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Spinal Position Sense and Trunk Muscle Activity During Sitting and Standing in Nonspecific Chronic Low Back Pain

Classification Analysis

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Study Design. A cross-sectional study between subgroups of nonspecific chronic low back pain (NSCLBP) and asymptomatic controls.

Objective. To investigate NSCLBP subgroup differences in spinal position sense and trunk muscle activity when repositioning thoracic and lumbar spine into neutral (midrange) spinal position during sitting and standing.

Summary of Background Data. Patients with NSCLBP report aggravation of symptoms during sitting and standing. Impaired motor control in NSCLBP, associated with sitting and standing postures nearer the end range of spinal motion, may be a contributing factor. Rehabilitation improving neutral (midrange) spinal position control is advocated. Postural and motor control alterations vary in different NSCLBP subgroups, potentially requiring specific postural interventions. There is limited evidence on whether subgroup differences exist when performing neutral spine position tasks.

Methods. Ninety patients with NSCLBP and 35 asymptomatic controls were recruited. Two blinded practitioners classified NSCLBP into subgroups of active extension pattern and flexion pattern. Participants were assisted into neutral spine position and asked to reproduce this position 4 times. Absolute, variable, and constant errors were calculated. Three-dimensional thoracic and lumbar kinematics quantified the repositioning accuracy and surface electromyography assessed back and abdominal muscles activity bilaterally.

Results. Irrespective of subclassification, patients with NSCLBP produced significantly greater error magnitude and variability than the asymptomatic controls, but subgroup differences were detected in the error direction. Subgroup differences in the trunk muscle activity were not consistently identified. Although both subgroups produced significantly higher abdominal activity, subclassification revealed difference in superficial multifidus activity during standing, with flexion pattern producing significantly greater activity than the asymptomatic controls.

Conclusion. Subgroups of NSCLBP had similar neutral spinal position deficits regarding error magnitude and variability, but subclassification revealed clear subgroup differences in the direction of the deficit. The trunk muscle activation was shown to be largely nondiscriminatory between subgroups, with the exception of superficial lumbar multifidus.

Key words: nonspecific chronic low back pain, subclassification, thoracic and lumbar repositioning sense, trunk muscle activity.

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Low-back pain (LBP) is a highly prevalent and costly musculoskeletal pain syndrome,[1,2] associated with recurrence and chronicity.[3] Approximately 75% to 85% of cases are classified as nonspecific chronic low back pain (NSCLBP), with no detected evidence of pathoanatomical/radiological abnormality.[4]

From clinical observations, impaired motor control during sitting and standing, potentially leading to changes in spinal posture, has been proposed to contribute to LBP.[5,6] The evidence is inconsistent; some studies report sitting and standing to increase the risk for LBP[7–10] whereas other studies show no relationship.[11,12] Moreover, a recent systematic review revealed limited evidence for a causal link between spinal postures and back pain.[13] The reviewed studies were of poor methodological quality, however,[13] and included largely heterogeneous LBP samples, potentially contributing to a large variation in spinal postures and difficulty identifying differences compared with healthy population.

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Classifying NSCLBP on the basis of pain-provoking postures and movements, using a classification system developed by O'Sullivan,[6,14] revealed that compared with healthy controls, CLBP patients have altered spinal postures that vary between the subgroups[15,16] and are associated with subgroup-specific trunk muscle activity changes.[17] Specific CLBP populations also demonstrated reduced ability to adopt and/or maintain a neutral (midrange) position of the spine[18] and a tendency to adopt postures nearer the end range of spinal motion compared with controls.[5,10,19,20] Although the causal relationship is unclear, long-term exposure of the spinal viscoelastic tissues to sustained or cyclic mechanical loads of high frequencies and/or rates has been shown to trigger acute inflammatory response indicative of collagen microdamage[21,22] and neuromuscular dysfunction,[23,24] suggested to lead to chronic inflammation and cumulative back pain disorder.[25]

Postural rehabilitation to improve neutral (midrange) position awareness and control forms the basis of LBP management in clinical practice.[26,27] The NSCLBP subgroup variation in postures, however, led to recommendations that rehabilitation must reflect subgroup variation and must be matched to the specific impairment.[16,17,28]

To develop subgroup-specific postural rehabilitation, it is important to determine whether differences exist in how subgroups perform neutral spine position tasks. Adequate performance of posture tasks depends on accurate sensory and motor function.[29] Some evidence exists that individuals with LBP have reduced neutral spine position sense during sitting,[18,30] with an indication of a directional specificity in flexion-related LBP.[18] However, sensory and motor function during neutral spine positions has not yet been investigated in different positions, spinal regions, and other NSCLBP subgroups.

The aim of the study was to investigate whether thoracic and lumbar neutral spine position sense and trunk muscle activity differences exist during sitting and standing in NSCLBP when considered as a whole and subclassified.[31]

MATERIALS AND METHODS

Of 224 patients with CLBP, referred for physiotherapy at Cardiff and Vale University Health Board, Wales (UK), 92 met the selection criteria (Table 1) and consented to participate. Asymptomatic controls (n = 38; 22 female participants), matched for sex and age; no LBP (minimum 1 yr); and no vestibular, visual, and neurological condition affecting balance, were recruited. The South East Wales Research Ethics Committee and the Cardiff and Vale University Health Board Research Committee approved the study. Sample size was based on a power calculation of repositioning error data published previously.[32] A mean difference of 1.79° (common standard deviation of 2.68)[32] gave an effect size of 0.66. Assuming a power of 80% and alpha level of 0.05, this equated to a sample of 38 subjects per group.[33]

Modified visual analogue scale,[34] evaluating pain "on average," "at its worst and best" and accepted to be representative of CLBP,[34] assessed pain. The Roland-Morris Disability Questionnaire,[35] which is reliable in CLBP[36] and correlates with other disability questionnaires,[37,38] assessed disability.

TABLE 1. Inclusion and Exclusion Criteria for the Nonspecific Chronic Low Back Pain (NSCLBP) Group*

Inclusion criteria
LBP for a minimum of 12 weeks
Pain in the lumbar and buttock regions
Clear mechanical basis of disorder: specific postures and movements that aggravate and ease the symptoms, and symptom relief in movements opposite to provocation testing as determined by subjective and objective clinical examination
Clinical diagnosis of FP or AEP motor control impairment
Key clinical features of FP
Symptoms provoked with movements and postures involving flexion of lower lumbar spine
Symptoms eased by movements into spinal extension
Loss of segmental lordosis, difficulty of adopting and/or maintaining neutral spine posture, with tendency toward flexed lower lumbar spine
Key clinical features of AEP
Symptoms provoked with movements and postures involving extension of lower lumbar spine
Symptoms eased by movements into spinal flexion
Difficulty of adopting and/or maintaining neutral spine posture, with tendency toward hyperextension of lower lumbar spine
Exclusion criteria
Not fulfilling inclusion criteria
Red flags (specific causes of LBP, such as disc prolapse with radicular pain, inflammatory disease, or other serious pathology)
Dominant yellow flags (evidence of distress on Distress Risk Assessment Method)[31]
Pregnancy/breastfeeding
History of spinal surgery
Vestibular/visual/neurological dysfunction affecting balance
Not able to sit and/or stand from a stool unaided

**All inclusion criteria had to be satisfied based on O'Sullivan.[6,14]*

LBP indicates low back pain; FP, flexion pattern; AEP, active extension pattern.

SUBCLASSIFICATION

A validated O'Sullivan's classification system[6,14,39] was used to subclassify patients using a process of diagnostics described elsewhere.[40] It includes (1) subjective assessment of the disorder history, aggravating and easing activities, and (2) functional movement and accessory/physiological joint assessment

TABLE 2. Group Characteristics for the Asymptomatic Controls and Nonspecific Chronic Low Back Pain Patients With the FP and the AEP

	Controls (n = 35)	FP (n = 51)	AEP (n = 39)	Test Statistic
Sex (%)				
Men	13 (37.1%)	22 (43.1%)	9 (23.1%)	$P = 0.139$
Women	22 (62.9%)	29 (56.9%)	30 (76.9%)	
Age (SD) (yr)	36.0 (10.3)	33.0 (10.3)	37.0 (11.4)	$P = 0.316$
BMI (SD) (kg/m^2)	23.3 (2.2)	25.1 (3.6)	24.9 (3.8)	$P = 0.03$* FP *vs.* H* AEP *vs.* H AEP *vs.* FP
VAS (SD)	…	4.8 (1.3)	4.5 (1.4)	$P = 0.306$
RMDQ (SD)	…	7.3 (3.8)	6.2 (3.5)	$P = 0.177$

**Significant at $P < 0.05$.*

FP indicates flexion pattern; AEP, active extension pattern; BMI, body mass index; H, healthy; VAS, visual analogue scale; RMDQ, Roland-Morris Disability Questionnaire.

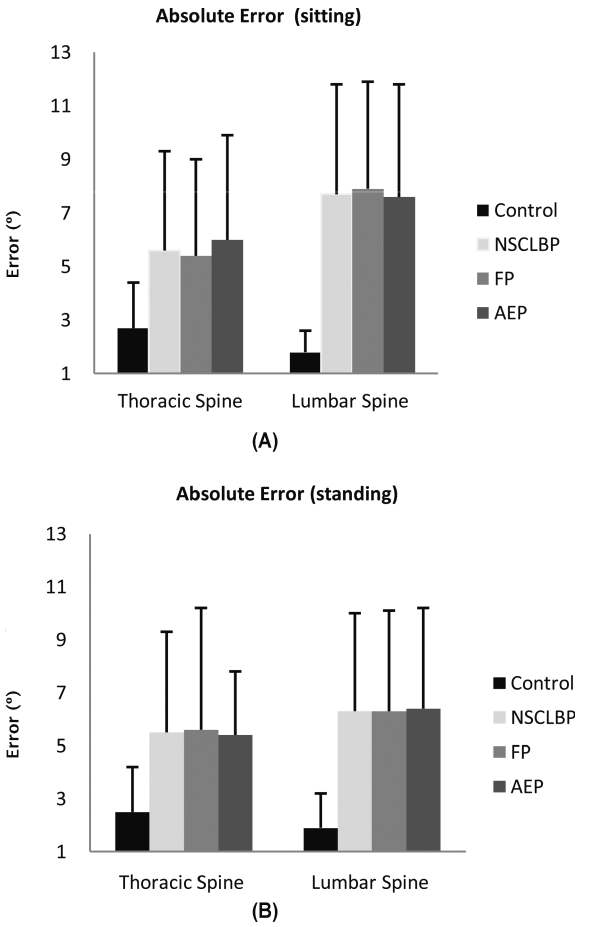

Figure 1. Absolute error during sitting (**A**) and standing (**B**) in asymptomatic controls, NSCLBP (subgroups combined), FP, and AEP subgroups. Error bars represent standard deviation. NSCLBP indicates nonspecific chronic low back pain; FP, flexion pattern; AEP, active extension pattern.

to determine the type and level of the impairment.[6,41] The functional movement assessment (forward/backward bending, sitting, standing, sit-to-stand, and a single leg stance) was video-recorded with 2 camcorders (posterior and sagittal views). Pain behavior and video data were used by 2 experienced physiotherapists (LS, VS) to subclassify. An identical classification process has been used previously,[15–17,42] demonstrating good interexaminer reliability.[42] Patients with clinical signs of a flexion pattern (FP) and an active extension pattern (AEP) (Table 1) were selected.

EXPERIMENTAL PROTOCOL

Testing was performed at the Research Centre for Clinical Kinaesiology, Cardiff University. Spinal position sense and trunk muscle activity were evaluated during participants' attempts to reproduce a target position of neutral lumbar lordosis and neutral thoracic kyphosis. The neutral spine position was defined as a thoracic and lumbar midrange position between end-range flexion and extension. Participants were blindfolded and wore loose clothing to minimize sensory cues.

Each participant was first seated on a fixed-height stool,[30] with feet positioned shoulder width apart and arms placed loosely on thighs. Participants were assisted in moving through their available range of spinal flexion and extension 3 times. They were then positioned by the researcher (LS) into a thoracic and lumbar neutral (midrange) position for 5 seconds and instructed to memorize it because they would be asked to reproduce it during the test trials.[18] Participants then relaxed into usual sitting for 5 seconds before being instructed to reproduce the target 4 times. In standing, participants first stood in a relaxed position with feet shoulder width apart. They were then assisted in moving through a full spinal flexion and extension 3 times before being positioned by the researcher (LS) into the neutral (midrange) standing position for 5 seconds and instructed to memorize this. Four repositioning tests with 5 seconds of relaxed standing between each trial were then performed. No feedback on the repositioning accuracy was provided. Synchronized recordings of the spinal kinematics and surface electromyogram (sEMG) were collected during each trial.

Spinal Kinematics

C7, T12, and S1 spinous processes were identified by the researcher (LS), checked by the physiotherapist (VS), and retro-reflective markers were affixed in relaxed sitting to limit the effect of displacement attributed to skin movement.[43] Thoracic and lumbar spines were measured using a 3-dimensional kinematic motion analysis system (VICON 512, VICON Motion Systems Ltd, Oxford, UK) that detected motion of the

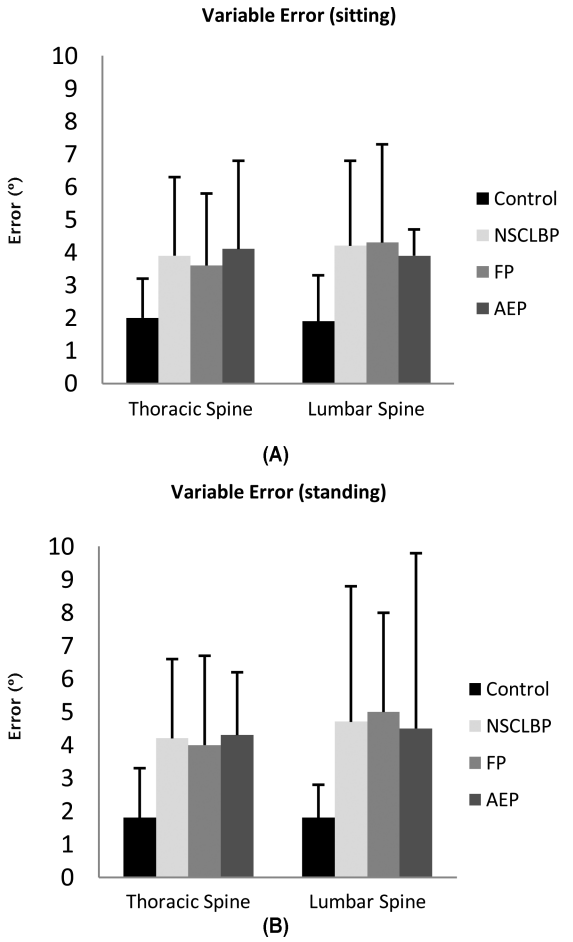

Figure 2. Variable error during sitting (**A**) and standing (**B**) in asymptomatic controls, NSCLBP (subgroups combined), FP, and AEP subgroups. Error bars represent standard deviation. NSCLBP indicates nonspecific chronic low back pain; FP, flexion pattern; AEP, active extension pattern.

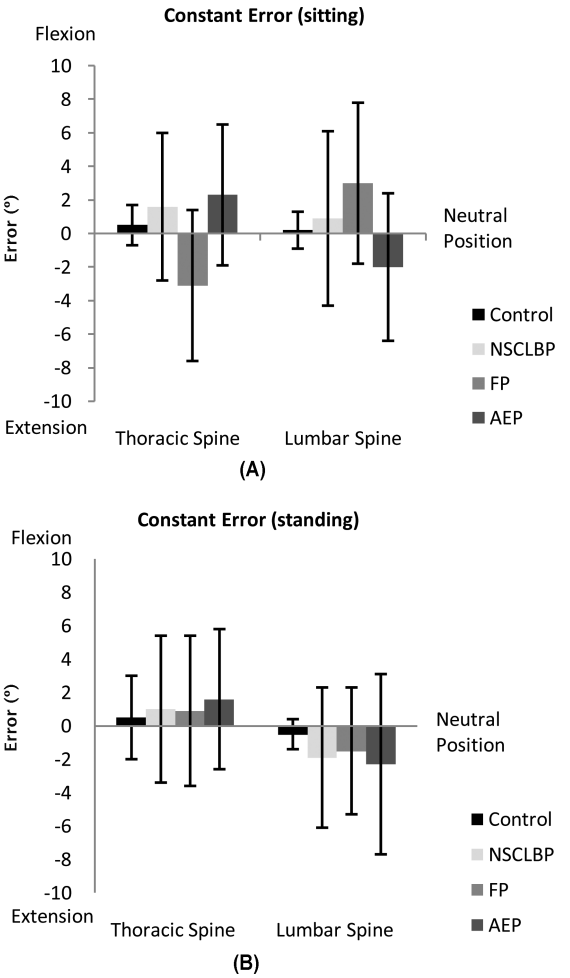

Figure 3. Constant error during sitting (**A**) and standing (**B**) in asymptomatic controls, NSCLBP (subgroups combined), FP, and AEP subgroups. Error bars represent standard deviation. NSCLBP indicates nonspecific chronic low back pain; FP, flexion pattern; AEP, active extension pattern.

Spinal Wheel, a hand-held device with a reflective marker in its center, which was guided along the spinal groove, to obtain the trace of the thoracic and lumbar curvatures. This method demonstrated excellent intratester reliability (intraclass correlation coefficient = 0.947–0.980) and acceptable measurement error (1.8°–3.7°).[44] In Matlab 7.0, the Spinal Wheel curvature was subdivided into 19 equidistant points, and an angle between the lines interconnecting the adjacent points was calculated. Positive values indicated flexion and negative values represented extension. The sum of 11 angles between T1 and T12 and 4 angles between L1 and L5 represented the thoracic and lumbar curvatures, respectively. Target and repositioning data were used to calculate absolute error (AE), representing error magnitude; variable error (VE), representing error consistency; and constant error (CE), representing error direction.

Trunk Muscle Activity

Eight-channel sEMG (Octopus Cable Telemetric System; Bortec Electronics Inc., Calgary, Alberta, Canada) recorded activity of left (L) and right (R) superficial lumbar multifidus (LM), iliocostalis lumborum pars thoracic (ICLT), external oblique (EO), and transverse fibers of internal oblique (TrIO). Standard electrode placement and skin preparation procedures were used, as reported elsewhere.[45] Trunk muscle activity was recorded on completion of each sitting and standing repositioning trial. Raw sEMG signals were preamplified with a fixed gain of 500, a common rejection ratio of 115 dB, and frequency response between 10 and 1000 Hz, visually inspected for heartbeat artifacts, full-wave rectified, and band pass filtered (0 phase lag, 20-Hz cutoff frequency), by using second-order Butterworth filter to generate a linear envelope for each channel. The sEMG amplitude was normalized using standardized movements that have been shown to produce stable submaximal voluntary contractions and excellent within- and between-day reliability in healthy and NSCLBP individuals.[45]

STATISTICAL ANALYSIS

Group differences for sex were assessed with χ^2 test, age, and body mass index (BMI) with 1-way analysis of variance, and independent *t* tests investigated pain (visual analogue scale)

TABLE 3. Group and Subgroup Means and Standard Deviations of the Repositioning Errors and sEMG Trunk Muscle Activity During Sitting and Standing

	Repositioning Errors (SD) (°)						Trunk Muscle (SD) sEMG (% Sub-MVC)			
	Absolute Error		Variable Error		Constant Error*					
	Th	L	Th	L	Th	L	LM	ICLT	TrIO	EO
Sitting										
Asymptomatic controls	2.7 (1.7)	1.8 (0.8)	2.0 (1.5)	1.9 (1.0)	0.5 (2.2)	0.2 (1.1)	11.5 (7.0)	11.3 (6.7)	21.7 (10.0)	17.7 (9.3)
NSCLBP	5.6 (3.7)	7.7 (4.1)	3.9 (2.4)	4.2 (2.6)	1.6 (6.2)	0.9 (7.7)	14.2 (8.6)	13.9 (7.9)	30.1 (15.5)	26.6 (12.6)
FP	5.4 (3.6)	7.9 (4.0)	3.6 (2.7)	4.3 (3.0)	–3.1 (4.9)	3.0 (6.9)	15.0 (8.5)	14.7 (8.4)	31.8 (15.2)	27.2 (12.2)
AEP	6.0 (3.9)	7.6 (4.2)	4.1 (2.2)	3.9 (1.8)	2.3 (7.2)	–2.0 (7.9)	13.1 (8.7)	12.9 (7.1)	29.8 (15.8)	25.7 (13.3)
Standing										
Asymptomatic controls	2.5 (1.7)	1.9 (1.3)	1.8 (1.2)	1.8 (1.4)	0.6 (2.5)	–0.5 (0.9)	14.6 (6.5)	13.2 (6.0)	32.8 (11.9)	23.0 (11.4)
NSCLBP	5.5 (3.8)	6.3 (3.7)	4.2 (2.4)	4.7 (4.1)	1.0 (4.4)	–1.9 (5.2)	18.9 (9.8)	14.1 (9.7)	40.8 (16.4)	32.5 (15.0)
FP	5.6 (4.6)	6.3 (3.8)	4.0 (1.9)	5.0 (5.3)	0.9 (4.5)	–1.5 (5.8)	20.3 (10.3)	15.8 (10.1)	41.7 (16.6)	33.3 (15.0)
AEP	5.4 (2.4)	6.4 (3.8)	4.3 (2.7)	4.5 (3.0)	1.6 (4.2)	–2.3 (4.4)	16.9 (8.8)	13.0 (9.1)	39.3 (15.9)	31.5 (15.2)

**Constant error positive value represents an underestimation of the neutral position target (relative flexion) and negative value represents an overestimation of the neutral position target (relative extension).*

sEMG indicates surface electromyography; % sub-MVC, percentage of submaximal voluntary contraction; Th, thoracic spine; L, lumbar spine; LM, superficial lumbar multifidus; ICLT, iliocostalis lumborum pars thoracis; TrIO, transverse fibers of internal oblique; EO, external oblique; NSCLBP, nonspecific chronic low back pain; FP, flexion pattern; AEP, active extension pattern.

and disability (Roland-Morris Disability Questionnaire) differences in NSCLBP subgroups. For the main analysis, independent *t* tests compared differences between the asymptomatic and NSCLBP (FP and AEP combined) groups. One-way analysis of variance with *post hoc* Bonferroni (AE, VE, and sEMG) and Games-Howell tests (normally distributed but unequal subgroup variance CE) compared differences among the asymptomatic, FP, and AEP groups. SPSS 14 (IBM, Chicago, IL) was used, with alpha level ($P = 0.05$) and *post hoc* comparisons ($P = 0.016$) to reflect the multiple comparisons (FP *vs.* AEP, asymptomatic *vs.* FP, and asymptomatic *vs.* AEP).

RESULTS

Five participants did not attend (3 asymptomatic and 2 NSCLBP), leaving 90 NSCLBP (FP = 51, AEP = 39) and 35 asymptomatic controls for the final analysis. There was no between-group difference in the group characteristics except for BMI ($P = 0.03$), with FP having higher BMI than the asymptomatic group (Table 2). The repositioning error means and standard deviations are presented in Table 3 and Figures 1 to 3, and the trunk muscle activity is presented in Table 3 and Figure 4. All group comparisons are detailed in Table 4.

Spinal Position Sense

The NSCLBP (combined and subclassified) group produced significantly greater AE and VE than the asymptomatic controls in the sitting and standing thoracic and lumbar spines, with no differences between the subgroups (Table 4). No difference was observed between NSCLBP (combined) and asymptomatic controls in thoracic and lumbar CE during sitting and standing. Only when the NSCLBP was subclassified were differences in CE apparent in the thoracic spine (sitting: $P = 0.001$) and lumbar spine (sitting: $P = 0.003$; standing: $P = 0.041$). In sitting, the FP underestimated the lumbar target and overestimated the thoracic target compared with AEP and asymptomatic groups ($P < 0.01$). Conversely, AEP overestimated the lumbar target and underestimated the thoracic target compared with FP ($P < 0.016$), but not reaching statistical significance compared with the asymptomatic group ($P > 0.016$). In standing, the only significant difference was in the lumbar spine where AEP overestimated the target position compared with the asymptomatic group ($P < 0.016$). There was no difference between subgroups in the thoracic spine during standing ($P > 0.016$).

Trunk Muscle Activity

Paired *t* test revealed no significant difference between L and R trunk muscles; therefore, the corresponding muscle data were averaged for the final analysis. Compared with the asymptomatic controls, the NSCLBP (FP and AEP combined) produced significantly higher TrIO and EO activity and comparable LM and ICLT activity during sitting and standing (Table 4). After subclassification, differences were apparent in LM during standing ($P < 0.017$), where FP produced

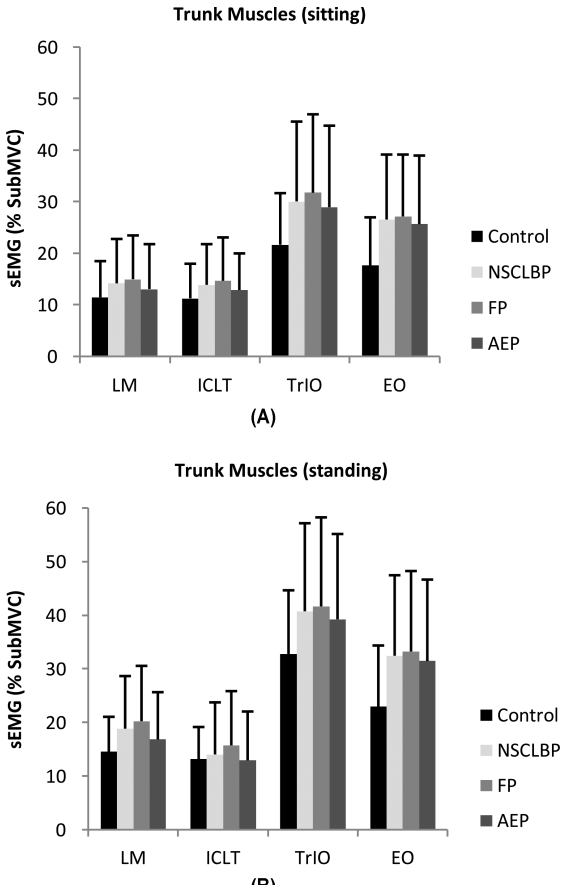

Figure 4. sEMG activity in LM, ICLT, TrIO, and EO during sitting (**A**) and standing (**B**) in asymptomatic controls, NSCLBP (subgroups combined), FP, and AEP subgroups. Error bars represent standard deviation. sEMG indicates surface electromyography; sub-MVC, submaximal voluntary contractions; LM, lumbar multifidus; ICLT, iliocostalis lumborum pars thoracis; TrIO, transverse fibers internal oblique; EO, external oblique; NSCLBP, nonspecific chronic low back pain; FP, flexion pattern; AEP, active extension pattern.

higher activity than the asymptomatic controls ($P < 0.016$), although a statistical significance was not reached between FP and AEP subgroups ($P > 0.016$). No subgroup differences were shown in TrIO and EO (sitting and standing), ICLT (sitting and standing), and LM (sitting).

DISCUSSION

Neutral spine position sense and trunk muscle activity were investigated in subgroups of NSCLBP. Subgroup differences were detected on basis of directional deviations from the neutral target in the thoracic spine (sitting) and the lumbar spine (sitting and standing) but not on the basis of error magnitude and variability. Trunk muscle activity was largely nondiscriminatory between subgroups. In accordance with previous research,[15–17] the detected subgroup differences in this study were lost when NSCLBP was treated as homogeneous, highlighting the importance of classification. The subgroup-specific directional deviation was reflected in the thoracic and the lumbar spines and was present during sitting in the FP and sitting and standing in the AEP subgroup.

Flexion Pattern

FP patients underestimated the lumbar target and overestimated the thoracic target adopting flatter lumbar lordosis and flatter thoracic kyphosis in sitting compared with AEP and asymptomatic controls. Similarly, O'Sullivan *et al*[18] demonstrated that patients with flexion-related LBP underestimated the neutral lumbar target compared with controls. Flexed sitting postures have also been demonstrated in FP subgroup of adolescents[15] and adults.[16] In this study, the FP subgroup flexion-biased deficit during sitting was not apparent during standing. This may be in keeping with the FP classification being characterized by patients reporting sitting as pain-provoking, whereas standing usually eases their pain.[41] FP produced significantly higher TrIO and EO (sitting and standing), LM (standing), and similar ICLT (sitting and standing) than the asymptomatic controls. This is in contrast with the study of Dankaerts *et al*,[17] in which adults with FP had lower activity in LM, ICLT, and TrIO than AEP and healthy controls, but in agreement with the study of Astfalck *et al*,[15] who found no differences in adolescents. Numerous factors affect muscle activity levels. Presence of spinal pain may alter muscle function.[46] In this study, patients reported mild pain during testing, making the influence of pain on these findings less. The higher BMI in FP subgroup unlikely affected the study results because the higher levels of subcutaneous fat levels would have decreased rather than increased sEMG amplitude.[47] The functional task evaluated may also influence muscle activity.[48] Unlike during static postures evaluated in the studies discussed earlier,[15,17] the active adjustment of the lumbar spine in this study may have been associated with substantial recruitment of LM,[49] particularly as in standing the FP subgroup overestimated the lumbar target.

Extension Pattern

In contrast with FP, the AEP group overestimated the lumbar target and underestimated the thoracic target, adopting greater lordotic/kyphotic postures than FP. Similarly, compared with FP and controls, postures of greater lordosis were demonstrated previously in AEP adolescents[15] and adults.[16] In this study, the AEP group significantly overestimated the standing lumbar target compared with the controls, which may be in line with AEP patients reporting standing as pain-provoking.[41] In this study, muscle activity in AEP was not different to the FP. In contrast, Dankaerts *et al*[17] demonstrated that AEP had higher trunk muscle activity than FP and controls, but they were in agreement with Astfalck *et al*,[15] who demonstrated no subgroup differences in adolescents. Clearly, motor patterns in NSCLBP are not yet fully understood and require further research. Moreover, in this study subtle adjustments around the neutral spine position may have led to low sEMG signals, arguably reducing the potential to detect differences.[50]

The FP and AEP subgroups demonstrated direction-specific neutral spine position deficits that coincided with abdominal muscle hyperactivity. It is unclear why the patients present in such a manner. Even small deviations from the neutral spine have been suggested to challenge the load-bearing capacity

TABLE 4. Results for the Repositioning Errors and sEMG Muscle Activity During Sitting and Standing

Sitting	Asymptomatic/NSCLBP (FP and AEP)		Asymptomatic/FP/AEP		
	t test		1-way ANOVA		
	t	*P*	$F_{2,122}$	*P*	*Post hoc* Tests
Absolute error					
Th	4.6	0.001*	10.78	0.001*	FP *vs.* H† AEP *vs.* H† AEP *vs.* FP
L	10.4	0.001*	54.55	0.001*	FP *vs.* H† AEP *vs.* H† AEP *vs.* FP
Variable error					
Th	3.18	0.002*	6.953	0.001*	FP *vs.* H† AEP *vs.* H† FP *vs.* AEP
L	5.21	0.001*	14.553	0.001*	FP *vs.* H† AEP vs. H† FP *vs.* AEP
Constant error					
Th	2.1	0.070	7.023	0.001*	FP *vs.* AEP† FP *vs.* H† AEP *vs.* H
L	0.842	0.402	6.030	0.003*	FP *vs.* AEP† FP *vs.* H† AEP *vs.* H
LM	1.54	0.126	1.686	0.190	…
ICLT	1.31	0.192	1.045	0.355	…
TrIO	2.93	0.004*	5.566	0.006*	FP *vs.* H† AEP *vs.* H† AEP *vs.* FP
EO	3.54	0.001*	6.324	0.002*	FP *vs.* H† AEP *vs.* H† AEP *vs.* FP
Standing					
Absolute error					
Th	4.6	0.001*	23.06	0.001*	FP vs. H† AEP *vs.* H† AEP *vs.* FP
L	10.3	0.001*	53.78	0.001*	FP *vs.* H† AEP *vs.* H† AEP *vs.* FP
Variable error					
Th	4.93	0.001*	12.182	0.001*	FP *vs.* H† AEP *vs.* H† FP *vs.* AEP
L	4.75	0.001*	11.850	0.001*	FP *vs.* H† AEP *vs.* H† FP *vs.* AEP

(*Continued*)

TABLE 4. (*Continued*)

	Asymptomatic/NSCLBP (FP and AEP)		Asymptomatic/FP/AEP		
	t test		1-way ANOVA		
Standing	*t*	*P*	$F_{2,122}$	*P*	*Post hoc* Tests
Constant error					
Th	1.90	0.060	1.742	0.179	…
L	–1.38	0.061	3.945	0.041‡	FP *vs.* AEP FP *vs.* H AEP *vs.* H†
LM	2.23	0.097	4.239	0.017‡	FP *vs.* H† AEP *vs.* H FP *vs.* AEP
ICLT	0.72	0.471	0.313	0.732	…
TrIO	2.16	0.033‡	3.056	0.050‡	FP *vs.* H† AEP *vs.* H† AEP *vs.* FP
EO	3.37	0.001*	5.705	0.004*	FP *vs.* H† AEP *vs.* H† AEP *vs.* FP

**Significant at $P < 0.01$.*

†Significant at $P < 0.016$.

‡Significant at $P < 0.05$.

NSCLBP indicates nonspecific chronic low back pain; FP, flexion pattern; AEP, active extension pattern; ANOVA, analysis of variance; Th, thoracic spine; L, lumbar spine; H, healthy; LM, superficial lumbar multifidus; ICLT, iliocostalis lumborum pars thoracis; TrIO, transverse fibers of internal oblique; EO, external oblique.

of the spinal tissues,[51] potentially increasing spinal tissue strain.[52] Direction-specific loading of already pain-sensitized tissues may exacerbate the disorder, potentially contributing to spinal degeneration.[25,41] Degeneration may in turn challenge the mechanical integrity of the spine forcing the trunk muscles to adopt stabilizing strategies.[52] Higher activation of antagonistically acting abdominal muscles in this study has been described previously as a functional adaptation with a purpose of maintaining spinal stability.[47] Nevertheless, prolonged increase of trunk muscle activity may be metabolically and mechanically costly,[53] potentially exacerbating LBP. Moreover, FP and AEP patients repositioned into the pain-provoking directions. The sensation of pain should arguably reinforce their desire to adopt postures away from the pain-provoking movement. This does not seem the case from this study results. It may be hypothesized that the repositioning deficit and abdominal muscle hyperactivity in FP and AEP patients in this study may be maladaptive not allowing them to deviate from the respectively flexed or extended postures, potentially perpetuating the pain disorder. Rehabilitation strategies normalizing these maladaptive patterns may therefore be warranted.[41]

Clinical Implications

The directional subgroup differences in the neutral spine position in this study may help guide specific interventions. Postural rehabilitation for FP may focus on regaining lumbar lordosis awareness and control, whereas AEP patients may benefit from regaining movement, awareness, and control in lumbar flexion.

Limitations and Future Research

Surface EMG has its limitations potentially introducing "cross talk" from the overlying muscles.[54] Fine-wire EMG would help overcome this and allow evaluation of other muscles, including deep multifidus, suggested to play a role in the control of spinal lordosis.[49] Investigation of muscle timing and ratios may help explore the complexity of the trunk muscle function in NSCLBP subgroups. The specific directional bias in FP and AEP also needs to be investigated throughout different functional tasks.

CONCLUSION

Subgroup differences in NSCLBP were detected in some but not all parameters of spinal control. Regardless of classification, both subgroups of NSCLBP demonstrated greater neutral spinal repositioning deficits in error magnitude and variability and higher abdominal activity compared with healthy controls. Back muscle activity was largely nondiscriminatory between the subgroups except for superficial LM. Clear subgroup differences were revealed when considering the direction of the repositioning deficit. These directional differences may guide specific interventions, highlighting the importance and clinical applicability of classifying patients with NSCLBP.

➢ Key Points

- ❑ Spinal position sense and trunk muscle activity when repositioning thoracic and lumbar spine into neutral (midrange) spinal position during sitting and standing were evaluated in subgroups of NSCLBP and asymptomatic controls.
- ❑ Subgroup differences were shown in some but not all parameters.
- ❑ Subgroups of NSCLBP can be detected on the basis of directional deviation of the repositioning error but not on the basis of error magnitude or variability.
- ❑ The subgroup differences in direction of error are apparent in the thoracic spine (sitting) as well as the lumbar spine (sitting and standing).
- ❑ Although both NSCLBP subgroups had significantly higher abdominal muscle activity compared with asymptomatic controls, the trunk muscle activity between the NSCLBP subgroups was largely non-discriminatory, with the exception of superficial lumbar multifidus during standing.

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