Evaluation of trunk acceleration in healthy individuals and those with low back pain

Augustine Aluko, Lorraine DeSouza, Janet Peacock

Aims: *The aim of this study was to investigate trunk acceleration as a measure of performance in both healthy individuals and those with low back pain (LBP). The study explored the difference in behaviour of trunk acceleration during flexion-extension movements between these two groups. This study investigated the test-retest reliability of the Lumbar Motion Monitor (LMM) using a single task protocol.*

Methods: *Trunk acceleration of a group of healthy participants (M=5, F=5) and a group of participants with LBP (M=4, F=6) was evaluated using the LMM. Two sets of measurements were obtained from participants performing trunk flexion-extension movements for 8 seconds. Each participant had a 10 minute rest period between measures. Data were analysed using a two-way mixed model for an intra-class correlation (ICC) analysis to investigate the reliability of the measure, and a Bland-Altman graph was used to demonstrate the levels of agreement between those repeated measures.*

Results: *The LBP group of participants demonstrated a slower three dimensional performance than the healthy group. The ICC for average sagittal acceleration (0.96, 95% confidence interval (CI) 0.90–0.98) and peak sagittal acceleration (0.89, 95% CI 0.75–0.96) with a 95% limit of agreement for the repeated measures of between -100.64 and +59.84 degrees/s^2 demonstrates the reliability of the measure. The higher ICC and its narrow confidence interval suggest that average rather than peak acceleration is more reliable. Within group measures for both the healthy and LBP groups demonstrated similar reliability for average acceleration (ICC 0.98, 95% CI 0.92–0.99) and for peak acceleration (healthy group ICC 0.94, CI 0.76–0.99; LBP group ICC 0.92, 95% CI 0.67–0.98).*

Conclusions: *Low back pain may reduce trunk acceleration. The LMM may be used to measure trunk acceleration as a descriptor of trunk performance in response to an onset of LBP. However, the Bland-Altman limits suggest that its reliability is dependent upon the harness upon which the LMM is secured remaining in a fixed position.*

Key words: ■ acceleration ■ kinematics ■ low back pain ■ lumbar motion monitor

Submitted 15 April, sent back for revisions 22 June; accepted for publication following double-blind peer review 31 August 2010

Augustine Aluko *is Lecturer in Physiotherapy and PhD student, School of Health Sciences and Social Care, Brunel University;* **Professor Lorraine DeSouza** *is Head of School and Professor of Rehabilitation, School of Health Sciences and Social Care, Brunel University, London; and* **Professor Janet Peacock** *is Professor, Public Health Sciences & Medical Statistics, University of Southampton, Southampton General Hospital, Southampton, UK*

Correspondence to: A Aluko
E-mail: toks.aluko@brunel.ac.uk

Low back pain (LBP) is a health burden (Koes et al, 2006) and a twentieth century health care enigma (Sieben et al, 2005). The incidence and prevalence of LBP has been widely documented (Croft et al, 1998; Campbell and Muncer 2005, Carragee et al, 2006; Cayea et al, 2006; Carreon et al, 2007; BackCare, 2007). Previous studies have investigated different strands of LBP; belief systems (Fullen et al, 2008), muscle pain and its affect on muscle activity and coordination (Graven-Nielson et al, 1997), the effects of manipulation (Assendelft et al, 2003; Bronfort et al, 2004; Ernst, 2007), the effect of loading on the spine (Callaghan et al, 1998), posture (Cholewicki et al, 2000), stabilization exercises (Ferriera et al, 2006) and management of onset (Hagen et al, 2002; Hagen et al, 2005; Gullick, 2008), but advances in knowledge have not made an impact on its prevalence, nor suggested a gold standard of intervention. A better understanding of underlying mechanisms occurring during an episode of LBP may therefore be useful for the clinical reasoning process required for effective and efficient intervention.

Flexion-extension movement of the trunk is a regular functional movement and is an integral component of the standard assessment protocol used to assess pain and disability caused by LBP (Petty, 2006). Quantification of this function is therefore both logical and beneficial for the development of practice. Previous work on the quantification of LBP has used various outcomes, such as pain and disability (Hagen et al, 2002; Hayden, 2005), range of movement (Marras and Wongsam, 1986; Kuukkanen and Malkia, 2000), palpation (Assendelft et al, 2003; Petty, 2006), muscle activation (Suzuki et al, 2002; van Dieen et al, 2003) and strength (Udermann et al, 2003). However, all these outcomes rely on subjectivity and could be influenced by bias (Altman, 1991; Hicks, 1998).

It has been suggested that objective measures of function are less susceptible to bias, and that trunk higher order kinematics (acceleration and velocity) are the most reliable objective measures as outcomes for the quantification of LBP (Kroemer et al, 1990). As a result, a wide array of objective methods for the quantification of LBP have been explored; video analysis (Wickstrom et al, 1996; Neumann et al, 2001; Chang et al, 2003; Trott and Fisher, 2005; Wong et al, 2007), EMG activity (Capodaglio et al, 1995; Oddsson et al, 1997; Chiou et al, 1999; Bonato et al, 2002; Pitcher et al, 2008), three dimensional (3D) motion analysis (Nakajima et al, 2007; Pazos et al, 2007) and the Lumbar Motion Monitor (LMM) (Marras and Wongsam, 1986; Ferguson et al, 2003; Ferguson and Marras, 2004).

The LMM is the most practical for use in the clinical environment because of its portability with minimal setup/labour time, and its ability to provide valid and reliable measures for the quantification of LBP (Marras and Wongsam, 1986; Marras et al, 1990; Marras, 1996). It is therefore proposed that the LMM can be used to efficiently and effectively quantify changes in trunk performance following treatment of an episode of non-specific LBP in a clinical environment.

The original protocol required for measurement with the LMM was intensive, because it required five tasks for evaluation. This protocol has been revised to require only one task (Ferguson and Marras, 2004) thereby increasing its practicality. The original five tasks consisted of flexion-extension movements in the sagittal plane, with 0º, 15º and 30º rotation to both the left and right. The revised protocol requires only one task of trunk movement in the sagittal plane, in the neutral position.

TABLE 1.
Descriptive statistics for the 20 participants

		Minimum	Maximum	Mean	Std Deviation
Healthy participants (*N*=10)	Weight (kgs)	54.5	99	71.2	14.4
	Age (yrs)	21	51	38.3	8.6
	Height (cms)	154	183	171.9	11.2
LBP participants (*N*=10)	Weight (kgs)	45	113	74.5	21.3
	Age (yrs)	20	44	31.7	7.5
	Height (cms)	157	191	171.3	12

Although the sensitivity and specificity of the LMM for this revised protocol was reported to be excellent, 90% and 92% respectively, (Ferguson and Marras, 2004) and comparable to the original protocol, its reliability and validity have not been reported. Furthermore, there is currently no evidence to suggest that this method of evaluation remains as good as when it was originally reported. This study was designed to evaluate the test-retest reliability of the LMM using this revised protocol.

Although it is proposed that the acceleration of the spine is reduced by LBP (Marras et al, 1993), this was a conclusion derived from the original protocol using five tasks. It is unclear whether a single task method would be as reliable. The test-retest reliability of the LMM using a single task protocol was therefore investigated.

METHODS

This study was approved by the School of Health Sciences & Social Care Ethics Committee at Brunel University, and Oxfordshire NREC ethics committee (Ref. 07/H0606/102). Participants were staff and students of Brunel University, and patients referred for treatment at the Musculoskeletal Physiotherapy Services, Hillingdon Community Health, in West London, UK. The study was over a 4 month period, commencing in September 2007. Participants were given the opportunity to read the participant information sheet and to ask any questions about the study, after which written informed consent was obtained. Anonymity and confidentiality were assured and all procedures were in accordance with guidance from the ethics committees.

Participants

Twenty participants were recruited by incidental sampling and classified into 2 groups on the basis of the presence or absence of non-specific LBP (*Table 1*). Participants with non-specific LBP with accompanying referred distal limb pain, paraesthesia or anaesthesia were excluded.

One group were healthy participants consisting of staff and students of Brunel University (M = 5, F = 5) with a mean age of 38.3 years (standard deviation (SD) 8.6). This group did not have a recent history of LBP, where recent history was defined as a period of 6 months. The other group of participants were patients referred for physiotherapy treatment for a current episode of LBP (M = 4, F = 6). This group had an mean age of 31.7 years (SD 7.5) with a mean onset of 5.7 weeks (SD 1.0), mean pain level of 2.9 (SD 2.3) on a visual analogue scale, and a Roland-Morris Disability Questionnaire demonstrated a mean disability score of 7.4 (SD 6.1). All participants within this group had experienced a previous episode of LBP, although the last episode was more than six months before the current episode.

Equipment

The Lumbar Motion Monitor (LMM) was used to collect 3D data of trunk performance in the sagittal, coronal, and transverse planes, simultaneously. The parameters of measure for the LMM are -35º to +65º in the sagittal plane and -45º to +45º in both the coronal and rotational planes. Its reliability and validity has been reported to be accurate to within plus or minus 0.25º, when using a 5 task evaluation method.

The equipment consists of a light weight exoskeleton within which are a set of potentiometers. The exoskeleton is connected, via an umbilical lead, to a laptop containing specialised software (Lumbar ProSoft 2.0, NexGen Ergonomics, Canada) for data analysis (*Figure 1*). The exoskeleton is positioned on the participant with a two-piece harness, one over the thorax, and the other over the pelvis; both secured in place with strapping. Potentiometers within the exoskeleton evaluate instantaneous position of the trunk in an analogue format. This information is transferred to the laptop, via the umbilical cord, where the information is converted to digital format by the programme software. Each channel of data is sampled at 60hz. The equipment has an accuracy of between plus and minus 0.25º degrees (Marras et al, 1990).

Procedure

Anthropometric measurements of height, weight and age of each participant were entered into the computer software program. With the exoskeleton in-situ within its holding case, the potentiometers were calibrated; a process which was repeated before measurement of each participant, and between tests. Suitable harnesses on which the exoskeleton was attached were selected and secured in place on the participant. The harnesses were secured as tightly as possible to avoid possible errors caused by unwanted movement.

Each participant was asked to stand with their feet shoulder width apart and their arms loosely folded across their chest (*Figure 1*). Each participant then performed flexion-extension movements in neutral (without rotation) in a sagittal plane as many times as they could within 8 seconds (s), without inducing pain or discomfort. None of the participants reported any pain or discomfort during or after testing. Time was measured with a Quantum stop watch (Model 2650, Physio Med Services Ltd). The participants were informed that the number of repetitions successfully completed within this period was more important than how far they could bend or extend their spine. No other encouragement or stimulus was provided. Two sets of data were collected with a 10 minute rest period between each test.

Figure 1. The Lumbar Motion Monitor.

TABLE 2.
Group comparison (acceleration)

		Sagittal acceleration (°/s^2)		Lateral acceleration (°/s^2)	(°/s^2)	Rotation acceleration	
		Average (SD)	**Peak (SD)**	**Average (SD)**	**Peak (SD)**	**Average (SD)**	**Peak (SD)**
Healthy	T1	215.86 (149.52)	627.06 (363.56)	42.63 (37.64)	175.50 (130.04)	20.82 (16.66)	88.88 (57.45)
	T2	253.86 (160.00)	674.51 (298.89)	33.62 (21.42)	130.40 (90.15)	28.58 (21.03)	106.56 (71.09)
LBP	T1	148.82 (103.06)	426.44 (177.33)	31.74 (17.90)	129.06 (60.58)	15.50 (7.30)	61.94 (24.33)
	T2	151.61 (114.34)	416.88 (208.27)	30.29 (22.29)	131.38 (79.31)	16.15 (11.48)	67.06 (34.91)

LBP = low back pain; T = time; SD = standard deviation

STATISTICS

Reliability was assessed using two measures – the two-way mixed model of intra-class correlation coefficient, which indicates the proportion of the total variance that is due to the variance between subjects alone, and the Bland-Altman method, which estimates the actual size of difference between repeated observations in the same subjects. Analyses were conducted using SPSS (version 15).

RESULTS

The LBP group demonstrated slower acceleration compared with the healthy participants within all planes of movement during both tests 1 and 2 (*Table 2*). The healthy participants demonstrated increases in both average and peak acceleration in both the sagittal and transverse planes, but a reduction in the coronal plane. This behaviour was not replicated by the LBP group. This group demonstrated a reduction in peak acceleration in the sagittal plane and an increase in peak acceleration in both the coronal and transverse planes.

Two-way mixed intra-class correlation analysis of all the participants and participants grouped on the basis of the presence of LBP suggests that measures of sagittal average acceleration and peak acceleration have a high degree of reliability (*Table 3*). However, it is suggested that average sagittal acceleration of all the participants is the most reliable (ICC 0.96, 95% CI 0.90–0.98) of the two measures as an outcome, because of the higher value and narrow confidence interval. Within group measures for both the healthy and LBP groups demonstrated similar reliability for average acceleration (0.98, 95% CI 0.92–0.99), and for peak acceleration (healthy group 0.94, CI 0.76–0.99; LBP group 0.92, 95% CI 0.67–0.98). The Bland-Altman plot for average acceleration for all the participants demonstrates the levels of agreement of the repeated measure (*Figure 2*).

TABLE 3.
Reliability statistics for each kinematic variable

Kinematic variable (°/s2)	Differences in the mean (SD)	Intra-class correlation coefficient	(95% CI)
Average Sagittal Acceleration	20.4 (40.1)	0.96	0.90-0.98
Average Lateral Acceleration	5.2 (19.1)	0.72	0.42-0.88
Average Rotation Acceleration	4.2 (9.1)	0.83	0.62-0.93
Peak Sagittal Acceleration	19.1 (133.6)	0.89	0.75-0.96
Peak Lateral Acceleration	21.9 (62.1)	0.77	0.51-0.90
Peak Rotation Acceleration	11.4 (30.4)	0.83	0.62-0.93

SD = standard deviation; CI = confidence interval

Only average sagittal acceleration of the participants was considered because testing did not involve maximum effort of the participants, and the revised protocol used movement within the sagittal plane only.

DISCUSSION

The evidence suggests that the average acceleration of the trunk in the sagittal plane is the most reliable outcome measure compared with the other planes of movement. It is therefore proposed that measures within this plane alone are sufficient to be used as an outcome measure, either for the quantification of levels of impairment due to an onset of LBP, or following intervention.

The results of this study suggest that the revised protocol, with a reduction in the number of tasks required for evaluation, maintains acceptable levels of reliability. This method for quantification of LBP could therefore be made more accessible in a clinical environment. To the authors' knowledge there has been no evaluation of the levels of agreement for the reliability of using the LMM for the quantification of trunk movement prior to this study, using either a protocol of 5 tasks of flexion-extension in various degrees of

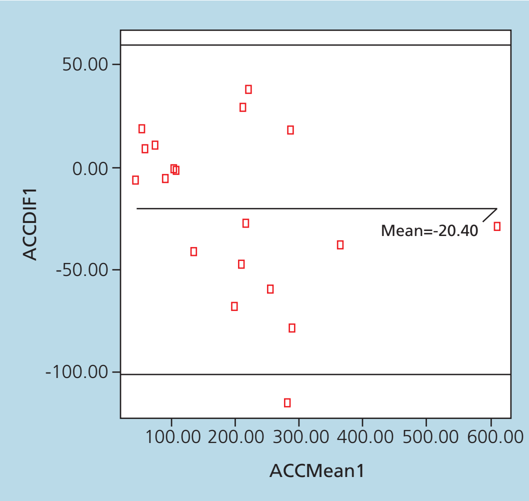

Figure 2. Bland-Altman plot showing the 95% limits of agreement for average sagittal acceleration (°/s^2).

rotation or using the single task in the neutral position. The evidence presented not only demonstrates the reliability of the LMM for measuring trunk acceleration, but also demonstrates the level of agreement of the measures (*Figure* 2).

A successful argument demonstrating effectiveness of intervention may depend upon the ability to provide objective measures of evaluation. Previous studies have proposed kinematic evaluation of the trunk as a method by which the objectivity for the assessment of LBP can be enhanced (Marras and Wongsam, 1986; Kroemer et al, 1990). Although the LMM has been reported to be valid (Marras and Wongsam, 1986; Gill and Callaghan, 1996; Marras, 1996) and reliable (Ferguson, Gallagher et al. 2003), the original protocol was labour intensive and time consuming. It is possible that it is for this reason the equipment has not been more widely used in a clinical environment. The single task evaluation may improve its popularity.

Although there have been studies investigating trunk velocity whilst performing various activities (Cox et al, 2000; Marras et al, 2000; McGregor and Hughes 2000, Pollock et al, 2009), there is paucity of literature that explores the behaviour of acceleration. Acceleration, the rate of change in velocity, is important because anecdotal evidence suggests that a significant level of pain is produced either when initiating or completing changes in trunk position.

The LBP group demonstrated slower acceleration compared with the healthy group, supporting previous findings that acceleration is reduced by LBP (Marras et al, 1993). The reduction in this cohort of participants may be explained as the inability for this group to coordinate co-contraction of the trunk musculature to facilitate movement (McGill et al, 2003). Although it may be proposed that the healthy group can develop 'learning processes', by which repeated measures demonstrate increases in acceleration, it appears from this study that the LBP group are not able to replicate this process. Although both groups of participants were able to demonstrate increases in average sagittal acceleration and rotational acceleration with a reduction in average lateral acceleration, the healthy group demonstrated larger changes. It could therefore be suggested that as the trunk is moved through flexion/extension within the sagittal plane, there is a need to regulate movement in the sagittal plane by reducing the tendency towards lateral flexion (*Table* 2). The inability of the LBP group to do this sufficiently may be because this particular group presented with unilateral conditions that favour movement in a direction of least resistance (McKenzie, 1981). Closer scrutiny of medical records, however, would be required to determine the accuracy of this assertion.

Although the healthy group demonstrated a possible 'learning process', this was shown with only one repeated measure. Further investigation is required to see if this can be demonstrated with a series of repeated measures, possibly over a period of time. However, this ability may influence the outcome of intervention during recovery in LBP patients. The results suggest that as the LBP group recovers there should be a corresponding increase in acceleration. The repetition of the measure within the asymptomatic group does demonstrate this possibility. This may account for the lack of evidence to suggest differences in effectiveness between different types of exercise intervention for the treatment of LBP (Hayden et al, 2005; Mannion et al, 2001).

Low levels of pain and disability have been shown to be present from three to at least 12 months after an acute episode of LBP (Pengel et al, 2003). It has been proposed that this may be due to instability of the trunk and the effectiveness of spinal stability. The spinal stability system (Panjabi, 1994) relies on the ability to accelerate efficiently through ranges of displacement, it is therefore plausible that inconsistent acceleration may result in the low levels of pain and disability that have been reported (Pengel et al, 2003). This may be a mechanism by which acute LBP becomes recurring or chronic.

Maintaining trunk balance requires efficient muscle co-ordination (Cholewicki et al, 2000). It is proposed that an inability to respond efficiently to changes in trunk position predisposes the trunk structures to stress and strain. Increases in acceleration observed in the healthy group may demonstrate an ability to respond to changes in trunk position quickly. The relative low increases in acceleration in the symptomatic group could be perceived to be as a result of subjective inhibition of effort but this is unlikely because the LMM is highly sensitive to levels of sincere effort (Ferguson et al, 2003).

Traditionally LBP has been categorised as either acute or chronic depending upon the length of time during which an episode of LBP has been active (Frank, 1993), but the behaviour of acceleration within the two groups as demonstrated by this study suggests that there may be a requirement for a volte-face of the way in which LBP is categorised. The historical time span commonly used as a benchmark for either category (BackCare, 2007) may no longer be fit for purpose. A more informative description of higher order kinematic variables of the trunk may be a more suitable descriptor, particularly because the ability to accelerate is dependent upon the speed of muscle activation to produce movement. However, it has been demonstrated that the sequence of muscle activation is inhibited by LBP (Hodges and Richardson, 1996; Hodges and Richardson, 1997; Barr et al, 2005; Barr et al, 2007). This may be the mechanism by which the symptomatic group in this study were unable to increase trunk acceleration with repeated measure.

It is not possible, in this study, to demonstrate a credible correlation between acceleration and age, weight or height, and further study is required to explore any relationship. However, the data presented does suggest that during an onset of LBP, changes in acceleration of the spine can be considered to be a reliable measure, irrespective of the changes in those anthropometric values during the period of intervention. A potential limitation of the study, however, is the small sample size, which may impact on the validity of the results. Further research involving a larger sample is required to enhance the interpretation of the results. A further limitation may be that being pain free for 6 months does not suggest normal muscle/strength if the healthy participants have a previous history of LBP, and further work is required to investigate if the results can be replicated with a longer pain free period.

CONCLUSION

This study demonstrated that the LMM is a reliable tool for measuring the rate of change of velocity of the trunk in the sagittal plane. Although the LMM demonstrated reliable results, its reliability is dependent upon the harness being secure to prevent movement. The results are comparable with the findings of previous studies, but, for the first time, also demonstrate levels of agreement between repeated measures for average acceleration. The healthy participants demonstrated higher acceleration measures than the LBP group and were able to demonstrate greater increases in acceleration during test-retest that the LBP cohort could not replicate. IJTR

Conflict of interest: none

Acknowledgements: The authors would like to thank Dr Ivy Man for her encouragement during this project, and also thank the Musculoskeletal Physiotherapy Services, Hillingdon Community Health, who assisted with the recruitment process, and all the participants who volunteered to take part in this study.

Altman DG (1991) *Practical statistics for medical research*. 1st edn. Chapman & Hall, London

Assendelft W, Morton SC, Yu EI, Suttorp MJ, Shekelle PG (2003) Spinal manipulative therapy for low back pain: A meta-analysis of effectiveness relative to other therapies. *Ann Intern Med* **138**(11): 871

Backcare (2007) *Back Facts*. Online.http://tinyurl.com/34lvh78 (accessed 13 December 2010)

Barr KP, Griggs M, Cadby T (2005) Lumbar stabilization: core concepts and current literature, Part 1. *Am J Phys Med Rehabil* **84**(6): 473–80

Barr KP, Griggs M, Cadby T (2007) Lumbar stabilization: a review of core concepts and current literature, part 2. *Am J Phys Med Rehabil* **86**(1): 72–80

Bonato P, Boissy P, Croce UD, Roy SH (2002) Changes in the surface EMG signal and the biomechanics of motion during a repetitive lifting task. *IEEE Trans Neural Syst Rehabil Eng* **10**(1): 38–47

Bronfort G, Haas M, Evans RL, Bouter LM (2004) Efficacy of spinal manipulation and mobilization for low back pain and neck pain: a systematic review and best evidence synthesis. *Spine J* **4**(3): 335–56

Callaghan JP, Gunning JL, McGill SM (1998) The relationship between lumbar spine load and muscle activity during extensor exercises. *Phys Ther* **78**(1): 8–18

Campbell C, Muncer SJ (2005) The causes of low back

KEY POINTS

- Low back pain may reduce trunk acceleration.
- Sagittal trunk acceleration is a reliable measure of trunk performance.
- The Lumbar Motion Monitor can be used effectively to quantify trunk performance.

pain: a network analysis. *Soc Sci Med* **60**(2): 409–19
Capodaglio P, Nilsson J, Jurisic DH (1995) Changes in paravertebral EMG spectrum parallel to strength increases after rehabilitation in chronic low back pain patients. *Clin Rehabil* **9**(4): 354–62
Carragee E, Alamin T, Cheng I, Franklin T, Van den Haak E, Hurwitz E (2006) Are first-time episodes of serious LBP associated with new MRI findings? *Spine J* **6**(6): 624–35
Carreon LY, Djurasovic M, Glassman SD, Sailer P (2007) Diagnostic accuracy and reliability of fine-cut CT scans with reconstructions to determine the status of instrumented posterolateral fusion with surgical exploration as reference standard. *Spine (Phila Pa 1976)* **32**(8): 892–5
Cayea D, Perera S, Weiner DK (2006) Chronic low back pain in older adults: What physicians know, what they think they know, and what they should be taught. *J Am Geriatr Soc* **54**(11): 1772–7
Chang CC, Hsiang S, Dempsey PG, McGorry RW (2003) A computerized video coding system for biomechanical analysis of lifting tasks. *International Journal of Industrial Ergonomics* **32**(4): 239–50
Chiou WK, Lee YH, Chen WJ (1999) Use of the surface EMG coactivational pattern for functional evaluation of trunk muscles in subjects with and without low back pain. *International Journal of Industrial Ergonomics* **23**(1-2): 51–60
Choleeicki J, Polzhofer GK, Radebold A (2000) Postural control of trunk during unstable sitting. *J Biomech* **33**(12): 1733–7
Cox ME, Asselin S, Gracovetsky SA, Richards MP, Newman NM, Karakusevic V, Zhong L, Fogel JN (2000)Relationship between functional evaluation measures and self-assessment in nonacute low back pain. *Spine* **25**(14): 1817
Croft PR, MacFarlane GJ, Papageorgiou AC, Thomas E, Silman AJ (1998) Outcome of Low Back Pain in General Practice. *BMJ* **316**(7141): 1356–9
Ernst E (2007) Adverse effects of spinal manipulation: a systematic review. *J R Soc Med* **100**(7): 330–8
Ferguson SA, Gallagher S, Marras WS (2003) Validity and reliability of sincerity test for dynamic trunk motions. *Disabil Rehabil* **25**(4/5): 236-41
Ferguson SA, Marras WS (2004) Revised protocol for the kinematic assessment of impairment. *Spine J* **4**(2): 163–9
Ferriera PH, Ferriera ML, Maher CG, Herbert RD, Refshauge K (2006) Specific stabilisation exercise for spinal and pelvic pain: A systematic review. *Aust J Physiother* **52**(2): 79–88
Frank A (1993) Regular Review: Low Back Pain. *BMJ* **306**(6882): 901–9
Fullen BM, Baxter GD, O'Donovan BGG, Doody C, Daly L, Hurley DA (2008) Doctors' attitudes and beliefs regarding acute low back pain management: A systematic review. *Pain* **136**(3): 388–98
Gill KP, Callaghan MJ (1996) Intratester and intertester reporoducibility of the lumbar motion monitor as a measure of range, velocity and acceleration of the thoracolumbar spine. *Clin Biomech (Bristol, Avon)* **11**(7): 418–421
Graven-Nielson T, Svensson P, Arendt-Nielson L (1997) Effects of experimental muscle pain on muscle activity and co-ordination during static and dynamic motor function. *Electroencephalogr Clin Neurophysiol* **105**(2): 156–64
Gullick DW (2008) Acute non-specific back pain management in the emergency setting: A review of the literature. *Australasian Emergency Nursing Journal* **11**(1): 13–19
Hagen KB, Hilde G, Jamvedt G, Winnem MF (2005) Bed rest for acute low-back pain and sciatica. *Cochrane Database Syst Rev* **18**(4): CD001254
Hagen KB, Hilde G, Jamvedt G, Winnem MF (2002) The Cochrane review of advice to stay active as a single treatment for low back pain and sciatica. *Spine (Phila Pa 1976)* **27**(16): 1736–41
Hayden JA, Van Tulder MW, Malmivaara AV, Koes BW (2005) Meta-analysis: Exercise therapy for non-specific low back pain. *Annals of Internal Medicine* **142**(9): 765
Hicks CM (1998) *Practical Research Methods for Physiotherapists.* Churchill Livingstone, London
Hodges P, Richardson C (1997) Contraction of the abdominal muscles associated with movement of the lower limb. *Phys Ther* **77**(2): 132–42
Hodges P, Richardson C (1996) Inefficient muscular stabilization of the lumbar spine associated with low back pain. A motor control evaluation of transversus abdominis. *Spine (Phila Pa 1976)* **21**(22): 2640–50
Koes BW, Van Tulder MW, Thomas S (2006) Diagnosis and treatment of low back pain. *BMJ* **332**(7555): 1430–4
Kroemer KHE, Marras WS, McGlothlin DR, Nordin M (1990) Towards understanding human dynamic motor performance. *Industrial Ergonomics Journal* **6:** 199
Kuukkanen T, Malkia E (2000) Effects of a three month therapeutic exercise programme on flexibility in subjects with low back pain. *Physiother Res Intl* **5**(1): 46–61
Mannion AF, Muntener M, Taimela S, Dvorak J (2001) Comparison of three active therapies for chronic low back pain: results of a randomised clinical trial with one year follow up. *Rheumatology (Oxford)* **40**(7): 772–8
Marras WS (1996) Quantification of motion characteristics in low back disorders. *Journal of Rehabilitation Research and Development* **33:** 186
Marras WS, Ferguson SA, Simon SR (1990) Three dimensional dynamic motor performance of the normal trunk. *International Journal of Industrial Ergonomics* **6**(3): 211–224
Marras WS, Parnianpour M, Ferguson S, Kim J, Crowell R. Simon S (1993) Vienna Physical Medicine Award 1993. Quantification and classification of low back disorders based on trunk motion. *Eur J Phy Med* **3:** 218
Marras WS, Wongsam PE (1986) Flexibility and velocity of the normal and impaired lumbar spine. *Arch Phys Med Rehabil* **67**(4): 213–7
Marras WS, Lewis KE, K, Ferguson SA, Parnianpour M (2000) Impairment Magnification During Dynamic Trunk Motions. *Spine (Phila Pa 1976)* **25**(5): 587–95
McGill SM, Grenier S, Kavcic N, Cholewicki J (2003) Coordination of muscle activity to assure stability of the lumbar spine. *J Electromyogr Kinesiol* **13**(4): 353–9
McGregor AH, Hughes SF (2000) The effect of test speed on the motion characteristics of the lumbar spine during an A-P flexion-extension test. *J Back Musculoskeletal Res* **3**(14): 99–104
McKenzie RA (1981) *The Lumbar Spine: Mechanical Diagnosis and Therapy.* Spinal Publications, New Zealand
Nakajima A, Kawakami N, Imagama S, Tsuji T, Goto M, Ohara T (2007) Three-dimensional analysis of formation failure in congenital scoliosis. *Spine (Phila Pa 1976)* **32**(5): 562–7
Neumann WP, Wells RP, Norman RW, Kerr Frank J, Shannon HS (2001) Trunk posture: reliability, accuracy, and risk estimates for low back pain from a video based assessment method. *International Journal of Industrial Ergonomics* **28**(6): 355–66
Oddsson LI, Giphart JE, Buijs RJ, Roy SH, Taylor HP,

Luca CJ (1997) Development of new protocols and analysis procedures for the assessment of LBP by surface EMG techniques. *Journal of Rehabilitation Research and Development* **34**(4): 415–26
Panjabi MM (1994) Lumbar Spine Instability: A biochemical challenge. *Current Orthopaedics* **8:** 100
Pazos V, Cheriet F, Danserau J, Ronsky J, Zernicke RF, Labelle H (2007) Reliability of trunk shape measurements based on 3-D surface reconstructions. *European Spine Journal* **16**(11): –91
Pengel LHM, Herbert RD, Maher CG, Refshauge KM (2003) Acute low back pain: systematic review of its prognosis. *BMJ* **327**(7410): 323
Petty NJ (2006) *Neuromusculoskeletal Examination and Assessment: A handbook for Therapists.* 3rd edn. Churchill Livingstone, London
Pitcher MJ, Behm DG, MacKinnon SN (2008) Reliability of electromyographic and force measures during prone isometric back extension in subjects with and without low back pain. *Appl Physiol Nutr Met* **33**(1): 52–60
Pollock CL, Jenkyn TR, Jones IC, Ivanova TD, Garland SJ (2009) Electromyography and kinematics of the trunk during rowing in elite female rowers. *Medicine and science in sports and exercise* **41**(3): 628–36
Sieben JM, Vlaeyen JWS, Portegijs PJM, Verbunt JA, Van Riet-Rutgers S, Kester ADM, Von Korff M, Arntz A, Knottnerus JA (2005) A longitudinal study on the predictive validity of the fear-avoidance model in low back pain. *Pain* **117:** 162
Suzuki H, Conwit RA, Stashuk D, Santarsiero L, Metter EJ (2002) Relationship between surface detected EMG signals and motor unit activation. *Medicine and Science in Sports and Exercise* **1**(9): 1509
Trott M, Fisher K (2005) Using Video Assessment for Clients with Chronic Low Back Pain: is it Reliable? *British Journal of Occupational Therapy* **68**(12): 538–44
Udermann BE, Mayer JM, Graves JE, Murray SR (2003) Quantitative assessment of lumbar paraspinal muscle endurance. *Journal of Athletic Training* **38**(3): 259
Van Dieen JH, Selen LPJ, Cholewicki J (2003) Trunk muscle activation in low back pain patients, an analysis of the literature. *Journal of Electromyography and Kinesiology* **13:** 333
Wickstrom G, Laine M, Pentti J, Hyytiainen K, Salminen JJ (1996) A video-based method for evaluation of low-back load in long-cycle jobs. *Ergonomics* **39**(6): 826–41
Wong WY, Wong, Lo, KH (2007) Clinical applications of sensors for human posture and movement analysis: A review. *Prosthetics and orthotics international* **31**(1): 62–75

COMMENTARY

The assessment and appropriate management of low back pain (LBP) continues to be a challenge for clinicians, and one way of investigating this problem is to compare people with LBP with those who do not have LBP. Many studies have investigated a variety of outcomes measures, including muscle recruitment, and there is a consistent finding among many recent studies that people with LBP had delayed reactions and poorer motor control when compared with a control group with no LBP (Radebold et al, 2000; Hodges, 2001; Hungerford et al, 2003; van Dieën et al, 2003; Silfies et al, 2005; Luomajoki et al, 2008; Silfies et al, 2009). Outcome measures that can assess aspects of motor control in a clinical setting may therefore be a valuable asset in evaluating and managing LBP.

This study

Effective spinal stability requires appropriate muscle recruitment and timing (Borghuis et al, 2008) – elements of motor control. One component of motor control is movement of the trunk, and this can be difficult to assess in an objective and reliable way. This study proposes using a lumbar motion monitor as an aid to clinical assessment of LBP by measuring trunk acceleration. The authors found that the monitor was a reliable method of measuring trunk acceleration in the sagittal plane and that there were differences in trunk acceleration between those with and without LBP.

> “A reliable and clinically applicable tool that can help quantify deficits in aspects of motor control may be a useful guide for clinicians.”

The authors also suggest that using a historical time span to categorise LBP into acute, sub-acute and chronic, 'may not be fit for purpose' as kinematic variables may be more relevant to categorising and subsequently managing LBP. This viewpoint is gaining credence as current research into the sub-grouping of LBP is moving from using these time-line based labels into more function-based categories. Further research into the validity and reliability of techniques and modalities that help assess function, will be useful, especially in a clinical setting.

Conclusions

Assessment of motor control can be a challenge for clinicians, especially in terms of using valid and reliable outcome measures. A reliable and clinically applicable tool that can help quantify deficits in aspects of motor control may be a useful guide for clinicians. Perhaps the next step in the use of movement monitors, is to determine clinical relevant parameters that can be used to guide management?

Borghuis J, Hof AL, Lemmink KA (2008) The importance of sensory-motor control in providing core stability: Implications for measurement and training. *Sports Med* **38**(11): 893–916
Hodges PW (2001) Changes in motor planning of feedforward postural responses of the trunk muscles in low back pain. *Exp Brain Res* **141**(2): 261–6
Hungerford B, Gilleard W, Hodges P (2003) Evidence of altered lumbopelvic muscle recruitment in the presence of sacroiliac joint pain. *Spine (Phila Pa 1976)* **28**(14): 1593–600
Luomajoki H, Kool J, de Bruin ED, Airaksinen O (2008) Movement control tests of the low back; Evaluation of the difference between patients with low back pain and healthy controls. *BMC Musculoskelet Disord* **9**: 170
Radebold A, Cholewicki J, Panjabi MM, Patel TC (2000) Muscle response pattern to sudden trunk loading in healthy individuals and in patients with chronic low back pain. *Spine (Phila Pa 1976)* **25**(8): 947–54
Silfies SP, Squillante D, Maurer P, Westcott S, Karduna AR (2005) Trunk muscle recruitment patterns in specific chronic low back pain populations. *Clin Biomech (Bristol, Avon)* **20**(5): 465–73
Silfies SP, Mehta R, Smith SS, Karduna AR (2009) Differences in feedforward trunk muscle activity in subgroups of patients with mechanical low back pain. *Arch Phys Med Rehabil* **90**(7): 1159–69
van Dieën JH, Cholewicki J, Radebold A(2003) Trunk muscle recruitment patterns in patients with low back pain enhance the stability of the lumbar spine. *Spine (Phila Pa 1976)* **28**(8): 834–41

Iseult Wilson PhD
Lecturer in Physiotherapy,
School of Health Sciences,
University of Ulster, Ulster,
Northern Ireland
I.Wilson@ulster.ac.uk