subjects in each category.

4. Discussion

This preliminary study supports that reduced back muscle endurance is a common finding in this sub-group with flexion-related LBP. No subjects reported pain during the test procedures, supporting that the presence of pain did not directly bias the results of the study. These findings are consistent with a number of other studies that have also reported reduced back muscle endurance in other more heterogenous LBP populations (Nicolaisen and Jorgensen, 1985; Holmstrom et al., 1992; Hultman et al., 1993). This may reflect previous reports that flexion-related pain disorders are the most common disorders observed in clinical practice (O'Sullivan, 2000).

In a bio-mechanical modelling study by Goel et al., (1993), it was proposed that lumbar spinal muscles impart stability to the ligamentous segment and also lead to a decrease in stresses in the vertebral body and the intervertebral disc. On the other hand, back muscle fatigue has been shown to be associated with reduced spinal proprioception in both healthy and LBP subjects (Taimela et al., 1999). It is considered that these factors in turn may lead to increased passive system loading and resultant tissue strain (Cholewicki and McGill, 1996). Possible causes of reduced back muscle endurance might include disuse through inactivity (Moffroid et al., 1994), altered motor control patterns (O'Sullivan et al., 1997), or prolonged passive system loading associated with reduced activity of spinal stabilising muscles (O'Sullivan et al., 2002). Some of these associations are supported by the data in the present study.

Poor back muscle endurance was correlated to increased periods of sitting and lower physical activity levels. This is supported by recent research which has shown a relationship between passive slumped sitting posture and reduced back muscle activity (O'Sullivan et al., 2002). A correlation has been previously reported between the presence of LBP and time spent watching television in studies on adolescents (Balague et al., 1988, 1994). Balague et al. (1988, 1994) proposed that this association might be due to prolonged sitting and/or 'poor' posture and/or physical inactivity. The previously identified relationship between psychosocial factors such as depression and (LBP) (Leinoa and Magnib, 1993) may also be associated with this relationship and requires further investigation.

There was no difference between the groups based on their lumbar spine posture angles in sitting. These findings are consistent with other literature (Raine and Twomey, 1994; Hartvigsen et al., 2000). However the LBP subjects sat with a greater degree of posterior pelvic rotation and with their lumbar spine closer to their end of range of available flexion compared to the control group subjects. By sitting with their lumbar spine towards the end of range flexion, recent research (O'Sullivan et al., 2002), suggests these subjects are adopting a more 'passive' posture.

On average, the LBP subjects sat within 6° of their end of range spinal flexion. It is therefore likely that they are sitting with relative inactivity of their spinal stabilising muscles and towards their elastic zone of motion in spinal flexion. This hypothesis is supported by the association observed between reduced back muscle endurance and subjects sitting closer to the end range of spinal flexion. The findings of this study suggest that the measure of an individual's 'usual' spinal posture relative to their end of range may be a more significant factor than simply comparing spinal flexibility or posture. There have been no previous posture studies identified by the present authors which have investigated the relationship between LBP and sitting posture in relation to end of range lumbar spine position. This manner of measuring spinal posture gives an insight into the posturing of the lumbar spine relative to its elastic zone of motion, where stress within the passive structures increases (Scannell and McGill, 2003).

No significant differences in standing posture were detected between the groups. This is contrary to some previous studies (Itoi, 1991; Adams et al., 1999), but consistent with others (Battie et al., 1990; Raine and Twomey, 1994). There was a broad range of standing postures among the groups. Perhaps standing posture is not easily classified in the manner which we carried out, and thus may not be a predictor of LBP, as previous literature documents (Battie et al., 1990; Raine and Twomey, 1994). All LBP subjects in this study had pain associated with flexed spinal postures and activities, which did not involve upright standing or extension postures. Given this, it may be that extension postures of the lumbar spine, such as standing, may not be as relevant to flexion-related pain disorders.

There was no significant difference between the groups for standing lumbar flexion or lifting measures. These findings are consistent with other research (Raine and Twomey, 1994). The authors noted during testing that while performing the lifting measure, many of the subjects asked for directions regarding how to perform the lift, and some suggested that they would lift as they had been previously taught. Subjects in both groups equally adopted a variety of lifting postures including stooped (12), semi-squat (20) and full squat (13). It seems that the single lift measure used in this research setting was not sensitive enough to record 'usual' or 'habitual' lifting postures for these subjects. Future studies may require a different methodological model such as that described by McGill et al. (2003), to induce a 'usual' lifting/bending posture which subjects regularly employ in their natural work environment.

4.1. Clinical implications

It should be noted that the LBP subjects reported pain associated with flexion postures and activities of the spine and yet they sat closer to their end range of spinal flexion. These findings do not support theories of fear avoidance behaviour in this group (Indahl et al., 1998), but rather indicate that the group with flexion-related LBP habitually posture their spines in a potentially more pain provocative manner. Habitual end range loading of pain sensitive tissue may in turn further sensitise nociceptive tissue thereby maintaining a chronic pain state.

Consistent with these findings, McGill et al., (2003) reported that industrial workers with a history of back pain performed certain tasks that resulted in higher spinal load than subjects without LBP. Burnett et al. (2004), reported that cyclists with a flexion pain pattern presented with increased lower lumbar spine flexion and rotation and a loss of co-contraction of lumbar multifidus, that was associated with an increased (LBP) while cycling. O'Sullivan et al. (2003), reported that subjects with (LBP) with a flexion pain pattern had poor spinal repositioning sense within the neutral zone of spinal motion, with a tendency to position their spines closer to end range of spinal motion and away from neutral positions. This observed behaviour represents a possible mal-adaptive response to a pain disorder whereby a person adopts habitual spinal postures that in fact result in increased spinal tissue loading. This may represent a mechanism for ongoing tissue sensitisation and pain in these subjects. Further studies conducted in this population will be necessary to determine whether these factors correlate with altered spinal position sense both in sitting and in bending of the spine.

This study highlights the multi-factorial nature of LBP with associations detected between flexion-related (LBP), reduced trunk muscle endurance, passive sitting postures, physical inactivity and time spent sitting. It is not known whether these factors existed prior to and therefore pre-disposed to LBP in these subjects, or are a result of LBP in these subjects. Prospective studies are required to determine these factors.

4.2. Limitations

The results of this preliminary study cannot be generalised over a broader, or older population, nor other sub-groups of LBP given the small sample size used and the inclusion of LBP subjects with flexion-related injury and pain. Further research is currently being conducted in another LBP population to compare these findings with subjects with extension-related back pain to determine whether different physical characteristics are associated with different patterns of spinal pain provocation. A questionnaire was designed for this study to gain information regarding levels of physical activity and habitual postures (particularly sitting) over a range of locations, not just at work. We acknowledge that using a validated questionnaire would have been preferable, although we were unable to locate a questionnaire specific to the requirements of the study at the time. Although reliability and validity was shown in the measurement of spinal angles using photo-reflective markers, a more sensitive measurement tool may have provided greater accuracy and given greater understanding in terms of regional differences in flexibility across the lumbar spine. The results of this preliminary study suggest that some important physical characteristics in specific LBP sub-groups may be present, however further investigation with a larger sample size and more sensitive measures is required to allow generalisation of the results.

4.3. Conclusion

This study provides preliminary evidence that there is a relationship between reduced lumbar muscle endurance, habitually posturing the lumbar spine close to end range flexion in sitting, reduced levels of physical activity and time spent sitting, in industrial workers with LBP who present with flexion-related pain disorders. Further research investigating these relationships is warranted.

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