LOW BACK PAIN AND SICKNESS ABSENCE AMONG SEDENTARY WORKERS: THE INFLUENCE OF LUMBAR SAGITTAL MOVEMENT CHARACTERISTICS AND PSYCHOSOCIAL FACTORS

JAMIE ALAN BELL

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ABSTRACT

LOW BACK PAIN AND SICKNESS ABSENCE AMONG SEDENTARY WORKERS: THE INFLUENCE OF LUMBAR SAGITTAL MOVEMENT CHARACTERISTICS AND PSYCHOSOCIAL FACTORS

Introduction:
Low back pain remains a burden for society, since it can lead to sickness absence and work disability. Physical occupational risk factors can contribute to the development of back pain, yet little is known about any risks in sedentary jobs posed by sitting. The influence of psychosocial factors on back pain and sickness absence amongst sedentary workers is also unclear. The aim of this study was to measure work activities, lumbar movement characteristics, symptoms and psychosocial factors in order to determine associations with low back pain and sickness absence.

Methods:
Phase 1: involved validation of a fibre-optic goniometer system that attaches to the lumbar spine and hip to continuously measure: (1) activities (sitting, standing, walking); and (2) lumbar movement characteristics (notably sitting postures and kinematics). New questionnaires were also validated to measure aspects of low back discomfort.
Phase 2: consisted of a cross-sectional survey of call centre workers (n=600) to collect data on: demographics, clinical and occupational psychosocial factors, and symptoms. An experimental sample (n=140) wore the goniometer system during work.
Phase 3: involved a 6-month follow-up survey to collect back pain and sickness absence data (n=367). Logistic regression was used to determine associations ($P<0.05$) between data.

Results:
Workers spent 83% of work-time sitting, 26% of which was spent adopting a lordotic lumbar posture. Current back pain (>24hrs: yes/no) was associated with a kyphotic sitting posture (time spent with a lumbar curve ≥180°) (R^2 0.05), although future back pain was not. Using multivariable models: limited variety of lumbar movement whilst sitting was associated with future (persistent) LBP, dominating other variables (R^2 0.11); yet high levels of reported back discomfort, physical aggravating factors and psychological demand at work were stronger predictors of sickness absence, and dominated other variables (R^2 0.24).

Interpretation:
Workers do not follow the advice from employers to maintain a lumbar lordosis whilst sitting, as recommended by statutory bodies. Furthermore, sitting with a kyphotic posture did not increase the risk of back pain, although a relative lack of lumbar movement did. Thus, ergonomic advice encouraging lumbar movement-in-sitting appears to be justified. Predictors of sickness absence were multi-factorial, and consideration of work-relevant biomedical and psychosocial factors would be more useful than adopting more narrow screening approaches.

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Chapter 1

Epidemiological overview of adult low back pain

1.1) Introduction

Low back pain (LBP) is a term used to describe a range of painful mechanical disorders afflicting the lumbar spine, associated with varying degrees of disability. Experience of LBP ranges from discomfort to severe pain, and may manifest as an everyday occurrence, recurrent episodic phenomena, or isolated discrete episode (Mason, 1994; Croft et al, 1998). The socio-economic impact of this problem on Western industrialised countries is substantial (Maniadakis and Gray, 2000), although the pathology responsible for LBP cannot be identified in the majority of cases. Those afflicted tend to reach a pain free state, irrespective of whether or not they receive treatment (Hutton et al, 2000; Pengel et al, 2003). Therefore, most researchers have moved away from searching for a structural (treatable) cause for LBP, adopting a biopsychosocial view. This approach is supported by evidence that physical factors can explain the onset of symptoms (Burton, 1997), with psychosocial factors influencing the subsequent course of recovery (Simmonds et al, 1996; Pincus et al, 2002). Understanding these factors could help to reduce the risk of LBP, subsequent disability and work loss (Burton, 1997). At present, little appears to be known about the physical (biomechanical) risks for LBP in sedentary jobs, or the influence of psychosocial factors on sickness absence due to LBP.

The following chapter reports on the epidemiology of LBP in general and working populations; risk determinants for LBP; and the course of LBP (including the progression to disability). Psychosocial risk factors associated with LBP and the epidemiology of sickness absence due to LBP are also presented.

1.2) Epidemiology of low back pain in general and working populations

Epidemiology is the study of how often a disease or symptom occurs in a specific population and why. Evidence about LBP is available from official resources (e.g. Department of Health), longitudinal and cross-sectional surveys, although critical appraisal of these data requires caution, due to varied research designs. Several epidemiological terms are relevant to understanding the LBP literature. *Incidence* is the percentage of a known population who develop new symptoms who were initially free of symptoms during a specific time period (Rothman, 1986). *Prevalence* is the proportion of people in a defined population who have symptoms at a specific time (point prevalence), or within a stated period of time (period prevalence). Thus, lifetime prevalence is the percentage of people who experience symptoms at some point in their life (Loney and Stratford, 1999).

In the UK, a cross-sectional survey of the general population (7699 adults) with prospective follow-up has shown LBP to have a 1 month prevalence of 39%, and a lifetime prevalence of 58% (Papageorgiou et al, 1995). Mason (1994) and Hillman et al (1996) found a similar lifetime prevalence of 58% and 59% respectively, and also reported the point (14% and 19%) and one year (37% and 39%) prevalence of LBP. The Department of Health (1999) reported similar 1 year prevalence (40%), and found that females in the youngest and oldest age groups were more likely to report LBP than their male counterparts. However, for the age range 45-54 years, males reported substantially more LBP than females (51% compared with 43%). Young adults (aged 16-24 years) reported the lowest prevalence of LBP, although 33% had still experienced some LBP. The highest prevalence was reported in the older working age groups (45-54 and 55-64 years). These findings are broadly similar to the results of a systematic review that included studies from Europe and America (Loney and Stratford, 1999). This review found that the peak prevalence of LBP is somewhere between 40-60 years of age, beyond which prevalence declines.

Based on the epidemiological literature, Palmer et al (2000) has questioned whether or not there has been an increase in LBP prevalence. However, the majority of epidemiological surveys would suggest that there has been no increase in the prevalence of LBP, which has remained fairly constant (Omnibus Surveys, 1993, 1998; Lebouef-Yde and Lauritsen, 1995). Reasons for the disparity in prevalence rates between some studies appear to stem from methodological differences, and the absence of a standardised definition for LBP (Walker, 2000). However, even when prevalence rates between studies are similar, these may not be accurate. Measuring the period prevalence of LBP is often unreliable, because the ability to recall pain diminishes with time (Deyo and Tsui-Wu, 1987). Based on anamnestic data this bias can be as high as 27%, leading to an underestimation of prevalence (Svensson and Andersson, 1982). Measurement of point prevalence is also limited, because LBP is often intermittent, increasing the likelihood of underestimating its frequency (Papageorgiou et al, 1995). Further complexity arises when establishing if the onset of LBP represents a new case, or a recurrence of a previous condition. Children and adolescents are known to report a prevalence almost as high as that of adults, although adults readily fail to recall this experience (Burton, 1996). Therefore, accurate determination of LBP incidence and prevalence rates in adults is difficult (Loney and Stratford, 1999).

Focused studies of working populations have found particularly high prevalence rates of LBP among agricultural workers; carpenters; drivers; nurses; cleaners; and domestic assistants (De Beeck and Hermans, 2000). Sedentary workers, however, are known to have a similar prevalence of LBP to that found in the general population (Burdorf et al, 1993; Omokhodion and Sanya, 2004; Spyropoulos et al, 2007). Much of the literature considers 'occupational LBP' as quite separate to the symptoms experienced by the general population, although this view has been challenged (Waddell and Burton, 2001). Indeed, the experience of symptoms at work (rather than at leisure) may be purely coincidental, and the physical demands of work are only thought to account for a modest proportion of the LBP occurring in workers (Waddell and Burton, 2001). Thus LBP may be considered 'occupational', but only in the sense that it is common in adults of working age and may present as an occupational health problem. At individual level, difficulty measuring exposure to the physical aspects of work means that the work-relatedness of reported LBP is highly subjective, and this has impaired research investigations

1.3) Risk determinants and indicators for low back pain

Prior to considering workplace hazards and the influence of risk determinants, it is necessary to first consider what is meant by these terms. A hazard has the potential to do harm (HSE, 2000), whilst risk determinants dictate the probability of someone coming to harm (Susser, 1991). Determinants can be either negative or positive, and depending on their effect, they are referred to as risk or protective factors (Rothman, 1986). Therefore, these factors increase and reduce the likelihood of developing LBP. Many studies have investigated so called 'risk factors' for LBP, but have adopting a cross-sectional rather than a prospective design. This has enabled associations to be described, but not assessment of cause and effect. An association means that the probability of the occurrence of one variable depends on one or more other variables, and this relationship maybe causal or non-causal (Susser, 1991). LBP is known to have a multifactorial origin, dependent on the interrelationships between variables. Thus, even if a strong association is demonstrated for one variable and is thought to be causal, this may not be the case. Factors may require the additive presence of another variable to exert their effects, although this variable may be unknown or unmeasured (Rothman, 1986). This has led to the development of the term 'risk indicator' (Susser, 1991), which is often used interchangeably with 'risk factor' within the literature.

1.4) Sedentary occupational risk factors associated with low back pain

The onset of LBP can be explained, in part, by exposure to biomechanical risk factors, some of which may be present in the workplace. Epidemiologists have established their importance in industrial and health care settings (Smedley et al, 1998; Hoogendoorn et al, 2000), although little is known about the biomechanical risk factors for LBP in sedentary jobs. This section will critically evaluate the risk posed by exposure to prolonged sitting at work (including lumbar postures).

Since the year 2000, the number of workers employed in sedentary occupations that involve sitting (e.g. call centre work) has steadily grown (Datamonitor, 2005). These workers spend at least 75% of work-time sitting, sometimes for up to eight hours per day (Hildebrandt et al, 2000). This has heightened concern that prolonged sitting may increase the risk of LBP (Gonzales et al, 2005). Epidemiologists have traditionally linked occupations that involve sitting with LBP (Kelsey, 1975; Magora, 1975), and aspects of sitting continue to be regarded by some as a risk factor for LBP (Phillips et al, 1996; Pynt et al, 2008). However, this view contradicts recent systematic reviews of the literature (Hartvigsen et al, 2000; Lis et al, 2007).

Hartvigsen et al (2000) aimed to determine if sitting at work was associated with LBP. Studies published between 1985 and 1997 were included, and thirty five reports were located. Only eight had a satisfactory experimental design, and all but one study failed to find a positive association. Furthermore, the authors found that all but three of the studies were cross-sectional, and hypothesised that these were probably subject to the healthy worker effect (due to workers with LBP in heavy jobs ending up in a sedentary job). This is known to produce higher prevalence rates for LBP, thus making the results even more remarkable given the lack of association. It was concluded that the literature does not support the view that sitting at work is associated with LBP. A more recent review by Lis et al (2007) also failed to find any association between sitting at work and LBP, although co-exposure to whole body vibration and awkward postures were each independently associated with LBP.

Despite these findings, the Health and Safety Executive imply that prolonged sitting at work can lead to LBP (HELA, 2006). The European Agency for Safety and Health at work have a more definite view, citing a *clear* link between prolonged sitting and self-reported LBP (Flaspoler et al, 2005). These views are not supported by the epidemiological evidence, although the conclusions of studies included in systematic reviews may be flawed due to methodological limitations; exposure to sitting has been measured using subjective and non-comparable methods such as job descriptions and self-reported questionnaires. These tools are not sensitive enough to quantify exposure to biomechanical factors (e.g. lumbar postures) in sitting (Neumann et al, 2001). Consequently, the ability of studies to identify associations between aspects of sitting at work and LBP may be reduced. Therefore, new risk assessment techniques need to be developed in order to objectively measure ‘exposure’ to sitting (Gonzales et al, 2005). Whilst existing measures such as video cameras and activity monitors might help to provide a more objective measure of sitting during work, they are unable to measure lumbar sitting postures. This may explain why exposure to sitting *per se* does not appear to be hazardous (Hartvigsen et al, 2000; Lis et al, 2007), although adopting particular postures might increase the risk of LBP.

To date, only cross-sectional studies appear to have been used to investigate the relationship between lumbar sitting postures and LBP. Williams et al (1990) compared the effects of two lumbar sagittal sitting postures (over 24-48 hours) on back pain intensity. Patients experiencing current LBP (n=209) were asked to sit in a lordotic posture (facilitated by a lumbar roll) and a flexed posture (facilitated by a cushion). The lordotic posture was associated with less pain than the flexed posture (*P<0.05*). A more recent study by Dankaerts et al (2006) measured the lumbar sagittal posture (using electromagnetic sensors placed over T12, L3 and S2) of asymptomatic (n=34) and chronic LBP patients (n=33) during unsupported and slumped sitting. Data were collected for three trials of 5 seconds each, and no significant differences were found between control and patient groups. However, analyses based on sub-classification revealed that patients classified with an active extension pattern were found to sit more lordotic, whereas patients with a flexion pattern sat more kyphotic, when compared with healthy controls (*P<0.001*). Womersley and May (2006) measured the relaxed lumbar sitting posture of students who did (n=9) and did not (n=9) report backache when sitting over a 10 minute period. Skin markers were placed on T12, L3 and L5, and a video camera was used to record posture. This footage was downloaded onto software that enabled digital points to be superimposed over the skin markers, allowing the angle between T12, L3 and L5 to be measured. The group with backache were found to sit significantly more flexed than the no backache group (*P<0.05*).

Vergara and Page (2002) measured the lumbar postures of healthy subjects (n=6) with a goniometer (placed inside a strap worn over the spinous processes) after 25 minutes of sitting with: (1) erect; (2) flexed; and (3) maximum flexed postures. Back discomfort was also measured, and the results indicated that sitting with a more lordotic posture increased low back discomfort. Subjects who moved regularly also had greater levels of discomfort, suggesting that movement may take place to alleviate discomfort, a finding that was also found by Liao and Drury (2000). In contrast, in their review Looze et al (2003) found five studies that measured the relationship between discomfort, posture or movement-in-sitting, none finding statistically significant relationships.

Critical consideration of studies that have attempted to measure the association between sitting and LBP suggests that research designs have been hampered by: (1) the lack of a standardised definition for LBP symptoms experienced whilst sitting, and (2) the inability to continuously measure exposure to lumbar sitting postures in non-experimental settings. Therefore, at present there is a lack of robust epidemiological evidence to support an association between lumbar sitting postures at work and LBP.

1.5) Physical activity during leisure time: association with low back pain

Whilst activity is advocated during an acute episode of LBP, and has been shown to be associated with less disability and less time off work than rest (Waddell et al, 1997; Van Tulder et al, 2000), its effects on pre-existing dormant LBP are unknown. Physical activity outside of work could either protect against or increase the risk of LBP at work (Abenhaim et al, 2000). Nourbakhsh et al (2001) evaluated the effects of leisure activity on LBP, and the occurrence of symptoms was significantly lower in subjects who exercised regularly. However, sedentary workload and activity was self-reported, and for studying exposure-effect relationships is not valid (Viikari-Juntari et al, 1996). Studies have also reported no association between LBP and leisure activity (Rossignol et al, 1993; Kuaja et al, 1996; Croft et al, 1999). Campello et al (1996) concluded that studies do support the hypothesis that general exercise protects against LBP. Another systematic review has also found that inactivity during leisure-time is associated with a high prevalence of LBP, and related sickness absence among sedentary workers (Hildebrandt et al, 2000). Overall, the use of surveys, lack of prospective follow-up, and absence of standardised definitions for ‘sedentary work’ and ‘leisure activity’ limits the literature. General and sporting activity have also not been regarded as factors that may infer separate levels of risk, these being contained under the term ‘leisure activity’ (Jacob et al, 2004).

Some objective measures of activity have been used, and Spenkelink et al (2002) used a Dynaport ADL monitor to measure differences in leisure activity between patients with chronic LBP (n=47), and asymptomatic controls (n=10). The results indicated that patients spent significantly more time lying down and less time walking than controls ($P<0.05$). Verbunt et al (2001) used tri-axial accelerometers on chronic LBP patients (n=13) and a pain free sample (n=13). Contrary to the findings of Spenkelink et al (2002), results indicated that the chronic group did not have significantly reduced levels of physical activity. Unfortunately, no evidence was provided to confirm the reliability of this measurement tool, and confidence in both studies is questionable due to their small sample sizes.

1.6) The course of low back pain

Episodes of LBP have traditionally been classified as acute (<6 days), subacute (7 days to 6 weeks) and chronic (>6 weeks) (CSAG, 1994). Many studies continue to use these cut-off points, although the epidemiological evidence suggests that the frequency of episodes over long periods of time, rather than current episode length, better describes the problem of LBP (Croft et al, 1997). A systematic review of prognostic factors for the course of LBP has shown that 75%-90% of acute episodes presenting in General Practice improve within 6 weeks (Pengel et al, 2003). However, although after 6 weeks most patients ceased to consult their doctor and had returned to work, the majority continued to experience LBP. Croft et al (1998) conducted a prospective study and found that 75% of patients had persistent LBP at one year. Burton et al (2004) also found that during a four year follow-up study of adults attending an Osteopathic practice, recurrence was reported by 78% of respondents, with half seeking further care. Therefore, it is axiomatic that LBP is a recurrent, intermittent and episodic lifetime phenomenon for the majority of people afflicted (Croft et al, 1998; Adams et al, 2002).

Despite its high prevalence, only a small proportion (1%) of individuals with persistent or recurrent LBP will become permanently disabled, and this represents a significant cost to society (Waddell et al, 2003). Work loss is widely regarded as the single most important measure of low back disability (Spitzer et al, 1987), and whilst chronic LBP (pain >12 weeks) and disability may be related, not all individuals with persistent pain are disabled, and many choose to remain in work (Kuijer et al, 2006). Therefore, understanding the transition from an acute episode of LBP through to chronic pain and perhaps disability has proven to be complex. The use of widely varying definitions for LBP chronicity and disability makes understanding the literature difficult. There is, however, now some consensus that chronicity is “symptom persistence >12 weeks” (Andersson, 1999; Pincus et al, 2002). In contrast, disability is quite different to pain, and is essentially restricted functioning (Waddell and Burton, 2004).

Up to 90% of individuals with disabling LBP have been shown to have pain in multiple (two or more) regions (Taylor and Curran, 1985), although relatively few studies have measured this ‘co-morbidity’. Thomas et al (1999) have demonstrated the importance of widespread symptoms; pain above and below the waist on both sides of the body was associated with a six-fold increase in disabling LBP. Hestbaek et al (2003) also found that LBP and its co-morbidities cluster in certain individuals. However, co-existing symptoms are often an incidental finding, and little is known about their relationship to LBP and disability.

Regardless of the location of symptoms, time is fundamental to the development of chronic pain and disability (Waddell et al, 2003), and biopsychosocial changes are thought to influence future progress and obstruct recovery (Main, 2000). Addressing the problem of LBP associated disability therefore requires critical appreciation of the Pain theory (see section 4.2) and the biopsychosocial model (see section 5.3), although the influence of psychosocial factors are thought to be more important than any underlying biological problem (Waddell and Burton, 2004).

1.7) Psychosocial risk factors associated with low back pain

The term ‘psychosocial factors’ is non-specific and will be used in this thesis, as it is in many studies, to encompass both psychological and social concepts. It is widely accepted that psychosocial factors better explain the behavioural consequences of LBP than its causes (Hartvigsen et al, 2004). Nonetheless, there is some evidence that psychosocial factors can explain a small proportion (up to 3%) of new onsets of LBP (Mannion et al, 1996; Papageorgiou et al, 1997). There is stronger evidence that they predict reporting of LBP and care-seeking (Bigos et al, 1991; Croft et al, 1996).

Epidemiological studies have shown that the majority of people remain at work despite their symptoms (Walker, 2000; Pengel et al, 2003), and most episodes of LBP will recover (at least enough to return to normal activities). Therefore, it seems logical to ask: why do some people with LBP not recover as expected? (Waddell and Burton, 2005). The development of disability is thought to be influenced partly by psychosocial factors, and many of these can also be ‘obstacles to recovery’ (Main and Burton, 2000; Waddell and Burton, 2001). Clinical psychosocial risk factors are essentially psychological parameters (distress and fear avoidance beliefs), whilst occupational psychosocial risk factors relate to individual perceptions about work (job dissatisfaction, poor social support, high psychological demand, and causal attributions). The influence of these factors on clinical and work-related outcomes will now be considered, although a more in-depth critique of their interrelationships and role within a biopsychosocial (overarching) framework is discussed in sections 5.3 and 5.5.

Clinical psychosocial risk factors

Distress is an abnormal stress response in which psychological and physical symptoms occur. Measuring this response has been problematic for researchers, since tools have been unable to differentiate between psychological distress, depressive symptoms and depressive mood. Pincus et al (2002) have suggested that the term 'psychological distress' can be used as a composite of these parameters. This systematic review focused on identifying predictors at an early stage (defined as <3 weeks) and found strong evidence for the role of psychological distress as a risk factor for the development of chronicity (persistent symptoms and/or disability). The effect size was moderate, and findings were generally consistent across different environments (primary care, clinics, workplace). Similar findings have also been reported by previous reviews (Linton, 2000; Truchon and Fillion, 2000).

The cognitive model of fear of movement/(re)injury explains how individuals who believe that activity will aggravate their pain will expect/fear more pain if they are active (Vlaeyen and Crombez, 1999). This model was based on early research by Waddell (1993) who developed the Fear Avoidance Beliefs Questionnaire (FABQ); in a 1 year retrospective study beliefs about work explained a substantial amount of the variance in disability and work loss. Fritz et al (2001) also demonstrated that fear avoidance beliefs about work (amongst subjects with LBP <3 weeks duration) predicted work status at 4 weeks, even after controlling for pain intensity. These findings have led to the notion that 'fear' plays an integral part in the avoidance of activity and the transition from acute LBP to disability (Crombez et al, 1999). However, a study by Burton et al (1995) found that the FABQ did not significantly predict future disability (measured using the Roland Morris Disability Questionnaire) in a multivariate model, thus indicating that it did not contain unique predictive qualities independent of other psychological measures in the model. This therefore suggests that fear avoidance beliefs may not be particularly influential when considered alongside other factors. Despite being integral to clinical models of disability, few prospective studies have measured fear avoidance beliefs. A recent systematic review found little evidence for fear avoidance as a strong risk factor for poor outcome (persisting symptoms and/or disability) both at 3 and 12-months; 6 of 9 studies failed to show a statistically significant link (or showed only a weak link) (Pincus et al, 2006).

Occupational psychosocial risk factors

Williams et al (1998) have suggested that high satisfaction with one's job may help to prevent disability following an acute episode of LBP. In this study, baseline job satisfaction was associated with less disability (measured using: Sickness Impact Profile, Quality of Well Being Questionnaire) at 6-month follow-up. Conversely, research has also found that job satisfaction is not related to absenteeism (Symonds et al, 1996). A more recent evidence based review has concluded that low job satisfaction is related to work loss (Waddell and Burton, 2001), although the size of this association was modest. Other reviews of the literature have also confirmed these findings (Turk, 1997; Truchon and Fillion, 2000; Linton, 2001). Linton and Warg (1993) have suggested that whilst it is assumed that LBP causes job dissatisfaction, job satisfaction may also influence perceptions about the cause of LBP, which may have a more powerful influence on work loss. This highlights a common methodological limitation present in the literature; few authors have measured multiple occupational psychosocial risk factors together, and so are unable to determine which are most influential to work-related outcomes.

Social support is purported to be an important factor in preventing sickness absence from work, since this acts as a coping resource, or a "social fund" from which people may draw when necessary (Thoits, 1995; Byrns et al 2002), helping to 'buffer' against the negative effects of stress (Ingledew et al, 1997). Amongst different occupational groups, low levels of social support at work have been found to predict the occurrence (Van den Heuvel et al, 2004; Burton et al, 2005; Ijzelenberg and Burdorf, 2005), and duration of sickness absence (Hemmingway et al, 1997; Tubach et al, 2002; Morken et al, 2003). In contrast, a systematic review of the epidemiological literature has failed to find any association between social support at work and sickness absence (Hartvigsen et al, 2004). Therefore, the role of social support in predicting absence appears to be unclear.

The concept of psychological demand relates to part of Karasek's Job Demand-Control model (Karasek, 1979), and was originally used in the study of cardiovascular disease. In an occupational health context, this model suggests that the interaction between perceived job demands and work control can be used to predict strain, when there are high levels of job demands and low levels of control over these demands. When high levels of control and demand exist, the job is described as 'active', meaning that the demands are challenging, rather than a source of stress. For LBP, there is insufficient evidence of control exerting a positive 'buffering' effect over psychological demand (Bongers et al, 1993; Hemmingway et al, 1997). Furthermore, a systematic review found only four studies that measured psychological demand, none finding a significant association with different work outcomes; return to work, >3 days absence, retirement, and sick leave (<8 days, > 8 days) (Hartvigsen et al, 2004).

Research suggests that some 66% of British workers with back pain believe that it was caused by their work (Hodgson et al, 1993). A cross-sectional study by Linton and Warg (1993) also found that a history of back pain was associated with increased attribution of cause related to the work environment. In contrast, DeGood and Kiernan (1996) found that patients who blamed their employer for their LBP had similar levels of pain and disability to those patients who did not. However, considering the results of studies from a range of different occupational groups shows that blaming work is associated with work loss (Burton et al, 1996; Symonds et al, 1996; Nordin, 1997; Burton et al, 2005). Nonetheless, beliefs about the work-related causes of LBP do not appear to have been measured amongst sedentary workers.

1.8) Sickness absence due to low back pain

Accurate information on work loss is particularly difficult to obtain, being dependent on social policy and local issues such as compensation systems and job availability (Adams et al, 2002). Therefore, the most robust data is available from the island of Jersey, because all work loss of more than 1 day requires medical certification, which is collated on a computer database. In 1994 LBP accounted for 10.5% of all sickness absence in Jersey. Just 3% of those off work with LBP were off for longer than 6-months, but they accounted for 33% of the benefits paid (Watson et al, 1998). A mainland survey conducted by the Clinical Standards Advisory Group (CSAG, 1994) estimated that work absence due to LBP in the previous year was about 52 million days, with 106 million being spent in benefits. However, not all workers with LBP will cease work, a four week study of 1136 working people with LBP found that in that time only 6% had been absent due to their symptoms (Mason, 1994). Approximately 85% of people that take absence are off work for a short period (a week or so) but account for only about half of lost work time, the remainder being accounted for by the 15% that are off work for more than one month (Waddell, 1999). Only 1-2% of workers that take absence go on to long term incapacity (Waddell et al, 2003).

Evidence from standardised surveys completed by the Health and Safety Executive provide a detailed indication of the prevalence of sickness absence due to LBP over time (HSE, 1995, 2003). Since 1995 the prevalence of self reported LBP has fallen, although the number of annual working days lost in 2003 (32.9 million) is substantially higher than in 1995 (18 million). This is due to an increase in absence durations, the average number of working days off per case in 1995 was 13.9 days, compared to 22.9 days in 2003 (Jones et al, 2003).

With reference to sedentary workers, there is no conclusive evidence that rates of absence due to LBP are any greater than amongst other groups of workers (Hemmingway et al, 1994; Hildebrandt et al, 2000). A large-scale household survey has also demonstrated that rates of sickness absence due to LBP are lower amongst sedentary workers than health and social welfare professionals, skilled construction workers and researchers (Jones et al, 2003). Several different measures have been used in the literature to measure sickness absence:

- *Time based measures:* These usually comprise the number of days lost, being classified as either calendar or working days (Borg, 2003).
- *Return to work time:* This measures the length of time taken for an individual to return-to-work (Burton et al, 2005).
- *Individual measures:* Such *as* the number of individuals sick listed, or the percentage sick listed at a certain point or period in time (Hensing, 2004).
- *Spell (episode) based measures:* This can relate to new, ongoing, or concluded spells, spell frequency or spell length (Hensing et al, 1998).

The most common set of measures in the literature are spell based along with days sick listed (Hensing, 2004).

1.9) Summary

This epidemiological review illustrates that most people will experience LBP during their life, and its consequences are a major problem for society. Despite considerable efforts to identify the risk factors for LBP, whether certain aspects of sedentary work are hazardous is unknown. The epidemiological evidence does not support the view that sitting at work is associated with LBP, although exposure to sitting and the dose-response relationship does not appear to have been accurately measured. Sitting relates to postural, kinematic and temporal factors, and only when these factors are considered together might the effect of sitting on LBP perhaps be understood. This may explain the lack of evidence for risk factors in sedentary jobs, because exposure variables assessed with inaccurate tools tend to systematically underestimate risk (Frank et al, 1995). The influence of leisure-time activity on LBP at work is also unclear.

Whilst some workers with LBP remain at work, others will take sickness absence, and a small minority will progress onto long-term disability. These consequences can be partly explained by clinical and occupational psychosocial risk factors (yellow and blue flags). The role of clinical psychosocial factors (generally measured once sickness absence has taken place) in the transition to disability is widely acknowledged. Occupational psychosocial factors have also been shown to play a significant role in the development of disability. However, amongst sedentary workers the influence of clinical and occupational psychosocial factors on sickness absence and disability due to LBP is unknown.

Chapter 2

Biomechanical effects of sitting and standing on the lumbar spine

2.1) Introduction

Due to the difficulties in measuring exposure to the physical aspects of sedentary work, considering the biomechanical evidence may offer some explanatory (theoretical) mechanisms for the onset of LBP in sedentary workers. Therefore, the following chapter will review: (1) how the lumbar sagittal curvature is typically measured; (2) studies that have investigated the effects of compressive forces on the lumbar spine in sitting and standing; (3) motion segment experiments in different sitting postures; and (4) the effect of sitting on the lumbar musculature. Whilst critical evaluation will take place, some description of concepts and methods is, however, necessary in order to establish background context.

2.2) Lumbar sagittal curvature in sitting and standing

Experimental evidence has shown the effects of compressive forces on the lumbar spine to be influenced by its curvature or posture (Adams et al, 1986; Dolan et al, 1987). Therefore, researchers have attempted to directly measure or simulate, in experiments, the characteristic lumbar curvature of everyday activities. However, the methods used to measure the lumbar curvature vary.

2.2.1) Shape based measurement of the lumbar curvature

Descriptions of the shape of the lumbar curvature in the sagittal plane relate to the terms ‘lordosis’ and ‘kyphosis’. A lumbar lordosis refers to a concave shape and is a characteristic feature of upright standing. To reduce this lordotic shape requires flexion to take place, although a flexed or kyphotic shape is only apparent when the curve formed by the alignment of the vertebral bodies becomes convex posteriorly. This transformation into a kyphosis is a feature of flexed sitting (Lengsfeld et al, 2000) (Figure 1). Using a fibre optic goniometer (FOG) attached to the skin overlying the spinous processes (see section 5.3.4), the shape of the lumbar curvature can be measured. Using such a device, 180° can be set as a point to delineate lordotic and kyphotic shapes, a surface curvature less than 180° being lordotic, with a curvature greater than 180° being kyphotic. Standing generally requires the adoption of a lordotic shape, and surface curvature measurements using a FOG have shown the standing lordosis to average 154° in males and 148° in females (Stigant, 2000). Lumbar flexion is considered to be a defining characteristics of sitting (Lord et al, 1997), and when compared to the standing lordosis some flexion will usually occur, although a flexed or kyphotic shape will not develop unless the curvature is greater than 180° and the lumbar lordosis is lost (Brinkmann et al, 2002).

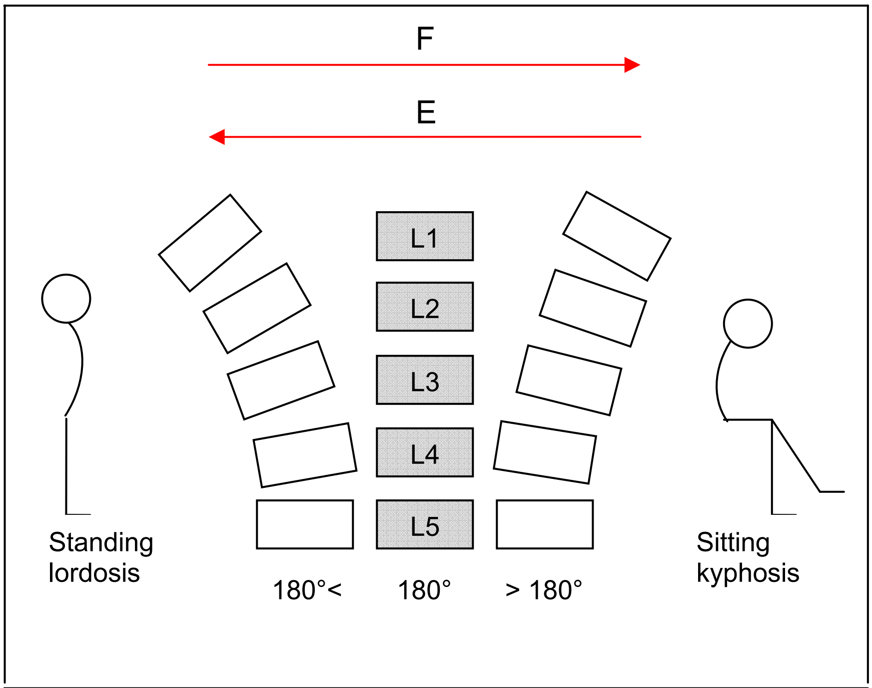

Figure 1: Lateral view of the lumbar spine curvature during standing and sitting. A lumbar lordosis in standing involves extension (E) to the left, and a lumbar kyphosis in sitting involves flexion (F) to the right

2.2.2) Radiographic and biomechanical interpretation of the lumbar curvature

Radiographic techniques are different to shape based measures of the lumbar curvature, and often define sagittal posture in terms of the angle subtended by the upper surface of L1 and the top of the sacrum (Adams et al, 2002). Figure 2 illustrates how the lumbar lordosis (including the lumbosacral angle) might be shown on x-ray, a typical angle (A) being 49-61° in erect standing. To measure the range of flexion or extension from standing this angle (A) is considered to be the 'reference' position. When sitting, lumbar flexion is likely to take place and would be measured by the amount of flexion from the standing (reference) position (Adams et al, 2002). Therefore, radiographs can determine the lumbar ROM required to adopt static positions (Lee, 2002; Pearcey et al, 1984). However, since these techniques do not directly measure the shape of the lumbar spine, they are unable to determine precisely when a kyphotic shape is formed. Therefore, individuals with a large standing lordosis may maintain a lordotic shape whilst sitting, although radiographs would describe this position in terms of the amount of flexion that has taken place from standing.

Cadaveric (biomechanical) research describes the curvature of an unloaded lumbar spine as 41-45° (neutral position), estimating that standing would increase the curvature by 8-16°, and that sitting would reduce it by about 10-21° (Adams et al, 2002). Knowledge of these angles enables the entire lumbar spine or specific motion segments to be loaded at set angles, in order to better understand how lumbar postures might produce pain.

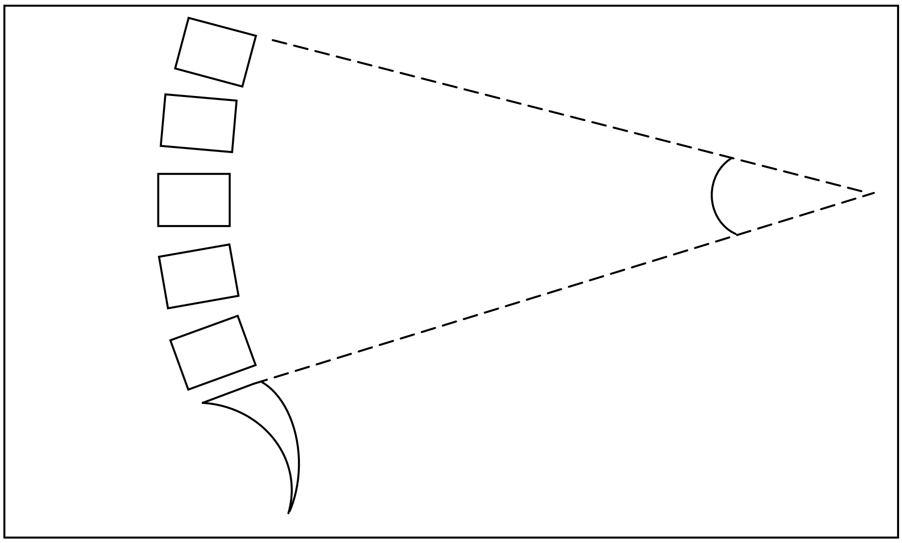

Figure 2: Lateral view of the lumbar spine illustrating the lumbar lordosis angle (A) between the top of the sacrum and the upper surface of L1 (Adams et al, 2002, p 161)

2.3) Compression of the lumbar spine in sitting and standing

Different methods to investigate compression of the lumbar spine in sitting and standing have been described, producing conflicting results. Early research used a cannula and pressure transducer to measure conditions in the human intervertebral discs of L3 and to a lesser extent L4 during a variety of activities (Nachemson and Elstrom, 1970). Results showed that in young adults the total load on L3 increased by about 38% in an upright seated position compared with standing, a finding that was confirmed by Andersson et al (1974). Later work by Nachemson (1992) repeated these results, and sitting with a backrest at an angle of 100° was also found to reduce the compressive force on the disc compared to upright sitting. More recent evidence is available from stadiometry studies. Althoff et al (1992) investigated stature change in a variety of sitting postures on a variety of chairs. Over a period of 30 minutes all sitting conditions unloaded the spine relative to standing. Sitting in an office chair with a backward inclined backrest unloaded the spine to the greatest extent producing a 4mm stature increase, and sitting upright with a straight backrest resulted in a 2mm increase in stature. These findings (increased stature when sitting compared to standing), were also found by Drerup and Granitzka (1994). Even during longer periods of sitting (6.5 hours), lumbar spine stature increases relative to standing for the same period (Leivseth and Drerup, 1997).

Therefore, stadiometry studies support the view that sitting unloads the lumbar spine relative to standing, although these contradict the findings from intradiscal pressure studies. However, these early in-vivo studies have been found to be flawed due to problems with the accuracy of the pressure transducer and the way in which the angle of the L3/4 endplate was measured to calculate pressure (Brinkmann et al, 2002). To complicate matters, the results from a study that estimated lumbar compression using EMG readings from 104 muscles found that sitting in a forward flexed posture for two hours resulted in significantly higher compressive loads than standing (Callaghan and McGill, 2001). On balance, the literature shows that sitting in an upright or relaxed (supported) position generates lower levels of lumbar spine compression than in standing, although certain sitting postures may generate higher levels of compression.

2.4) Experimental studies on motion segments

Due to the ethical difficulties of conducting invasive experiments, in-vitro testing of cadaveric motion segments provides a useful source of information about the behaviour of specific lumbar structures in response to compressive loads. These experiments have attempted to mimic the conditions affecting the lumbar spine in various seated postures.

2.4.1) Conditions affecting motion segment experiments

Experimental conditions should match in-vitro conditions as closely as possible to enable their results to be extrapolated to the real world. However, this is problematic, because death and the process of preparing a motion segment (dissecting ligaments and muscles) is known to alter its mechanical properties (Koeller et al, 1986). Nonetheless, motion segments can be prepared in such a way so as to minimise these effects, e.g. using wires to mimic the action of muscles (Wilke et al, 1999). The compressive loads encountered during sitting can also be estimated (typically 2kN) (Dolan and Adams, 2001), although it is more difficult to determine at which angle to test motion segments. In-vitro studies of how individuals sit have provided some assistance in the development of lifelike experimental conditions (Callaghan and McGill, 2001). These studies have shown that when the relative range of flexion from upright standing to full flexion (touching toes) is compared with lumbar motion during sitting, it is possible that some motion segments could be strained close to their maximum in-vivo limits (Pearcey et al, 1984). From an upright standing position the lumbar spine will typically exhibit 16° of extension and 54° of flexion (Portek et al, 1983), and contributing motion segments will each flex and extend to varying degrees (depending on the level) to produce these movements. Based on the 'neutral' (unloaded) position, cadaveric motion segments that simulate different standing and sitting postures are typically loaded at angles ranging from 2° extension through to 8° flexion (Adams et al, 1994).

2.4.2) Effects of a simulated sitting postures

Cadaveric research has shown that when a motion segment is loaded in a simulated lordotic posture (2° of extension), intradiscal pressure within the nucleus reduces by 36% when compared to a kyphotic posture (4-8° of flexion) (Adams et al, 1996). Similarly, when compressed in 4° of extension, the intradiscal pressure in a motion segment is 40% less than at 0° (neutral position) (Adams et al, 1994). These findings suggest that lordotic postures reduce intradiscal hydrostatic pressure, load being transferred to the posterior annulus fibrosus and zygoapophyseal joints (Hedman and Fernie, 1997).

Stress profilometry has shown that when discs are compressed in the neutral position they exhibit a small peak of compressive stress in the posterior annulus, but with an even compressive stress throughout the rest of the nucleus and anterior annulus (Adams et al, 1994). However, when a lordotic posture is simulated (2° of extension) the size of this stress peak increases (Adams et al, 1994). Therefore, experimentally induced lordotic postures load the posterior elements, and these structures are recognised as a source of LBP (Kuslich et al, 1991). This suggests that lordotic sitting postures may produce LBP, although evidence of a harmful effect is not yet available. Hedman and Fernie (1997) conducted a cadaveric study that could clarify this situation. Twelve lumbar spines (L1-S1) were subjected to constant loading conditions while in flexed and extended seated postures. Time-dependant forces were measured in the anterior column at the L4 and L5 superior end plates, and in the four facet joints of the L3-L4 and L4-L5 motion segments. When loaded in a lordotic posture an initial increase in facet joint forces was found, but after 30 minutes the total facet load did not increase significantly (1% overall), whereas disc compression and anterior longitudinal forces increased markedly. Therefore, the lumbar spine may be best designed to accommodate moderate periods of static loading in a lordotic posture.

It is important to note that the results of cadaveric studies may well differ, and should not be directly extrapolated to the in-vivo lumbar spine. This is because the condition of individual intervertebral discs is known to vary and influence experimental findings. Adams et al (2000) have found that degenerated discs are more sensitive to changes in posture than healthy hydrated discs, developing much greater stress concentrations in the posterior annulus in 2° of extension. However, severely degenerated discs subject to the same conditions demonstrated reduced hydrostatic pressure in the nucleus, with stress peaks in the posterior annulus reducing by 40%, presumably due to the neural arch stress shielding the posterior annulus from high compressive forces. Therefore, lordotic sitting may possibly unload the IVD in some (but not all) individuals.

Experimental studies have also loaded motion segments in simulated flexed sitting postures. When a compressive force is applied to a moderately flexed motion segment (8°), stresses are distributed across the IVD more evenly than when in a lordotic posture (Adams et al, 1994). There is a tendency to generate stress peaks within the anterior annulus at full flexion, but this is rarely as high as the stresses generated in the posterior annulus during full extension (Adams et al, 1994). Thus, flexion reduces compressive loading of the posterior elements. However, the consequence of reduced load sharing from the posterior elements in full flexion is a 100% increase in hydrostatic pressure within the nucleus. This is partly due to flexion stretching the posterior ligaments of the neural arch, thus serving to further compress the IVD (Dolan and Adams, 2001).

Proponents of a flexed sitting posture cite experimental findings related to enhanced IVD nutrition. Adams and Hutton (1986) have shown that flexion can reduce the diffusion path length within the IVD, enhancing metabolite absorption into the inner posterior annulus. Simultaneously, as flexion stretches the posterior annulus by 50%, increasing its surface area, the expulsion of fluid containing metabolites is increased. Conversely, when loading is reduced (by moving towards extension), the fluid previously expelled under high load returns, bringing metabolites with it. These results corroborate work by Ishihara et al (1996), who found that improved matrix synthesis takes place when compression is applied and released, as might occur when moving from a flexed to a lordotic posture. These in-vitro findings suggest that dynamic sitting, characterised by regular changes in position into and out of flexion may help to ensure IVD health. Furthermore, periods of moderately flexed sitting may improve diffusion into the inner posterior annulus. The presumed benefits of these experimentally induced postures are also known to be perceived as comfortable by sedentary workers (Mclean et al, 2001). However, the nutritional benefits of a reduced diffusion pathway may be counterproductive if the IVD is loaded in a static flexed sitting posture for a prolonged period. Experimental evidence has shown that fluid loss is accelerated in these conditions, and can lead to a dehydrated disc (Mc Millan et al, 1996). This is theorised to impair nutrition and accelerate IVD degeneration (Oshima et al, 1989; Handa et al, 1997), suggesting that prolonged flexed sitting postures may be hazardous.

2.5) Effects of sitting on the musculature

Depending on the sitting posture adopted the recruitment and contraction patterns of the erector spinae muscles vary (Andersson et al, 1974). Upright lordotic sitting postures increase levels of muscle contraction, whilst the use of a supportive lumbar roll, passive reclined or flexed posture is known to reduce contraction (Chaffin et al 2002). This suggests that relaxed sitting postures should be adopted to reduce the work of the extensor musculature. However, using volunteers with a history of LBP, McGill et al (2000) found that even at low levels (2% maximum voluntary contraction), oxygen transport into muscle when sitting can be impaired. Using healthy subjects (n=22), Callaghan and Dunk (2002) also found that lumbar erector spinae muscles fail to fully relax in slumped sitting. Therefore, muscular LBP might theoretically develop as a consequence of sustained contraction to maintain a particular posture, although there is no conclusive evidence of an association between prolonged muscle contraction whilst sitting and LBP. This lack of evidence appears to be partly due to researcher’s apparent preoccupation with the IVD as a source of LBP.

2.6) Summary

Precise in-vivo biomechanical measures have shown that sitting unloads the lumbar spine relative to standing, suggesting that loading conditions in sitting may not be hazardous. However, improved experimental techniques have enabled scientists to investigate how motion segments respond to everyday simulated sitting postures. These studies explain how concentrations of force may be generated within parts of the motion segment from innocuous everyday sitting postures. If prolonged, such forces could potentially result in LBP. It would appear that arguments for the benefits and disadvantages of both lordotic and flexed sitting postures can be proposed and defended based on current biomechanical evidence. The evidence suggests that the nutritional health of the IVD is dependant on regular changes in position, and simply advocating either a lordotic or flexed sitting posture would be wrong. In fact, the notion of an ‘ideal’ posture does not seem to fit with the evidence. Rather, sedentary workers should perhaps change their sitting posture regularly.

Despite preoccupation with the IVD, mechanisms by which other structures may produce LBP in certain sitting postures have also been proposed. Thus, there is an abundance of experimental literature to suggest that the LBP experienced by sedentary workers could relate to their sitting postures. Nonetheless, experimental conditions cannot reflect the behaviour of sedentary workers, and it seems that our understanding of LBP does not relate to actual biomechanical evidence from humans, but experimental studies. This severely limits its generalisability to sedentary working populations.

Chapter 3

Measurement of lumbar movement characteristics

3.1) Introduction

The term lumbar movement characteristic is used in this thesis to describe the characteristics of the lumbar (sagittal) curvature during an activity, posture or movement. The concepts of activity, posture and movement have often been considered as distinct, but are in fact inter-related. Measurement of lumbar movement characteristics has involved using static methods (collecting data at one point in time) and dynamic methods (collecting data continuously over time). This chapter will review both static and dynamic measures in order to determine their accuracy, reliability, and potential value for measuring the lumbar movement characteristics of sedentary workers. The impact of age, gender and LBP on lumbar movement characteristics will also be considered.

3.2) Results of static measures

3.2.1) Radiographs

The most accurate method of measuring the orientation of the lumbar vertebrae is stereoradiography (Stokes et al, 1981). This technique involves taking radiographs from several angles to produce a three-dimensional image of the lumbar spine (Lee, 2002). When measuring changes in the orientation of the lumbar vertebrae during sagittal flexion and extension the standing lordosis is considered to be the 'reference' position (see p18). Measuring the actual position of each vertebrae in relation to this allows the range of movement at each lumbar level to be determined. This is done by using optimisation techniques to identify bony landmarks and compute individual vertebral angles (Dvorak et al, 1991). These techniques also enable the full range of movement in the lumbar spine to be directly measured in-vivo and explains why radiographs are considered the 'gold standard' (Pearcey et al, 1984). A bi-planar method was used by Pearcey et al (1984) to assess the three-dimensional movements of the lumbar spine in 11 asymptomatic volunteers. Each intervertebral joint had a total range of flexion and extension of approximately 14°, L1/2 was shown to have slightly more flexion than extension, while L2/3, L3/4 and L4/5 displayed little extension beyond the erect standing position. The L5/S1 joint showed no consistent pattern, and the overall standing lordosis was 74° with the mean total range from full extension through to full flexion being 70°. Putto and Tallroth (1990) have stated that this value may be too high, since the best mean total range they could achieve was 45.3°, although this might be because they included chronic LBP patients. It has been suggested that variations in the size of the lumbar lordosis and ROM may be indicative of pathology or LBP (Lee, 2002). However, supporting evidence is conflicting, and may be explained by variations in the procedural and mathematical methods used in different studies (Pearcey et al, 1984; Adams, 1999; George et al, 2003; Murrie et al, 2003; Norton et al, 2004).

3.2.2) Skin surface methods

There are a variety of static measures of lumbar ROM that utilise the skin surface; this section will critique three of the most widely reported techniques: (1) Skin stretching, (2) inclinometry, and (3) flexicurve based measures.

The technique of measuring skin stretching described by Schober (1937) has been used both in its original and modified form to measure lumbar ROM (Macrae and Wright, 1969; Salisbury and Porter, 1987). The modified Schober's technique is now accepted as the more reliable test (Moll and Wright, 1971; Gill et al, 1988). This involves first drawing a horizontal line between the posterior superior ilac spines (lumbosacral junction), and then placing two marks 10cms above and 5cms below the first mark. A tape measure is then used to measure the distance between the marks at full range flexion and extension. Reports of the inter and intra-rater reliability of this technique are conflicting (Miller et al, 1992; Mahadevi and Andrea, 1996), and inconsistent marking of the lumbosacral junction and skin are reported limitations (Miller et al, 1992). In terms of validity, Macrae and Wright (1969) were the first to use radiographic markers placed over the skin to investigate the relationship between skin and vertebral movement, and skin distraction correlated with radiographic measures. More recent evidence has shown that skin stretching does not correlate well with radiographic measures of lumbar mobility (Portek et al, 1983; Dolan et al, 1995). Therefore, the modified Schober's technique provides a measure of skin stretching (Miller et al, 1992), and its scientific value as a measure of lumbar movement is questionable.

Inclinometers use the constant vertical direction of gravity as a reference point, requiring that one side of the device rests against the body surface (Williams et al, 1993). By using two of these instruments, one over the surface of the sacrum and the other over the T12/L1 spinous process, Loebl (1967) described a method to measure lumbar ROM. In standing, full forward flexion and extension readings from the inclinometers are recorded. The differences between these measures can then be used to establish lumbar ROM, an approach used by several authors (Gill et al, 1988; Williams et al, 1993; Saur et al, 1996; Chen et al, 1997; Mayer et al, 1997). Overall, inclinometers are regarded as a quick and reliable method of measuring lumbar ROM (Dillard et al, 1991; Mayer et al, 1997; Lee, 2002). In terms of validity, Saur et al (1996) took measures from patients (n=54) with radiographic markers on the T12 and S1 vertebrae as reference points. Results indicated that radiographic and inclinometer techniques showed a high and almost linear correlation for measurement of total lumbar ROM ($r=0.97$, $P<0.001$), and flexion ($r=.98$, $P<0.01$), whereas extension ($r=.75$, $P<0.05$) did not correlate as well. Mayer et al (1984) reported the mean lumbar ROM to be only 2° larger when measured by radiography than by inclinometer. Adams et al (2002) suggests a reason for this; inclinometric measurements are comparable to radiographs because the skin surface lies at 90° to the top surface of the vertebral bodies and sacrum.

Burton (1986) investigated the so called flexicurve method for estimating lumbar sagittal mobility. The T12, L4 and S2 spinous processes were marked, and the flexicurve was moulded to the midline contour of the lumbar spine in standing, maximal flexion and extension. The resulting curves, together with the position of the spinous processes are traced onto paper, and a computerised digitiser is used to fit tangents to the curves (at T12, L4 and S2), from which four intersection angles are measured (Burton et al, 1989). The technique gives different measures of mobility including: (1) the total range of lumbar motion (sum of all the angles); (2) the separate flexibility available in flexion and extension; and (3) the mobility of the upper (between T12 and L4) and the lower region (between L4 and S2) of the lumbar spine (Tillotson and Burton, 1991).

Burton (1986) investigated the intra and inter-observer accuracy of this method and found the results to be 91% accurate for the same observer, and 85% accurate for different observers. Later analysis by Tillotson and Burton (1991) further established the reliability and validity of this technique. They found that the flexicurve had an acceptable level of intra-observer reliability (least significant difference: 3° to 4° of movement), and was not significantly influenced by intra-subject variability. In terms of validity, flexicurve derived measures of flexion and extension were within 6° and 5° of radiographic measures. Earlier research by Stokes et al (1987) found the flexicurve technique to be less valid, within ±13.2° or ± 25.5% of radiographic measures (for total lumbar motion). The results of Stokes et al (1987) may be explained by the fact that radiographic exposure did not take place simultaneously with flexicurve measurements, and the test position was not standardised. Research using the flexicurve technique has shown that mobility decreases with age, and gender differences seem to exist; women extend more from the standing position, whereas men flex more (Burton and Tillotson, 1988).

3.3) Results of dynamic measures

3.3.1) Lumbar motion monitor

The lumbar motion monitor (LMM) is a tri-axial electrogoniometer contained within a lightweight exoskeleton running over the lumbar spine (Marras et al, 1995; Marras, 1999). It is attached to the shoulders and pelvis by a harness, and is composed of a series of T sections that overlie the transverse and spinous processes of the lumbar vertebrae. This system moves with the lumbar vertebrae to record three-dimensional lumbar motion in the frontal, sagittal and transverse planes. The ends of each edge of the exoskeleton are connected by wires to three potentiometers contained in the base of the LMM. These wires differentially change the voltage readings in the potentiometers as the exoskeleton moves forwards, backwards and to the sides (Marras et al, 1992). A cable is also placed through the junction of each T section and is connected to a fourth potentiometer, this being capable of detecting rotation. The signal output from the potentiometers are interfaced with an analogue-digital converter and recorded on a computer. These signals have been calibrated to correlate with trunk angles, so they can be used to determine the position, velocity, and acceleration of the trunk as a function of time (Marras et al, 1992).

Marras et al (1992) have established the accuracy and repeatability of the LMM. Using a three-dimensional calibration frame the LMM was moved through pre-selected ranges of motion (15°, 30° and 45°) in each plane. Taking the average deviation of all conditions from the calibration frame as an indicator of accuracy, deviations in the frontal, sagittal and transverse planes were 1.71°, 0.96° and 0.50° respectively. Ten repetitions of the LMM were also performed in 20 different ranges of motion in the frontal, sagittal and transverse planes. The results of the repeatability tests showed that the maximum standard deviations were relatively small: 0.34° (frontal), 0.82° (sagittal), and 0.90° (transverse). Therefore, the results of this study indicated that the LMM system was an accurate and repeatable system. In terms of measuring velocity and acceleration, Marras et al (1992) compared the LMM to a motion analysis system. The LMM consistently produced lower values of acceleration and velocity, although the two systems were found to correlate closely ($P<0.01$). Gill and Callaghan (1996) have examined the intra and inter-tester reproducibility of the LMM. Results indicated that the reproducibility for ROM and velocity was sufficiently high to be used for research purposes.

Early work by Marras and Wongsam (1985) used the LMM to measure the lumbar movement characteristics of 34 subjects, 16 of which had current LBP, the remainder being pain free. Full extent flexion, extension and normal/maximal velocity was measured in all subjects. Results indicated that the LBP group had less flexion and extension than the pain free group, although this did not reach a level of significance. More pronounced between group differences were shown for velocity. The maximum flexion velocity of people with LBP was reduced by 50%, compared to the pain free group ($P<0.05$). Maximum extension velocities between the groups showed the greatest differences ($P<0.01$), people with LBP producing velocities that were <10% those of their pain free counterparts. Later work by Marras et al (1995, 1999) has confirmed these findings.

The LMM is novel because it can be worn by the user to provide a continuous measure of three-dimensional lumbar movement characteristics, including higher order motion characteristics. These qualities have led to its widespread use in both laboratory and industrial settings. In particular, the LMM has been used to analyse risk related to manual handling tasks (see section 6.2). The main disadvantage of using the LMM to measure sedentary workers is that its relatively large size and dorsal placement over the lumbar spine would prevent normal use of a chairs back rest. Therefore, it is likely that altered rather than typical seated lumbar movement characteristics would be measured.

3.3.2) CA-6000 spinal motion analyser

The CA-6000 spinal motion analyser is a triaxial potentiometric analysis system consisting of a link arm containing six potentiometers, three in the sagittal plane and two in the frontal plane (McGregor et al, 1997). The link arm is attached to the subject via harnesses that attach around the chest and pelvis. During movement the resistance of the potentiometers changes, which is then converted from an analogue to a digital signal and interpreted via a computer as angles over time. Signals are recorded at a rate of 10Hz (McGregor et al, 1995).

McGregor et al (1995) reported the inter-observer repeatability of this system, finding minimal observer errors, the mean difference for flexion being 2.4° (SD 3.3°), and for extension 1.4° (SD 3.9°). With regards to intra-observer repeatability, a mean difference of 1.1° (SD 4.5°) was found for flexion, and 1.4° (SD 4.5°) for extension. Similar findings have also been reported by other researchers (Mannion and Troke, 1999, Dopf et al 1994).

Dopf et al (1994) used the CA-6000 system to establish normal values of lumbar spine movement in 120 subjects aged 20-35. The mean total range of flexion (from full extension to full flexion) was 115°, with mean flexion from standing being 80°, and extension from standing being 35°. Using the CA-6000 spinal motion analyser, the lumbar movement characteristics of 138 LBP patients have also been compared to normal subjects (McGregor et al, 1995). The results indicated that both ROM and velocity measures were significantly different between the two groups ($P<0.001$). Patients with LBP had reduced lumbar ROM and angular velocity compared to normal subjects, and these findings corroborate results obtained with the LMM (Marras and Wongsam, 1986; Marras et al, 1995).

The main limitation of the CA-6000 spinal motion analyser is that the link arm is fixed to a computer system, so it could not be used to measure the lumbar movement characteristics of sedentary workers whilst working.

3.3.3) Flexible electrogoniometers

The flexible electrogoniometer employs a spring gauge to measure linear displacements that occur during movement, this information being stored on a datalogger. Using a calibration formula angular values over time can then be displayed on a computer (Rowe et al, 1989). The device is attached over the first and second sacral vertebrae and the T12 spinous process using hypafix tape (Boocock et al, 1994). The precision and reliability of this technique has been investigated by Boocock et al (1994), who also compared it to a flexicurve and inclinometer. Results indicated that the precision was good, the electrogoniometer correlating closely with a calibration rig ($r = 0.96$). For overall lumbar sagittal mobility the most reproducible measure was achieved using the inclinometer, the least significant difference (LSD) being 6.2° ($r=0.96$). The LSDs for the electrogoniometer and flexicurve were 12.9° and 12.4° respectively, with correlation coefficients (r) of *0.78* and *0.86*. The mean value recorded by the electrogoniometer was only 1° more than that recorded using the other techniques, so it was concluded that the electrogoniometer was equally as accurate as the inclinometer and flexicurve.

Boocock et al (1994) subsequently conducted a field study measuring the lumbar movement characteristics of four garage mechanics. The amount of time each mechanic spent in positions of flexion and extension relative to standing were recorded. Each mechanic was monitored for a period of up to 2 hours, their behaviour being stopped every 27 minutes for approximately 2 minutes in order to download the information stored on the datalogger. Therefore, this system would be unable to continuously measure the lumbar movement characteristics of sedentary workers, at least not without interrupting their normal pattern of work to collect data. Furthermore, although considered good at the time, this system only provides basic information of lumbar angles over time, failing to record acceleration and velocity like other dynamic systems.

3.3.4) Fibre optic goniometer (FOG)

The fibre optic goniometer (FOG) consists of a base plate and a flexible rod (Figure 4) designed to continuously measure lumbar sagittal surface curves (Stigant, 2000). Light is launched into a 1mm polymer optical fibre by an infra-red LED and captured at the other end by phototransistors in the baseplate.

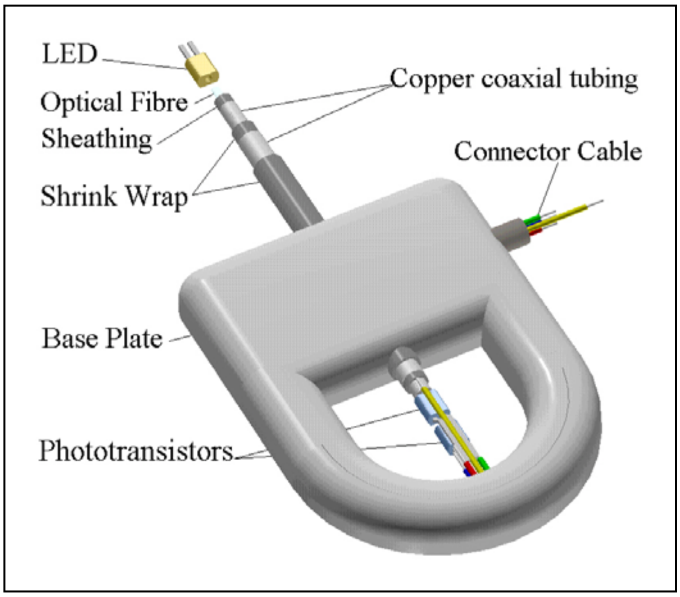

Figure 4: Cutaway and shortened view of the FOG (Stigant, 2000, p85)

The FOG has been engineered to allow the rate of loss of light between the LED and phototransistor to vary with the direction of bend in the optical fibre. Bending towards a more extended position causes the output (voltage) to fall, while motion in the opposite direction causes the output (voltage) to rise. This information is transmitted via the connector cable to a datalogger sampling at 50Hz where it is stored as analogue digital counts on a compact flash card. The datalogger is attached to the belt of the user and is thus mobile, while the length of a logging period is determined by the compact flash card which must be programmed prior to use. The FOG is designed to record values over a range of 120° (100°-220°). It does this by using a calibration equation to convert analogue digital counts into angular values.

Angles derived from calibrated FOGs are known to be accurate, agreeing closely with the known angles of a calibration jig (1°-2° LSD, SD 0.75°-1.52°) (Stigant, 2000). The FOG has also been shown to be intrinsically accurate and robust. When worn the total variability in output (± 2°C temperature fluctuation) is at worst ±1.5° of angular drift, and hysteresis is a maximum of 4° (following repeated movement through a range larger than that normally expected: 100-260°). Some 320,000 oscillations (at a rate of 37 per minute) over the same range are required to fracture the optical fibre. The FOG is attached to the lumbar spine by adhesive tape applied to its baseplate and two slider tubes

(Figure 5). A more detailed description of the attachment procedure is described later (see section 8.5).

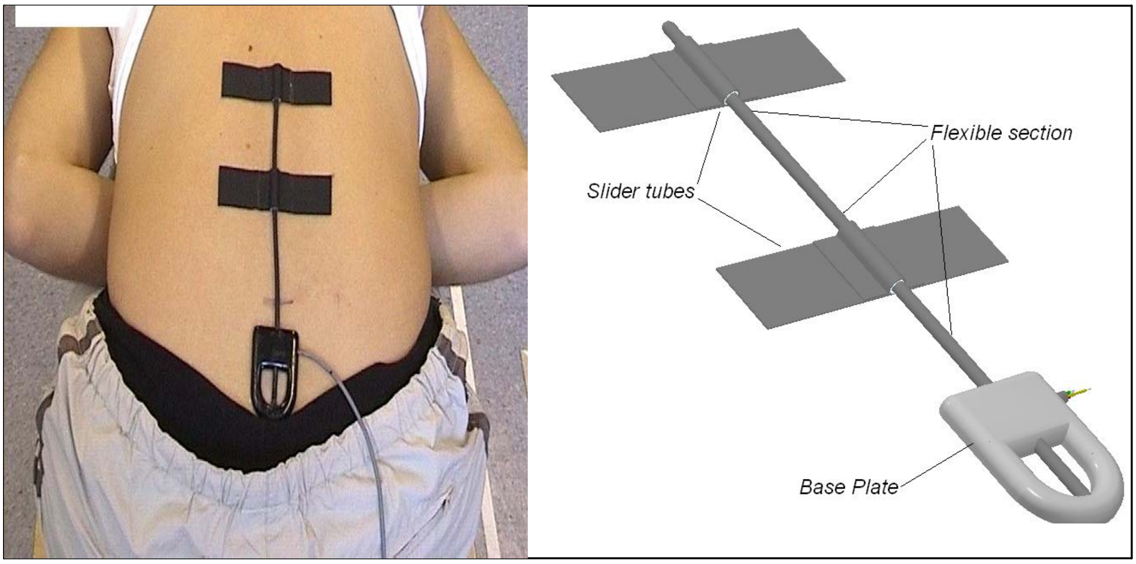

Figure 5: Attachment of the lumbar FOG using the baseplate and slider tubes (Stigant, 2000, p 84)

The overall intra-examiner repeatability has been calculated for the same application and reapplication of the lumbar FOG. Using three lumbar positions: (1) full forward flexion from standing; (2) standing; and (3) full extension from standing, the least significant differences were reported as 8.08° and 14.4° respectively (Stigant, 2000). These results suggest that the lumbar FOG has good reliability.

Stigant (2000) has also compared the lumbar FOG to the flexicure using the above positions, finding that the limits of agreement (LoA) were good for standing (-5° to 10°). However, at the extremes of flexion and extension the LoA were between -8° and 22°, which is too wide for the interchangeable use of both techniques. Using a dynamic electromagnetic tracking skill system (Polhemus, Colchester, USA), intra-instrument repeatability with the lumbar FOG was shown to be better; the LSD for both instruments being similar, 8.6° and 4.6° respectively (Stigant, 2000). The FOG has not been compared to radiographic measures, so its validity as a measure of the lumbar sagittal curvature is unknown. Nonetheless, Stigant (2000) has measured the sagittal lumbar motion characteristics of 77 subjects (38 male, 39 female) aged 20-60, which appear to closely relate to other measure of sagittal lumbar motion (Gill et al, 1988; Lee, 2002), and are described later (see section 8.6.5).

To display and analyse lumbar angles measured by the FOG a software package (Interrogator) has been developed in Visual Basic (Stigant, 2000). This reads raw data files and applies calibration equations to produce angular values that can be displayed on a datatrain graph over time. By clicking on the 'interrogate' option automatic analysis of the datatrain begins, opening a spreadsheet in Excel. This displays basic movement characteristics (e.g. maximum and minimum values, range, mean and standard deviation) and some higher order motion characteristics (e.g. velocity and acceleration). The Interrogator software can also measure periods of relative inactivity, these being defined as periods of time taken to accumulate 5° of lumbar motion. It calculates this arbitrary measure of inactivity by comparing each data point to the previous datapoint, the difference in angle being added to the cumulative total. When the cumulative total reaches 5° the number of data points that have accumulated is used to calculate the period of inactivity.

The software can also build a profile of positional use, taking the minimum and maximum recorded lumbar angles to represent a range of 0-100%, splitting the range into ten equal 10% chunks and then placing each datapoint into one of the ten groups depending on its angular value. Each datapoint assigned to a group is then added to the group's cumulative total. Both the overall amount of time (secs) and the percentage amount of time spent in specific portions of the lumbar range can then be calculated.

The software analysis procedures described here have previously been validated and tested using data from 77 normal subjects who wore the lumbar FOG for up to 24 hours (Stigant, 2000). All subjects reported that the system was comfortable to wear, and the results of automated data analysis were error free. However, the FOG system cannot identify whether the user is sitting, standing or walking when lumbar movement characteristics are recorded.

3.3.5) Digitised videofluoroscopy

This Chapter has so far concentrated on the techniques used to measure sagittal motion of the whole lumbar spine. Based on the evidence, dynamic measurement of inter-vertebral motion might also be important to quantify associations with LBP (Stokes et al, 1981; Dickey, 2002).

Early research by Breen et al (1988) pioneered the development of a digital videofluoroscopy system to measure inter-vertebral angles, and quantified its accuracy in the coronal and sagittal planes (Breen et al, 1989). More recently, the reliability and validity of an Objective Spinal Motion Imaging system (OSMIA) was developed (Breen et al, 2006). Thirty male volunteers (with no LBP in the previous year) were screened using the system (whilst recumbent), through 80° arcs in the coronal and then sagittal plane. Analogue images from the fluoroscope were accessed at 5 frames per second. The volunteers were then allowed to move around at their own convenience for 30 minutes, after which they were screened again. Using the first image frame, two observers blind to each others results drew templates around each vertebrae to define reference points (typically vertebrae corners), and to enclose each vertebral body in its entirety. Automated analysis was then used to calculate the absolute position and orientation of the vertebrae in each frame

Inter-observer variation (measured using the RMS difference) was small for the coronal (1.86°) and sagittal (1.94°) planes, and the maximum intra-subject variation (for the two observers) was 2.91° (SD 2.92). Unfortunately, it was not possible to validate sagittal motion tracking due to technological limitations. However, it was suggested that the rapid rate of fluoroscope development would mean that future digital units would overcome these limitations. Wong et al (2006) have since developed a system to automatically track inter-vertebral motion in the sagittal plane.

This review has shown that techniques to continuously measure the functional movement characteristics of the whole lumbar spine exist, although these measures are not able to quantify inter-vertebral motion. However, due to the limitations of current technology it is not possible to measure inter-vertebral motion outside of a controlled imaging environment.

3.4) Summary

The reliability and practicality of static and dynamic measures have been evaluated to determine their potential value for measuring the daily lumbar movement characteristics of sedentary workers. There is a large body of research, and some measures have shown to be more accurate and practical than others. However, all static measures are limited, only being able to provide information on the position or flexibility of the lumbar spine. Dynamic measures such as the LMM and CA-6000 have the added benefit of being able to measure kinematic patterns of movement for extended periods of time, and are well suited for industrial and laboratory based research. However, the use of these measures to record the lumbar movement characteristics of sedentary workers is limited, because their large size and positioning over the lumbar spine would prevent the user from adopting natural sitting postures.

On balance, it would appear that the FOG system may be the most useful tool for this current study, being comfortable and small enough to provide a portable measure of lumbar sagittal curves. Despite its limited use to date, the FOG has been shown to be as accurate and reliable as established dynamic measures such as the LMM. However, like all of the tools evaluated, the FOG system is currently limited due to its inability to identify activities (sitting, standing, walking).

Chapter 4

Pain and discomfort

4.1) Introduction

Low back pain is a common presenting symptom, although providing an answer to the question "What is Pain?" is not straightforward. It has often been regarded as a 'signal of a physical injury', and early ideas of pain focused on the close relationship to damage (Descartes, 1644). Such ideas relate well to clinical examples of acute pain, but do not work well for patients with persistent pain. The following chapter will critique the literature pertaining to pain theory (including pain behaviour), with special consideration to the measurement of LBP amongst sedentary workers.

4.2) Current understanding of pain theory

The gate-control theory (GCT) proposed by Melzack and Wall (1965) is arguably the most widely accepted to explain pain in physiological terms. The term 'gate' implies an opening through which something can pass. 'Control' implies that outside forces can interact to vary gate aperture. Both these descriptors relate to components of this model. Melzack and Wall (1965) postulated two types of fibre: (1) large (L) fast conducting A-beta fibres, and (2) smaller (s) slower conducting A-delta fibres. Both these fibres communicate with the substantia gelatinosa (SG) and then to transmission (T) cells in the spinal cord. The SG exerts an inhibitory effect on the T-cell, and the action of the SG is increased by activity in the A-delta fibres and decreased by the A-beta fibres. Normally these circuits are balanced. When activity in the large fibres predominates, the inhibitory effect of the SG is increased resulting in a closed gate. Conversely, if nociceptive input predominates (e.g. back injury), there is more activity in the s fibres, reducing inhibition of the SG. This results in an opening of the gate and nociceptive impulses being transmitted to the spinal cord and brain.

Whilst the pain gate theory has advanced our understanding of basic pain physiology, its predominance has meant that researchers have found it hard it hard to move away from considering pain as a purely sensory phenomenon. Therefore, the fact that injury does not only produce pain, but has emotional and behavioural consequences appears to have been ignored for a time (Melzack, 2001). Recent evidence has shown that cells in the spinal cord also receive input from higher centres (Sufka, 2000). This therefore provides a mechanism to explains how psychosocial factors can influence the affective and cognitive dimensions of pain (Melzack and Katz, 1999; Ranney, 2001). These interactions have been explained by the 'neuromatrix theory of pain' (Melzack, 2001). This theory extrapolates from the premise that pain is a multidminesional experience (Breen et al, 2005), and places genetic contributions and the neural-hormonal mechanisms of stress (incorporating cognitive functions) on a level of equal importance to traditional sensory inputs. It is the combination of these multiple influences that is thought to predispose towards the development (and maintenance) of chronic pain (Melzack, 2001). However, it is important to recognise that associations between aspects of the 'neuromatrix' and chronic pain remain poorly understood, and require investigation.

Although difficult to define, The International Association for the Study of Pain offer a definition for pain that fits with current thinking: "it is an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage (Merskey, 1986). Therefore, pain is a perception, not only a sensation, and involves tissue sensitivity to chemical changes and the interpretation that such changes are harmful. Whether harm has occurred or is occurring, this perception is real. Cognitive processes are involved in the formulation of this perception, which have emotional and behavioural consequences (Rainville et al, 2000). Thus, a unidimensional view of pain as an aversive sensation can no longer be justified, and appreciating the influence of psychosocial factors has enabled pain behaviour to be better understood. Importantly, the neuromatrix theory suggests that there can be multiple (individualised) determinants of pain, which accounts for why patients' reactions to pain are not uniform or easy to predict.

Pain behaviour refers to how an individual reacts to their symptoms and can be a normal response (Waddell, 1987). An individual visiting their GP is an example of pain behaviour, and is understandable given that tissue damage might be associated with anxiety. In this circumstance symptoms might well be reported, but the tendency is to recover spontaneously (Walker, 2000). Thus, the decision to seek health care apparently depends on the person's perceptions and their interpretation of the significance of their symptoms (i.e. psychosocial factors). Indeed, not everyone with LBP will seek health care, and there is little evidence that the pain intensity of individuals reporting LBP is greater than that of individuals who manage the problem themselves (Waddell, 1999). However, some workers will become permanently disabled, this being a form of maladaptive pain behaviour, where pain becomes dissociated from tissue damage (Jones et al, 2003). The biopsychosocial model is now accepted as the best way to understand LBP associated disability (Waddell, 1987; Wright et al, 1995; Truchon, 2001), and is considered in section 5.3.

4.3) Measurement of low back pain among sedentary workers

Any definition of LBP should be clear and meaningful. Sickness absence and care-seeking have both been used to quantify an episode of LBP, but these relate more to its consequences than symptoms. Epidemiological studies have defined an episode of LBP as 'a period of pain in the lower back lasting more than 24 hours, preceded and followed by a period of at least one month without LBP' (Mason, 1994; Croft et al, 2002). Describing symptoms within a standardised timeframe has enabled researchers to examine the prevalence and clinical course of episodic LBP. However, despite providing a means to identify people with LBP, episodic definitions fail to take into account those people who have intermittent and transient symptoms. For workers, LBP symptoms may fluctuate over the course of a day, or from day to day in response to everyday positions (Jensen et al, 2002), but do not necessarily last longer than 24 hours. This is particularly pertinent to sedentary workers, who are known to report that sitting aggravates their LBP (Biering-Sorenson, 1983; Williams et al, 1990), even though such symptoms may not follow a predictable pattern every time they sit, or last for longer than a few minutes or hours. Symptoms might also be experienced that seem unrelated to a current episode of LBP. In both circumstances, symptoms might not be best measured by using episodic definitions. More sensitive measures are important, because even transient symptoms if perceived as damaging and attributed to work could conceivably result in sickness absence.

In order to account for the complex and varied nature of symptoms, some researchers have begun to use the term low back trouble (LBT) to encompass the occasional twinges of discomfort, felt by us all from time to time, through to severe or persistent bouts of pain (Adams et al, 2002). This is perhaps more useful than LBP definitions based purely on episodic features (Mason, 1994). However, researchers do not appear to have measured the intermittent everyday symptoms experienced by sedentary workers. These symptoms (e.g. aching, stiffness) have often been described using the term low back discomfort (Fahrbach and Chapman, 1990), although respondents may not necessarily regard such symptoms as painful, or report them on a pain scale. This may be because pain tends to be associated with more severe and intense symptoms (Melzack, 1987). Our ability to select words to describe pain is also known to depend on our previous experiences of pain, the use of words by others around us, and the environmental setting (Melzack, 1975; Melzack and Katz, 1999).

So, is discomfort really different from pain? To confuse matters the literature often uses these terms interchangeably (Ringdahl et al, 1983), and discomfort may well be a variant personal expression of pain. The recognised definition for pain emphasises its unpleasant nature (Merskey, 1986), suggesting that discomfort and pain are the same. However, sedentary workers may not be aware of this fact, and will articulate their symptoms in an individual fashion. Therefore, it seems important that researchers accept that pain as a sensory experience is exactly what a person says it is (Merskey and Bogduk, 1994).

4.4) Measurement of low back discomfort

Despite the widespread use of tools to measure ‘back discomfort’ (Demure et al, 2000; Falou et al, 2003), it is not clear what this term means, and the absence of a standardised definition prevents direct comparison between studies (Fenety et al, 2000; Falou et al, 2003). It has been established that discomfort seems to describe a range of unpleasant symptoms synonymous with LBP, and is a concern to many sedentary workers (Zhang et al, 1996). Many authors have measured discomfort using a graded likert scale on a unidimensional discomfort/comfort continuum (Kamijo et al, 1982; Helander and Zhang, 1997), presuming that discomfort and comfort relate to opposite ends of the same construct. Zhang et al (1996) used factor and cluster analyses to try and classify discomfort and comfort. Discomfort was associated with numerous adjectives including stiffness, soreness, strain, aching, and pain. Comfort related to feelings of happiness, safety and well being. Therefore, comfort and discomfort represent two distinct constructs, and it is permissible that reduced discomfort does not bring about feelings of comfort. Consequently, claims that “comfort is merely the absence of discomfort“ (Hertzberg, 1972, p41) do not appear to be justified, and discomfort should be measured on an independent scale.

Numerous discomfort measures exists, but many relate to a qualitative description of this feeling (Looze et al, 2003). Quantitative tools to measure discomfort intensity do exist, but all to often their reliability and validity is not stated, they do not relate to the low back, and fail to define discomfort (Demure et al, 2000; Liao and Drury, 2000; Falou et al, 2003). Subsequently, it is not surprising that biomechanical studies of sitting that have incorporated discomfort measures to investigate potential associations with lumbar or workplace characteristics have produced inconclusive and conflicting results (Eklund and Corlett, 1987; Salewytsch and Callaghan, 1999; Vegara and Page, 2002). Therefore, it might be advantageous to develop a reliable and valid back discomfort scale that has practical value in sedentary work environments. This scale should enable workers to indicate the intensity of their back symptoms whilst sitting, irrespective of the adjectives they use to describe such symptoms.

4.5) Summary

Pain is a subjective phenomenon that has been extensively investigated by the scientific community, and it is now understood that pain is not merely a sensation, but has complex emotional and behavioural dimensions. To date, many researchers have defined LBP by its episodic nature (symptoms >24 hours). However, not all individuals will necessarily describe their symptoms in a way that fits such definitions. Symptoms are known to follow an intermittent and chaotic course and might not even be described as ‘painful’, individuals perhaps preferring to use alternative adjectives such as ‘aching’ or ‘stiffness’. Therefore, previous studies do not appear to have measured the full breadth of transient symptoms described by sedentary workers. Considering individual reports of low back pain symptoms experienced whilst sitting at work, using a broad definition, might help to generate data that could be used for the purposes of quantitative analysis and modelling. It is the relationship of these symptoms to biomechanical factors (e.g. lumbar sitting postures), psychosocial factors, LBP, and sickness absence due to LBP that is unknown. Understanding more about this area might inform better occupational management of LBP.

Chapter 5

Prediction of low back pain and sickness absence among sedentary workers

5.1) Introduction

Whilst the epidemiological, biomechanical and physiological aspects of LBP related to this thesis have been critically reviewed in previous chapters, to provide background context, this chapter will review the overarching literature pertaining to the prediction of LBP and sickness absence. However, prior to discussing the results of predictive occupational studies, the justification for such research will be critically examined in relation to: (1) the management of LBP in sedentary work environments; and (2) the biopsychosocial model of LBP and disability.

5.2) Management of low back pain in sedentary work environments

Research has shown that the physical risks for LBP in industrial work environments can be reduced (Marras, 2000), and evidence based occupational health guidelines guidelines for the management of LBP at work suggest that related sickness absence is also preventable (Carter and Birrell, 2000). However, little is known about the risk factors for LBP and sickness absence in sedentary jobs, and there are specific aspects of this type of work that need to be better understood.

Despite the lack of evidence to support a sedentary hazard (Hartvigsen et al, 2000; Lis et al, 2007), sedentary workers are known to report that sitting at work caused their LBP. Therefore, it is not surprising that workers should ask how they should sit in order to reduce the risk of LBP. However, inconclusive evidence makes it difficult for employers and occupational health professionals to offer practical advice about the best way to sit, if such a posture exists. Health and Safety guidelines do suggest that prolonged sitting is a risk factor for LBP (HSE, 1997, 2006; EASHW, 2000; HELA, 2006), and sedentary workers are advised to sit upright (with a lumbar lordosis), take regular breaks, and not to spend too long in an uninterrupted sitting position. The extent to which these recommendations are followed in practice is unknown, and the relationship between work-break patterns, LBP and lumbar sitting postures has not been investigated (Crawford et al, 2005). Therefore, primary prevention strategies (efforts directed at preventing new cases of LBP) in the form of work policies and ergonomic interventions (e.g. lumbar rolls) currently lack evidence based justification (Linton and Van Tulder, 2001). More current thinking suggests that ‘primary prevention’ might not even be realistic (Adams et al, 2005), given the high prevalence of LBP, up to 68% of which is thought to be explained by genetic factors (MacGregor et al, 2004). However, given the consensus that sitting can exacerbate current LBP (Dankaerts, 2006), a view supported by the clinical evidence (Williams et al, 1990), there is perceived scope to prevent the aggravation and recurrence of LBP. Anecdotal reports from patients and workers alike suggest that prolonged sitting and the adoption of flexed lumbar postures are common aggravating factors, with movement-in-sitting and the adoption of lordotic lumbar postures helping to relieve symptoms. Nonetheless, how LBP symptoms and perceived symptom modifying factors relate to lumbar sitting postures and sickness absence is currently unknown.

5.3) The biopsychosocial model of LBP and disability

The biopsychosocial model illustrates the interactions between biological, psychological and social factors (Waddell, 1987), helping to explain how reactions to LBP are shaped by the social environment, beliefs and emotions (Figure 3). In the presence of LBP, psychological factors (e.g. heightened emotional state, adverse beliefs about pain), and social factors (e.g. job dissatisfaction, low social support at work) are known to influence the development of disability. These interdependent risk factors for disability also have perceived importance within clinical and occupational health guidelines (RCGP, 1999; Carter and Birrell, 2000).

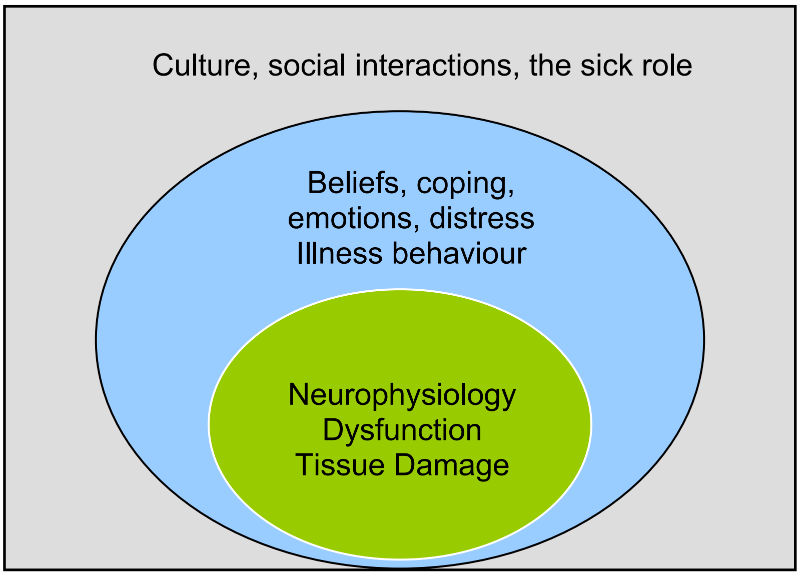

Figure 3: A biopsychosocial model of LBP and disability (Waddell, 1999)

Key factors:  = Biological  = Psychological = Social

Although the role of clinical psychosocial factors in the development of disabling LBP is well documented (Pincus et al, 2002), this largely relates to patients presenting in clinical and primary care settings. In contrast, occupational psychosocial factors have received less attention, but have equally been shown to predict disability (Bongers et al, 1993; Burton, 2001; Linton, 2001). However, researchers have tended to use generic measures to investigate the impact of occupational psychosocial factors in different types of jobs. The influence of psychosocial factors, and different elements of the biopsychosocial model may instead vary between occupational settings (Hansson and Jensen, 2004).

Little is also known about the beliefs of different worker cohorts about specific aspects of their work. In particular, for sedentary workers with LBP it is unknown how they perceive their occupational environment or the significance of their symptoms. Thus, factors which might drive sickness absence behaviour have not been measured. Gaining a better understanding of early disability risk factors is thought to be important (Shaw et al, 2005), because for workers who notice minimal improvement in terms of pain and disability after three months, recovery is uncertain (Pengel et al, 2003); the determinants of chronic disability have developed (14 days after the onset of LBP) (Kovacs et al, 2004), and the likelihood of returning to work has reduced over time (Andersson, 1997).

Therefore, management would seem to require a better understanding of the factors which predict future sickness absence, particularly of long duration. This might help to reduce work loss by informing the development of interventions designed to overcome obstacles to recovery. Such approaches are designed to help prevent chronic incapacity in those workers not yet chronically incapacitated, a concept known as ‘secondary prevention’ (Dasinger et al, 1999). Hence the importance of being able to identify workers at risk of long-term problems; so that cost-effective interventions can be directed to those in need (Linton and Hallden, 1998), and at an early stage (Breen et al, 2005). Whilst this section has mainly dealt with psychosocial factors, biomedical and socio-demographic factors are also known to predict sickness absence, and are considered in section 5.5.

5.4) Occupational lumbar movement characteristics associated with low back pain

A dynamic tool that could be used in sedentary work environments to measure the activities and related lumbar movement characteristics of workers currently fails to exist. Therefore, accepting that the risk determinants for LBP may well be different between jobs, industrial studies that have measured occupational lumbar movement characteristics will now be considered. It is anticipated that such a broad remit will help to determine how studies to predict future LBP amongst sedentary workers might be designed and analysed.

Marras et al (1993) have utilised the LMM to investigate lumbar movement characteristics during a lifting task. More than 400 repetitive industrial lifting jobs were studied in 48 industries, and medical records were examined to identify high and low risk jobs. Workers performed their handling tasks in the workplace while wearing the LMM, allowing a multiple logistic regression model to produce odds ratios in an attempt to discriminate high risk jobs (where previous LBP injury had been reported), from low risk jobs. An Odds Ratio (OR) provides an indication of the odds of occurrence of an event when two groups (exposed and unexposed are compared) (Bland and Altman, 2000). A value of 1 suggests no association, while an OR>1 means there is a positive association (increased risk for the exposed group), or an OR<1 indicates a negative association (exposure protects against risk) (Davies et al, 1998). Results indicated that lifting frequency, load moment, trunk lateral velocity, trunk twisting velocity and trunk sagittal angle were able to identify the high risk jobs where workers were more likely to have experienced LBP (OR 10.7). Other than load moment, sagittal velocity was the second best predictor of a high risk job (OR 3.3), and the overall model had a predictive power three times greater than that of lifting guidelines at that time. Despite these findings it is important to consider potential limitations. Most notably, Marras et al (1993) failed to take repeated measures of individual workers, suggesting that the results obtained might not have been entirely representative of a normal days work. Furthermore, the study fails to establish causality.

The only study found that has used dynamic lumbar movement characteristics to predict future LBP was also conducted by Marras et al (2000). From 36 jobs, 32 underwent ergonomic intervention and 4 acted as a control, receiving no intervention. The trunk motions and workplace features of 142 employees were measured at work with the LMM before and after workplace ergonomic intervention. Each jobs risk value was then calculated from five motion variables previously shown to be associated with high risk jobs (Marras et al, 1993, 1995): maximum external moment; lift rate; maximum sagittal flexion, maximum lateral velocity and average twisting velocity. The incidence of LBP was documented pre and post intervention. Results indicated that a statistically significant correlation existed between changes in the jobs estimated risk values and changes in the future incidence of LBP. Where ergonomic intervention took place to reduce the jobs risk value, the mean low back incidence rate reduced. Whilst this study has shown promising results, it should be acknowledged that the number of 'control' jobs was disproportionate to the number of jobs undergoing ergonomic intervention. Furthermore, more detail was required to clarify how these two groups were selected. These factors might have influenced the strength of the association identified.

The industrial studies by Marras et al (1993, 2000) have implications for the measurement of lumbar movement characteristics in sedentary jobs. It would appear that measuring multiple lumbar movement characteristics may be more powerful than measuring a small number of potential risk factors. Furthermore, knowledge of occupational (biomechanical) risks has been shown to positively influence ergonomic intervention. Assuming that similar developments are also possible in sedentary jobs, this might help to reduce the costs associated with LBP. However, the large size of the LMM would preclude its use in sedentary work environments, suggesting that a new tool (with comparable accuracy and precision) would be needed to measure exposure to dynamic (seated) lumbar movement characteristics.

5.5) Biopsychosocial determinants of sickness absence due to LBP

This section will review studies that have measured multiple bio-psycho-social risk factors, in order to evaluate their relative influence on sickness absence. To date, most knowledge relates to psychological or social factors, researchers measuring clinical and occupational 'psychosocial' risk factors in their respective settings. In reality, both sets of factors will likely operate together (Main and

Burton, 2000), and there is a purported need to investigate the interactions between these factors (Crook et al, 2002; Shaw et al, 2007).

Burton et al (2005) have conducted one of the few large scale investigations of psychosocial factors in industry. A clinical psychosocial factor (psychological distress), and occupational psychosocial factors (job satisfaction, social support, work attribution, control, organisational climate) independently predicted the occurrence but not the duration (>7 days) of future sickness absence (over a 2 year follow-up). Cut-off points for each of the psychosocial factors were established by considering each value of the variable as a potential cut-off. When stable, maximum ORs were found (with no cell in a 2 x 2 table consisting of a count of less than 20), the cut-off points, labelled as 'flags', were selected. Depending on the scale direction, any respondent who scored above or below these cut-off points was considered to have 'flags flying'. Retrospective analysis of absence due to LBP in the previous 12-months showed that associations were incremental; increasing numbers of risk factors (yellow and blue flags) were associated with a greater proportion of workers having taken absence. Although not significant, this analysis showed that the effect of any blue flag alone was similar to the effect of the yellow flag alone, but no single flag was dominant; rather the pattern of psychosocial flags varied from individual to individual. Demographic factors (gender, job-type, age-group) were also measured, and older workers (aged 41-65) were significantly more likely to take prolonged (>7 days) absence.

Whilst designed to incorporate both clinical and occupational psychosocial risk factors, the study by Burton et al (2005) is limited in some respects. First of all no multivariable statistical techniques were formally used to evaluate the relative influence of the different psychosocial and demographic factors measured. Therefore, potential interrelationships within and between different groups of risk factors were not examined. Importantly, such analysis may have demonstrated which factors were the most potent predictors of absence (i.e. dominant over other co-variates). This would also have helped to identify the extent to which such risks are potentially 'modifiable', thus adding to the evidence base.

In a large prospective cohort study of prognostic factors for sickness absence in a variety of worker types in the Netherlands, Van den Heuvel (2004) measured: demographics (gender, age, smoking habits, BMI); pain characteristics (duration, intensity, radiating symptoms); psychosocial work characteristics (decision authority, skill discretion, co-worker support, supervisor support, job satisfaction); and work-related physical load variables (driving a vehicle, flexion or rotation of the upper body, morning heavy loads). In a multivariable model, high disability, low co-worker support and low job satisfaction were predictors of sick leave occurrence, yet none of these predictors particularly stood out. A limitation of this study is that the work-related load variables measured comprised dichotomous data. The use of such gross categorical exposure measurements is unable to measure dose-response (Fallentin, 2001), and so their inclusion in the multivariable model is unlikely to accurately represent the influence of biomechanical load.

A Canadian review of occupational disability found similar results (Crook et al, 2002), and included socio-demographic, biomedical and psychosocial factors. For work-related outcomes (time to return to work, working/not working): having children at home, being older, having greater disability, having radiating pain, and having pain that is worse on standing and lying each predicted a poor outcome. The level of disability related to the LBP episode was one of the strongest predictors of work absence. However, although significant predictors were identified, it should be borne in mind that the ORs were not very high. Nonetheless, this systematic review identified some of the key weaknesses of studies to date; most compartmentalised the factors they considered, which has limited the development of a comprehensive multivariate biopsychosocial job-related model of work disability.

Gheldolf et al (2005) measured the role of pain (severity, radiation), work characteristics (physical workload, job stressors, job satisfaction), negative affect and pain related fear in accounting for sick leave amongst 1294 employees from 10 companies in Belgium. Short term sick leave (<30 days in the past year) was associated with severe pain, high physical workload and high fear of movement. Long term sick leave (> 30 days in the past year) was associated with radiating pain and high fear of movement. A lack of co-worker support reduced the risk of long-term sick leave. These results suggest that reported physical load factors and symptoms may lead to sick leave, with pain-related fear, radiating pain and job stressors acting as obstacles to recovery. Whilst these findings appear to fit with the literature to date, the fact that exposure to physical load was based on subjective reports represents an important limitation. Indeed, it is permissible that the role of clinical and occupational psychosocial factors in delaying recovery has been overemphasised, due to the fact that physical factors are rarely quantified with equal adequacy.

Shaw et al (2007) measured job satisfaction, stress and coping, pain and related beliefs, perceived functional disability and mood disturbance among military recruits reporting sub-acute (2 month average duration) first onset LBP. Work status (working or not working) was assessed at baseline, 6 and 12-months. In logistic regression analysis, at baseline self-reported pain intensity and functional limitation accounted for most of the variance in work status explained by psychosocial factors. Beyond two months, the extent to which pain was believed to interfere with function was the only significant predictor of a change in work status. Job dissatisfaction was associated with not working, but not after controlling for higher levels of income.

Overall the literature shows that whilst psychosocial factors can predict sickness absence due to LBP, little appears to be known about their independent and mediating influences. Although there is an emerging evidence base, cohorts of sedentary workers do not appear to have received much attention. Furthermore, interactions between all components of the biopsychosocial model and their relative importance do not appear to have been investigated. Therefore, future studies to predict sickness absence among sedentary workers should consider measuring elements from all risk factor domains, and utilise multivariable statistical techniques to control for a wide range of variables. Such models should include objective biomechanical data (quantifying exposure to prolonged sitting and lumbar postures at work) and symptoms measured at work, since models incorporating these types of data are not prevalent in the literature.

5.6) Associations between occupational lumbar movement characteristics, psychosocial factors and low back pain

It has been reported that occupational biomechanical and psychosocial demands can be associated (Devereux et al, 1999), suggesting that both need to be measured in predictive models to control for potential confounding variables. Indeed, several studies have found that jobs with high biomechanical demands are associated with poor social support (Skovron et al, 1987; Leino and Hanninen, 1995). Furthermore, Marras et al (1995) found that job dissatisfaction was a significant predictor of LBP in bivariate, but not multivariate models that controlled for kinematic (biomechanical) variables. Bongers et al (1993) and Marras et al (2000) have posed plausible explanations to account for the association between work-related biomechanical demands, psychosocial factors and LBP. However, it is not possible to draw firm conclusions due to the poor methodological quality of the literature. Part of the problem is that there has been a preference to undertake measurement of psychosocial factors, rather than also incorporating measurement of biomechanical factors. Davis and Heaney (2000) provide evidence that there is a 20% increase in null results, for associations between psychosocial factors and LBP, when studies control for biomechanical demands. Thus, future LBP studies should consider measuring both sets of factors, since it may not be possible to separate the contributions of the physical workplace from that of the psychosocial components of the work. Furthermore, the measures used (particularly for the assessment of biomechanical exposure) should be of high quality; very few studies have used valid measures, preferring to collect self-reports, which are highly subjective (Van den Heuvel, 2004; Gheldolf et al, 2005)

Assuming that occupational lumbar movement characteristics, psychosocial factors and LBP may be associated has important implications. The techniques used to measure lumbar movement characteristics must be reliable, because these could influence the strength of association with LBP (in univariate models), and the association between psychosocial work characteristics and LBP (in multivariable models) (Davis and Heaney, 2000). Furthermore, if biomechanical factors at work are associated with LBP then these factors might also be important to consider when predicting sickness absence.

5.7) Summary

The current epidemiological evidence has shown that little is known about the physical and psychosocial risks for LBP and related sickness absence in sedentary work environments. Whilst a better understanding of the physical risks might help to make this work environment safer, identifying psychosocial risks and symptom modifying factors could help to improve our understanding of sickness absence among sedentary workers. However, few predictive studies to determine the effect of occupational lumbar movement characteristics on the risk of future LBP have been conducted, and those that do exist pertain to industrial rather than sedentary jobs (Marras et al, 2000). This is perhaps due to the status of current technology, which lacks sufficient sensitivity to quantify exposure to sitting and lumbar sitting postures at work. Thus, the magnitude at which exposure to biomechanical factors in sedentary jobs might result in LBP is unknown. Future investigation of occupational lumbar movement characteristics might also consider measuring psychosocial factors, since the evidence suggests that these factors might be associated.

The literature has shown that clinical and occupational psychosocial risk factors can predict future sickness absence. However, few studies have measured a wide range of psychosocial factors and considered possible inter-relationships between variables. Furthermore, psychosocial factors do not appear to have been readily measured alongside lumbar movement characteristics and biomedical factors. Thus, little appears to be known about the inter-relationships between different types of risk factors, or their combined influence on sickness absence due to LBP among sedentary workers. A study of this nature might help to explain the separate mechanisms responsible for LBP and sickness

Chapter 6

Themes of the literature review and synthesis

6.0) Themes of the literature review and synthesis.

The literature review has shown that LBP has a high prevalence and complex aetiology, and for those individuals affected, symptom recurrence is commonplace (Croft et al, 1998). At present, little appears to be known about the physical risk factors in sedentary jobs, and how they may contribute to the development of LBP. This is problematic, because like all occupational groups' sedentary workers are known to experience LBP, often when sitting at work, and for some this can lead to sickness absence and disability. These consequences are costly and troublesome to workers, employers, the healthcare system and society.

Anecdotal evidence from sedentary workers and current Health and Safety recommendations suggest that prolonged sitting and lumbar postures can result in LBP (HELA, 2006). In contrast, systematic reviews of the contemporary epidemiological evidence fail to support the view that sitting at work and LBP are associated (Hartvigsen et al, 2000; Lis et al, 2007). However, the conclusions of these reviews are based on studies that used imprecise (although the best available at the time) experimental techniques to assess exposure to sitting and related lumbar postures. In contrast, the biomechanical evidence proposes plausible mechanisms by which certain lumbar sitting postures might contribute to the development of LBP (Adams and Hutton, 1986; Ishihara et al, 1996; Hedman and Fernie, 1997). Considering the literature suggests that sitting static and maintaining a kyphotic lumbar posture might aggravate current symptoms, whilst lumbar movement-in-sitting and maintaining a lordotic lumbar posture may reduce current symptoms. At present, little appears to be known about how lumbar movement and postures in sitting (i.e. lumbar movement characteristics) relate to temporal factors or LBP symptoms among sedentary workers.

Due to technological limitations, the daily activities and lumbar movement characteristics of sedentary workers do not appear to have been measured. This literature review suggests that a FOG system (if further developed) might be able fit these requirements. Assuming this were possible, gaps in the literature could then be investigated, most notably the potential associations between sitting at work, leisure time activity and LBP. However, existing tools that have been used to measure LBP do not appear sensitive enough to measure the transient discomfort (i.e. range of symptoms) experienced by workers whilst sitting at work. Improved tools may help to measure low back discomfort and assist investigation of reported symptom aggravating and relieving aspects of sedentary work. Little is known about these so called 'symptom modifying factors', how they relate to seated lumbar movement characteristics, or sickness absence.

Some workers who develop LBP will subsequently take sickness absence, and psychosocial factors are known to explain some of this behaviour (Bongers et al, 1993; Grossi et al, 1999). However, the extent to which clinical (psychological distress, fear avoidance beliefs), and occupational (beliefs about the causes of LBP, job satisfaction, social support, psychological demand) psychosocial factors are associated with work-relevant low back discomfort and future sickness absence amongst sedentary workers is unknown. Studies have been completed in clinical and occupational settings, but have generally used a small number of psychosocial measures to predict absence (Grossi et al, 1999; Hoogendoorn et al, 2002; Morken et al, 2003). The results of these studies may not be applicable to sedentary workers, and because prediction of sickness absence is complex, a wider range of psychosocial factors (alongside other variables) also need to be measured.

Based on the evidence there is reason to believe that physical and psychosocial aspects of sedentary work may increase the risk of LBP, and related sickness absence. Therefore, a prospective epidemiological investigation of LBP in sedentary work environments seems justified, and should measure lumbar sagittal movement characteristics, demographics, symptom modifying factors, and clinical and occupational psychosocial factors. This may help to inform Health and Safety policy and the development of interventions to reduce the impact of LBP in sedentary jobs.

Hypotheses

Based on gaps identified in the literature, several hypotheses were proposed. To test these hypotheses, instruments were first developed, followed by a workforce survey and experimental investigation.

Main hypothesis

Dynamic lumbar sagittal movement characteristics measured during sedentary work are statistically significant predictors of future self-reported LBP, yet clinical and occupational psychosocial factors are stronger predictors of future sickness absence due to LBP.

Sub-hypotheses

1. Psychosocial factors (psychological distress, work-related causal beliefs, job satisfaction, psychological demand and social support) are not significantly associated with self-reported low back discomfort at work, but do predict the occurrence and extent (>7 days duration) of subsequent sickness absence due to LBP.
2. Workers who maintain a lordotic lumbar sitting posture will report significantly less low back discomfort at work and future LBP than workers who adopt a kyphotic lumbar sitting posture.
3. High levels of fear avoidance beliefs about activity are significantly associated with reduced walking outside of work, and are statistically significant predictors of future sickness absence occurrence due to LBP.
4. Workers who sit with a static lumbar posture will report significantly more low back discomfort at work than workers who adopt more dynamic sitting postures
5. Physical aspects of sitting reported to aggravate low back discomfort at work are statistically significant predictors of future sickness absence occurrence due to LBP.
6. Higher levels of physical activity (walking) outside of work will significantly reduce the probability of recurrent LBP and future sickness absence (occurrence and extent) due to LBP.
7. Future self-reported LBP can be significantly predicted from dynamic lumbar sagittal movement characteristics at work, although the addition of psychosocial and demographic data will enhance predictive ability.

DEVELOPMENT OF THE EXPERIMENTAL INSTRUMENTS

METHODS 1

Development and validation of a FOG system

8.1) Introduction

In order to investigate this thesis's hypotheses, technology was required that could reliably quantify exposure to everyday activities (sitting, standing, walking) and measure lumbar sagittal movement characteristics. Such a device could not be found in the literature, so a new system was developed, the details of which are outlined in this chapter.

8.2) Modification of the lumbar FOG to measure sagittal hip movement

The lumbar FOG designed by Stigant (2000) could not identify daily activities from lumbar sagittal movement characteristics. Therefore, to help identify activities the sagittal hip angle was also measured. To avoid the potential difficulties of integrating two different sensors a second FOG was used to measure sagittal hip movement alongside the lumbar FOG. However, the lumbar FOG was only sensitive to movement in the sagittal plane, and if attached to the lateral aspect of the hip it would be unable to measure sagittal hip movement, which would be in the sensors coronal plane. Therefore, the baseplate of the FOG was rotated 90° around the axis of the optical fibre, enabling it to be sited on the lateral aspect of the hip to measure hip flexion and extension (Figure 6).

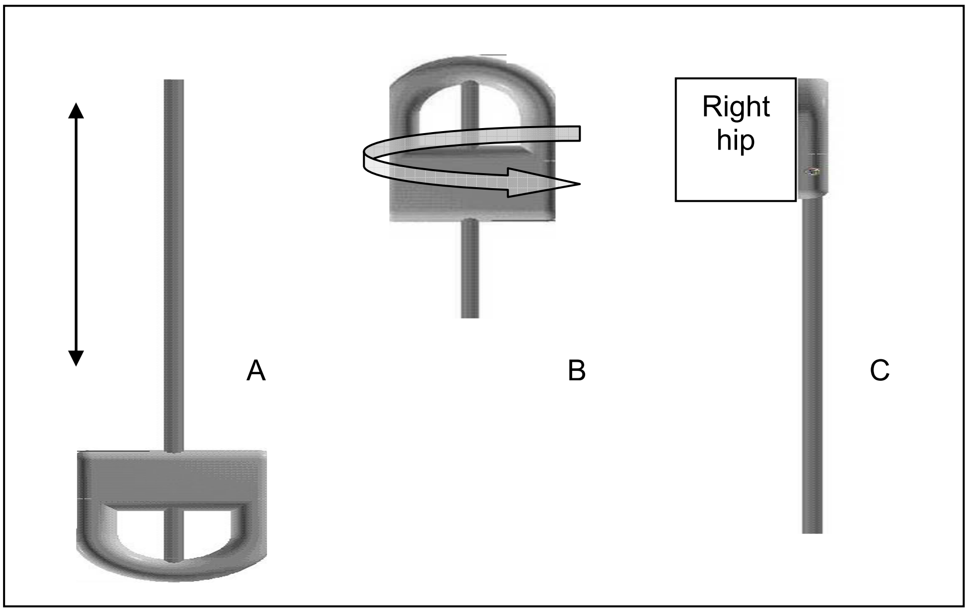

Figure 6: Sagittal plane posterior view of: (A) the lumbar FOG, (B) baseplate rotation around the optical fibre, and (C) the modified hip FOG attached laterally to a representation of the right hip

The following sections describe how the accuracy of the lumbar and hip FOGs was first determined in a calibration jig, and then on a group of subjects. The sensors were then used to measure the lumbar and hip movement of subjects during daily activities, to help develop activity detection software.

8.3) Calibration procedure

Previous research has described a procedure to calibrate the lumbar spine FOG using a slotted calibration jig (Stigant, 2000). A similar procedure was adopted in this present study, although the slotted calibration jig was modified to also incorporate the hip FOG.

8.3.1) Calibration of the lumbar and hip FOGs

The modified slotted calibration jig consists of a series of curves etched into a perspex jig at 22.5° grooved intervals, enabling calibration over a 180° arc from 90° through to 270° (Figures 7 and 8). The shapes of these curves were taken from a previous jig developed by Stigant (2001), and were constructed using trigonometric calculations. How the angle formed by these curves relates to lumbar sagittal postures has previously been described (see 2.2.1). In relation to the hip, angles >180° would indicate an extended hip, while angles <180° indicating a flexed hip. Therefore, taking the 180° angle to represent the neutral standing position or 0°, in the jig the hip FOG was capable of measuring 90° flexion and 90° extension. Maximal hip flexion and extension ranges have been reported as 88° (Balague et al, 1999), and 30° (Bierma-Zeinstra et al, 1998), suggesting that the hip FOG was calibrated over a sufficiently large range of movement to measure the sagittal hip angle during daily activities.

To calibrate the sensors, the baseplate was orientated either vertically (lumbar) (Figure 7), or horizontally (hip) (Figure 8) in the jig. The optical fibre was then placed in each of the etched grooves (up to 225°), allowing the Analogue digital count (ADC) displayed on the datalogger to be recorded at each angle. Using the paired values for jig angle and FOG output (ADC), regression analysis and curve estimation was undertaken, producing a cubic polynomial equation from which analogue digital counts were converted into angular values for the curve in the FOG (Stigant, 2000).

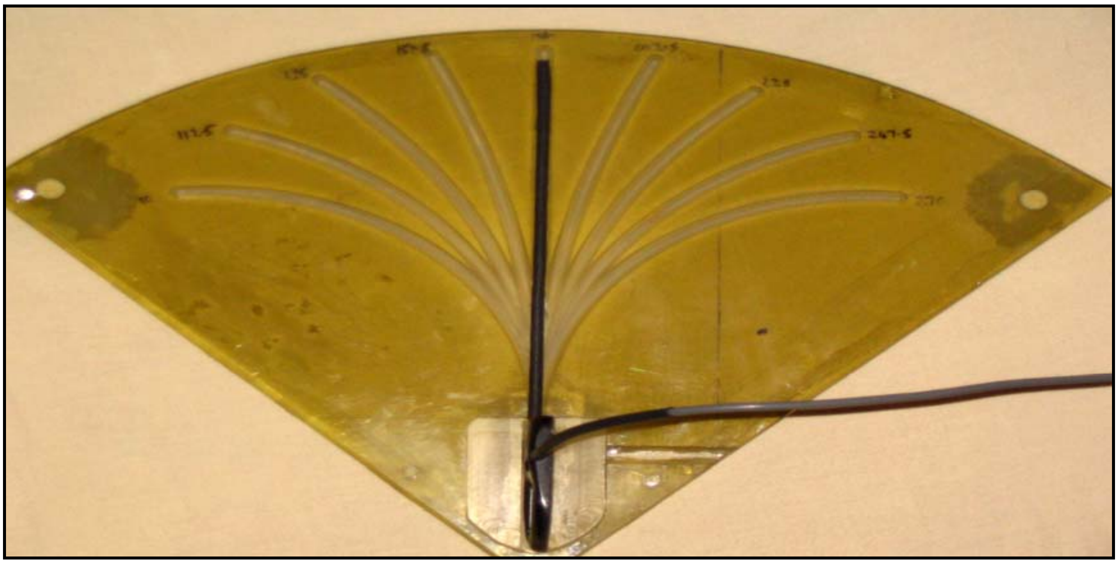

Figure 7: The modified slotted calibration jig containing a lumbar FOG

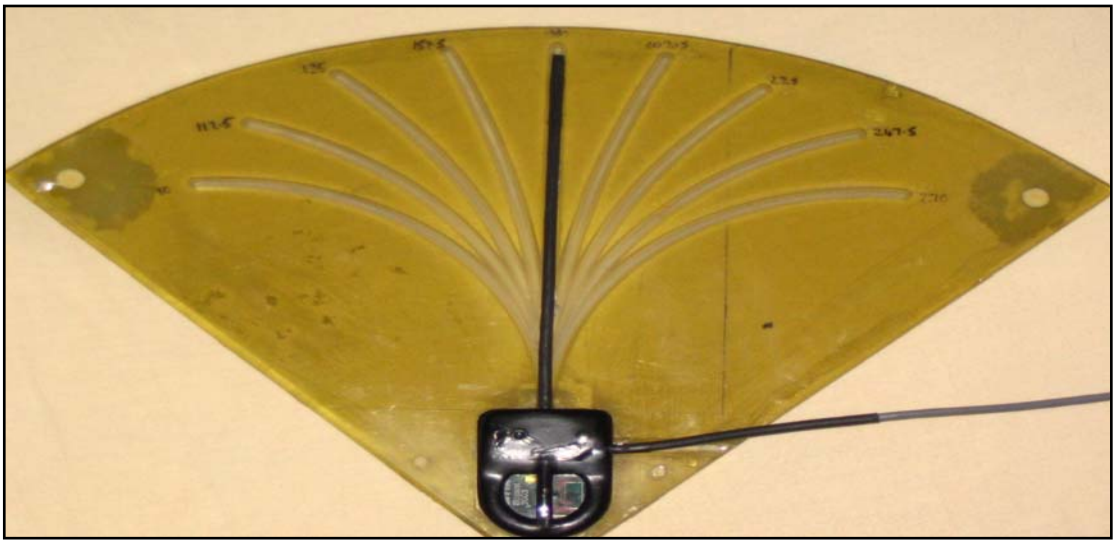

Figure 8: The modified slotted calibration jig containing a hip FOG

8.4) Accuracy of the FOG sensors

Three calibrated lumbar and hip FOGs were individually placed in the calibration jig and their outputs (ADC) were converted into angles and compared to the known jig angles. This sequence was repeated three times. These procedures would indicate if: (1) the researcher could accurately calibrate the FOGs; and (2) the FOG sensors were precise (because there were no lengthy time intervals to allow systematic errors to creep into the system). Readings from the hip and lumbar FOGs were repeated at five days and then eight weeks after calibration to investigate measurement repeatability and changes in output over time.

8.4.1) Statistical methods used to establish accuracy

Accuracy quantifies the degree of correctness of a measurement to its true value, while precision describes whether further measurements will show the same or similar results (Morris, 1996). There is no standard convention to express error, so the mean difference (đ) between the known angles of the calibration jig and the observed FOG angle was chosen as a concise indicator of accuracy. Limits of agreement (LoA) were also used to provide a measure of agreement between the FOG and the calibration jig, representing the interval between which 95% of observations should exist (if normally distributed), and can be calculated using the following equations: Lower LoA = đ – t x SD, Upper LoA = đ + t x SD (Bland and Altman, 1996). The value for t at the 5% significance level is obtained from two-tailed tables with degrees of freedom equal to the number of differences on which the SD is based minus one. The benefit of this statistical approach over the traditional correlation coefficient (r) has been widely documented (Burton, 1987; Bland and Altman, 1986; Stigant, 2000).

8.4.2) Comparison of the lumbar FOG with the modified calibration jig

Taking FOG measurements in the calibration jig using the calibration equation obtained on the same day, which represents the best possible situation, LoA showed that FOG readings may be up to 2° below or 7° above calibration jig angles. The mean difference ranged from 0.9° to 2.1° (Table 1). However, the first calibrated FOG (5001) appeared to be less accurate than the other two sensors. This may be due to the fact that this was the first lumbar FOG formally calibrated by the researcher. Using sensors 5002 and 5003 the mean difference and LoA were smaller, ranging from 0.9° to 1.4° and -0.6° to +3° respectively. Overall, the calibrated lumbar FOGs produced readings on the same day as calibration that were considered accurate. The FOG readings taken five days later were more consistent with each other and the earlier results from sensors 5002 and 5003, with the best sensor (5003), producing a mean difference of 1°, with LoA between -1° and +3°. The mean differences between measures were small for all FOGs, showing that readings taken five days after calibration are repeatable.

Table 1: Lumbar FOG errors in the modified slotted calibration jig, measurements being taken on the same day of calibration (day 0), and after five days (day 5)

	Day 0			**Day 5**		
FOG no.	5001	5002	5003	5001	5002	5003
đ	2.08	1.41	0.89	1.59	1.32	1.03
SD	2.16	0.86	0.68	1.13	1.03	0.92
LoA	-2 to +7	-0.6 to +3	-0.5 to +2	-0.8 to +4	-0.8 to +3	-1 to +3

All value are in degrees. đ = mean of differences between measures; LoA = limits of agreement between measures; n=20, t=2.08 at 95% confidence level.

To determine if the accuracy of the lumbar FOGs may fall after a long period of data collection, readings were taken after 8 weeks using the original calibration equation (obtained on day 0), and then compared to the known jig angles. This resulted in the upper LoA increasing for all FOGs, up to a maximum of 8° (Table 2). The mean difference also increased compared to values obtained on the same day as calibration, ranging from 2° to 2.6°.

Table 2: Lumbar FOG errors in the modified slotted calibration jig, measurements being taken eight weeks after calibration

FOG number	5001	5002	5003
đ	2.58	1.95	2.57
SD	2.43	1.54	1.40
LoA	-2 to +8	-1 to +5	-0.4 to +5

All value are in degrees. đ = mean of differences between measures; LoA = limits of agreement between measures; n=20, t=2.08 at 95% confidence level.

8.4.3) Comparison of the hip FOG with the modified calibration jig

When hip FOG measurements taken in the calibration jig using the calibration equation obtained on the same day were compared to the known jig angles, the LoA and mean differences were found to be small, ranging from -0.6° to +5° and 0.7° to 2° respectively (Table 3). Readings taken five days later produced very similar results, showing that measurements have good short term repeatability.

Table 3: Hip FOG errors in the modified slotted calibration jig, measurements being taken on the same day of calibration (day 0), and after five days (day 5)

	Day 0			**Day 5**		
FOG no.	4001	4002	4003	4001	4002	4003
đ	0.72	1.05	1.98	0.97	1.18	1.74
SD	0.55	0.82	1.42	0.95	0.66	1.04
LoA	-0.4 to +2	-0.6 to +3	-1 to +5	-1 to +3	-0.2 to +3	-0.4 to +4

All value are in degrees. đ = mean of differences between measures; LoA = limits of agreement between measures; n=20, t=2.08 at 95% confidence level.

Hip FOG readings taken in the calibration jig after 8 weeks were less accurate, the mean difference for all FOGs increasing up to a maximum of 3.5°, with 95% LoA between –1° and +8° (Table 4).

Table 4: Lumbar FOG errors in the modified slotted calibration jig, measurements being taken eight weeks after calibration

FOG number	4001	4002	4003
đ	2.28	2.05	3.48
SD	1.39	1.17	2.06
LoA	-0.6 to +5	-0.4 to +4.5	-1 to +8

All value are in degrees. đ = mean of differences between measures; LoA = limits of agreement between measures; n=20, t=2.08 at 95% confidence level.

8.4.4) Summary

Measurements taken by both FOGs in the calibration jig on the same day as calibration were found to be accurate when compared to the known jig angles. After a period of five days, measurements from either FOG remained repeatable. However, after 8 weeks the LoA for both FOGs increased, apparently due to an increase in the mean difference between the known jig angles and measurements taken by the FOGs. The result was an upwards shift of the upper and lower LoA, and because the SD remained fairly constant such increases are likely due to natural drift in the FOG outputs, a bias that was also found by Stigant (2000). Therefore, the FOGs do become less accurate over time, and failure to consider these facts would mean that serial measurements might not be reliable.

8.5) Attachment procedures

A standardised method to attach the lumbar FOG has previously been described (Stigant, 2000) and was used for this current study, although a new attachment procedure was developed for the hip FOG.

8.5.1) Attachment of the lumbar spine FOG

First the skin was cleaned using an alcohol swab, 3M double sided adhesive tape (No.1522) was then applied to the baseplate and guidetubes in 5cm and 2.5cm width strips. The lumbosacral junction between the sacrum and L5 was palpated in sitting using the index finger (Figure 9a), identification of this interspace being facilitated by asking the subject to tilt their pelvis anteriorly and posteriorly in the sagittal plane (Stigant, 2000). Using this landmark the FOG was then attached with the upper edge of the base plate level with the top of the sacrum. Next, the subject was asked to flex their lumbar spine, and the lower tube was fixed halfway up the flexible section of the FOG, with the upper tube being placed with its superior aspect level with the tip of the FOG (Figure 9b).

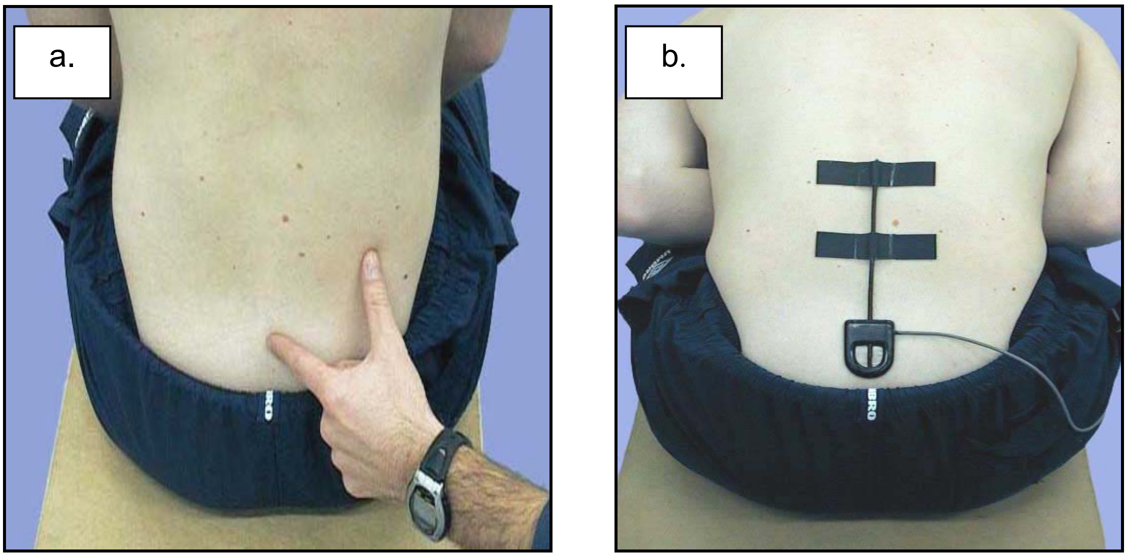

Figure 9: Attachment of the lumbar spine FOG (a) using the index finger to palpate the L5/S1 Interspace, and (b) placement of the FOG

8.5.2) Attachment of the hip FOG

Using the index and middle fingers the lateral tip of the iliac crest and the greater trochanter were palpated (Figure 10a). The hip FOG was then positioned so that the lower edge of the baseplate was beneath the iliac crest, the upper edge rested 1-2 cm above the greater trochanter, and the fibre aligned with the iliotibial tract. The lower guide tube was fixed halfway up the flexible section of the FOG, with the upper tube being placed near the tip of the FOG (Figure 10b).

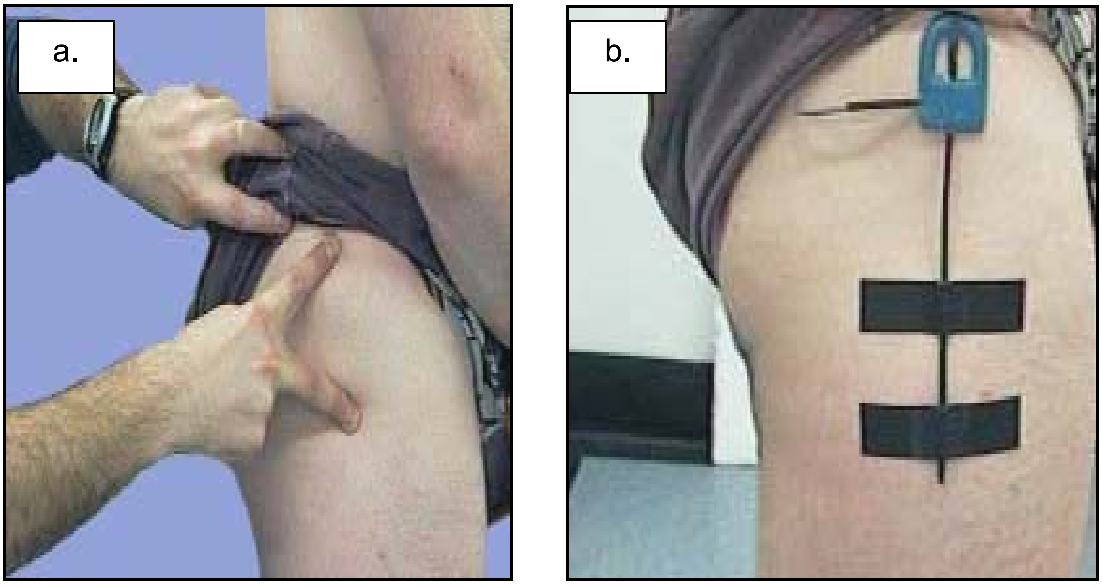

Figure 10: Attachment of the hip FOG: (a) palpating the iliac crest and greater trochanter, and (b) placement of the FOG

8.6) Intra-examiner repeatability using the FOGs

Measuring intra-examiner repeatability would help to establish if the researcher could reliably apply the FOG sensors to a group of subjects.

8.6.1) Repeatability test procedures

To minimise variability in the posture adopted by subjects the standardised test procedure described by Stigant (2000) was used. This would enable the results from this current study to be compared with the previous work of Stigant (2000). To standardise the lumbar FOG test procedure, all subjects stood on a wooden board with battens that set their feet apart, and three positions were adopted: full forward flexion in standing (Figure 11a); standing (Figure 11b); and full extension in standing (Figure 11c) (Stigant, 2000). For full forward flexion each subject was asked to bend forwards, reach to hold their own ankles, and if possible tuck their head between their legs. In the standing position, subjects were simply asked to stand still with their hands held in front of them. Extension in standing was achieved by asking subjects to put their hands over the top of their iliac crests, and to bend backwards as far as possible, and then breathe out (Stigant, 2000).

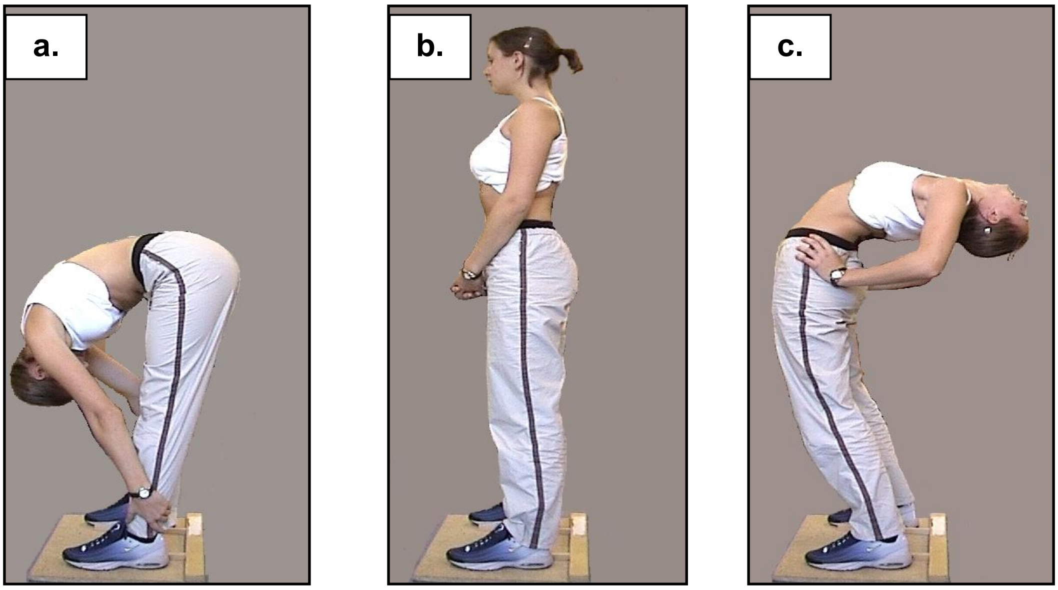

Figure 11: Standardised lumbar positions to determine repeatability (a,b,c)

Three standardised positions were chosen for the hip FOG: full hip flexion in standing (Figure 12a); standing (Figure 12b); and full hip extension in standing (Figure 12c). For hip flexion each subject was asked to maximally lift their right thigh while keeping their knee flexed at 90° and maintaining a natural lumbar lordosis. The standing position was unchanged, and hip extension required the subject to move their right leg straight behind them, without twisting their trunk.

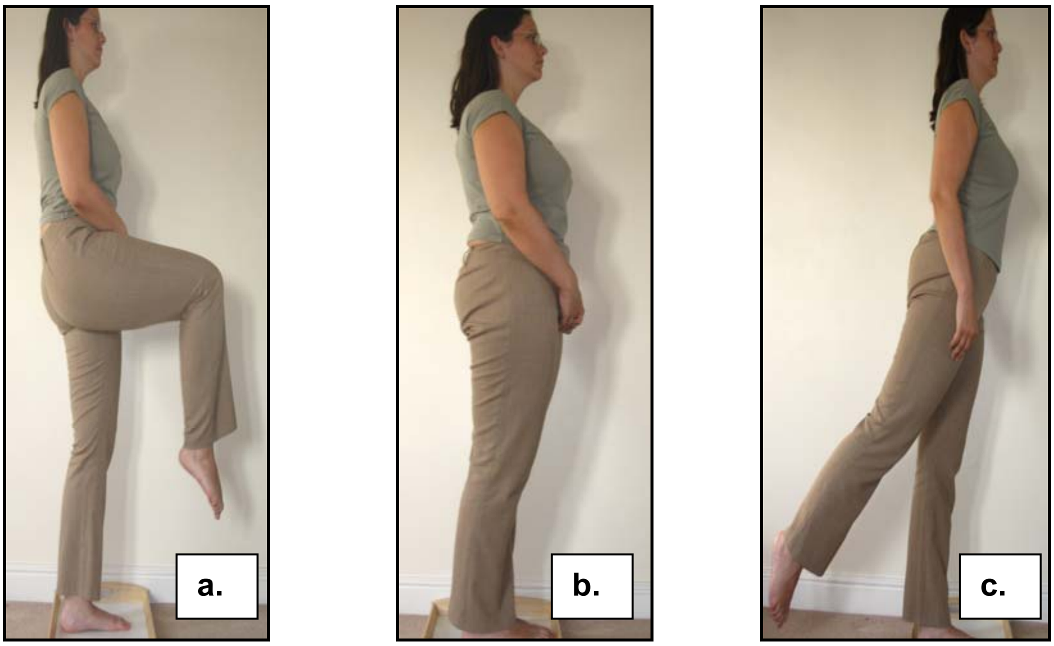

Figure 12: Standardised hip positions to determine repeatability (a,b,c)

Twenty student subjects were recruited from the Physiotherapy Department at the University of Huddersfield (11 male, 9 female, mean age: 21 years). In order to establish intra-examiner repeatability a lumbar FOG was attached to the subject and two sets of data were collected from each of the three test positions. This FOG was then removed, reapplied, and two more sets of data were collected. The same process was then repeated using the hip FOG. The order of testing varied, i.e. if subject one completed the lumbar FOG procedures first then subject two would then complete the hip FOG procedures first. This made it possible to determine the agreement of repeated measures for the same examiner, both for the first application and with reapplication of both FOG sensors.

8.6.2) Statistical methods

To determine the accuracy of the FOG sensors on a group of subjects the mean difference between measures (đ), standard deviation (SD), and the least significant difference (LSD) were calculated. The LSD uses the standard deviation (SD) of the test-retest differences and is calculated as follows: LSD = t X SD. The value for t at the 5% significance level is obtained from two-tailed tables with degrees of freedom equal to the number of differences on which the đ is based minus one. The LSD was chosen to provide an estimate of the difference between a pair of matched (test-retest) FOG readings which is significant at the 5% level. Conversely, where the measured difference is below the LSD, there is insufficient evidence to conclude that the readings are different (Bland and Altman, 1996). The above values were calculated for standing, lumbar flexion and extension. An overall measure of repeatability that took into account the differences between all three test-retest positions was also determined.

8.6.3) Intra-examiner repeatability using the lumbar FOG

The overall LSD for repeated measures without removing the lumbar FOG was 6.7°, and this increased to 11° when the FOG was removed and reapplied between measures (table 5). Lumbar flexion was shown to be the most repeatable position with a relatively small LSD (4.1° and 7.3°) under both conditions. Standing was the next most repeatable position with a LSD of 8° on the same application and 12° on reapplication. Extension was the least repeatable position with a LSD of 7.1° and 12° for the two conditions. Overall, repeated measures with the same FOG application had less variance (SD 3.19°) than with reapplication of the FOG (SD 5.27°). This is because the main source of error with the same application of the FOG is due to subjects not assuming the exact same position on repeated occasions. With reapplication of the FOG a further repositioning error is introduced by the examiner, hence this condition being less repeatable for all positions. Comparing the results of test-retest measurements for the same application of the FOG (overall LSD 7°), and reapplication (overall LSD 11°), it seems that any error introduced by reapplication of the baseplate is likely to be smaller than intra-subject variability. Test-retest mean differences were below the LSD for all conditions, showing that there were no statistically significant differences between measures ($P<0.05$).

Table 5: Intra-examiner repeatability using the lumbar FOG (n=20)

	Same FOG application				**Reapplication difference**			
	Overall	**Flexion**	**Standing**	**Extension**	**Overall**	**Flexion**	**Standing**	**Extension**
đ	0.58	0.75	1.28	-0.29	-0.69	1.46	-1.66	-1.86
SD (diff)	3.19	1.96	3.85	3.41	5.27	3.50	5.73	5.83
LSD	6.68	4.10	8.07	7.14	11.04	7.34	12.01	12.02

All value are in degrees. đ = mean of differences between test-retest measures; LSD = least significant difference between test-retest measures; t=2.093 at 95% confidence level.

8.6.4) Intra-examiner repeatability using the hip FOG

For the same application of the hip FOG the overall LSD was 9.9° (Table 6). When the FOG was removed and reapplied between measures this increased to 13.6°. Compared to the repeatability of the lumbar FOG these values are similar, although it would appear that the hip FOG positions were less repeatable. The small overall differences in the LSD between the same application and reapplication of the hip FOG (<4°), would suggest that the reapplication error was small, and intra-subject variation was again the main source of error. Notably, with the same application of the FOG the standing position had a high level of repeatability, producing a LSD of 6°. Both hip flexion and extension were less repeatable with larger intra-subject variation (SD 4.1° and 6.2°), this being reflected by a higher LSD (8.6 and 13.1°). Reapplication of the hip FOG made all measures less repeatable, although across all conditions there were no statistically significant differences between test-retest measures ($P<0.05$).

Table 6. Intra-examiner repeatability using the hip FOG (n=20)

	Same FOG application				**Reapplication difference**			
	Overall	**Flexion**	**Standing**	**Extension**	**Overall**	**Flexion**	**Standing**	**Extension**
đ	-1.72	-1.64	-0.19	-3.35	0.31	1.08	0.92	-1.08
SD (diff)	4.74	4.12	2.88	6.26	6.48	6.62	4.82	7.76
LSD	9.92	8.63	6.03	13.10	13.56	13.86	10.08	16.25

All value are in degrees. đ = mean of differences between test-retest measures; LSD = least significant difference between test-retest measures; t=2.093 at 95% confidence level.

8.6.5) Comparison with previously used instruments

The repeatability results for the lumbar FOG were compared to previous FOG measures by Stigant (2000), to provide an approximate measure of validity (Table 7). Stigant (2000) used the same test procedure, and the results from both studies are similar. Both examiners had previous experience attaching the lumbar FOG. The overall LSD was marginally lower in this current study (11°), compared to Stigant (14°). This was largely due to a smaller LSD for standing and extension (12° instead of 17°). Since the mean difference were similar between examiners, the higher LSD for Stigant (2000), particularly for standing and extension, was due to higher standard deviations. Measurements in flexion were almost exact, with Stigant (2000) having the best LSD of 7.3°.

Table 7: Intra-examiner repeatability for the lumbar FOG - test/retest by two different examiners on two different groups of subjects

	Examiner 1 (current study)				Examiner 2 (Stigant, 2000)			
	Overall	Flexion	Standing	Extension	Overall	Flexion	Standing	Extension
đ	-0.69	1.46	-1.66	-1.86	-0.48	-2.69	-0.49	2.02
SD (diff)	5.27	3.50	5.73	5.83	7.35	3.74	8.73	8.73
LSD	11.04	7.34	12.01	12.02	14.41	7.32	17.11	17.12

All value are in degrees. đ = mean of differences between test-retest measures; LSD = least significant difference between test-retest measures. n=20, t=2.093 (95% confidence) for the current study; n=18, t=2.110 for Stigant (2000).

Using the three test positions for the same application of the lumbar FOG the results of two different examiners that measured the lumbar ROM of two different groups of subjects were compared. Unfortunately, examiner 2 in Table 7 failed to describe the sex and age of the subjects. Therefore, a second set of data produced by Stigant (2000) was used (Table 8). However, these data included a larger and older sample (n=77, mean age: 35 years) than the current study (n=20, mean age: 21 years), and may not be directly comparable.

The mean flexion and extension range from standing and the total lumbar range were calculated. For males, the flexion (48° and 47.8°), and extension ranges (26.4° and 27.1°), were very similar for both studies. However, for the female group differences between the flexion (52.4° and 49.7°), and extension ranges (28.6° and 32.2°), were more pronounced. The total range of lumbar sagittal motion for males and females was 74° and 76° in this current study, compared to 75° and 82° for Stigant (2000). In both studies, females were shown to have a larger standing lordosis and greater range of extension, a finding supported by the literature (Pearcey, 1984). No large differences in relation to age were apparent, and this may be due to using disproportionate sized samples. Researchers have found similar ranges of lumbar sagittal movement for each of the parameters described above, despite using different measures (Mellin, 1986; Marras et al, 1993; Mayer et al, 1995). Therefore, it would appear that

FOG angles obtained using the lumbar test positions are comparable to results obtained using different instruments.

Table 8: Comparison of the mean ROM of two different groups of subjects measured by two different examiners using the lumbar FOG

	Examiner 1 (current study)				Examiner 2 (Stigant, 2000)			
	Sex	**n**	**Mean**	**SD (diff)**	**Sex**	**n**	**Mean**	**SD (diff)**
End point: extension	**Male** **Female**	11 9	127.2 122.1	17.66 17.81	**Male** **Female**	38 39	127.7 116.5	17.54 25.14
End point: flexion	**Male** **Female**	11 9	201.6 203.1	11.10 10.07	**Male** **Female**	38 39	202.6 198.5	7.47 8.46
Standing lordosis	**Male** **Female**	11 9	153.6 150.7	14.69 17.01	**Male** **Female**	38 39	154.8 148.8	13.23 14.78
Flexion range (from standing)	**Male** **Female**	11 9	48.0 52.4	28.5 30.0	**Male** **Female**	38 39	47.8 49.7	27.2 29.1
Extension range (from standing)	**Male** **Female**	11 9	26.4 28.6	21.9 22.4	**Male** **Female**	38 39	27.1 32.2	24.4 29.7
Total range (end flexion – end extension)	**Male** **Female**	11 9	74.4 75.9	11.08 13.35	**Male** **Female**	38 39	74.93 82.27	15.62 24.94

Mean and SD values are in degrees.

The mean standing hip angle measured by the hip FOG was 179° for females and 181° for males. Previous studies do not appear to have used a FOG to measure the standing hip angle, and measurements using video analysis, goniometers and electronic inclinometers have considered this angle to be 0° (Bierma-Zeinstra et al, 1998; Tully et al, 2002). Substituting 180° for 0° thus enabled the range of hip flexion and extension from the standing position, as measured by the FOG, to be compared to previous work. The mean range of hip flexion from the standing position was 79° for females and 76° for males, while the mean extension range was 15° for females and 10° for males. From the standing position, Tully et al (2002) found the average range of adult hip flexion to be 94°, and Bierma-Zeinstra et al (1998) found the mean range of hip extension to vary from 21.5° to 27.6°. These results show that the hip FOG apparently underestimated the range of hip flexion and extension, perhaps because the hip FOG was not calibrated for use over a single joint that has a centre of rotation.

8.6.6) Summary

Intra-examiner errors appear to be similar for both lumbar and hip FOGs, and difficulty controlling the subjects test positions was the greatest source of error for both sensors. These positions were chosen due to the authors' clinical belief in their reproducibility, and the work of Stigant (2000). The author now recognises that more standardised positions exist, and would have provided a more useful test of FOG repeatability. The difficulty of achieving a standardised position was more pronounced for the hip FOG, and for both sensors placement errors contributed to the overall loss of accuracy. The actual positions did not change very much, even with reapplication of the FOGs, as demonstrated by the small mean differences between pairs of measurements, < 2° for the lumbar spine FOG, and <3.5° for the hip FOG. Therefore, it would appear that FOG measurements of sagittal lumbar and hip angles are repeatable. Results obtained using the lumbar FOG also seem to relate closely to previous studies that have measured lumbar movement using different methods, although this is not the case for the hip FOG. These findings are not a formal test of validity, but do support the view that the lumbar FOG is of comparative value to existing measures.

8.7) Measuring hip and lumbar angles to characterise activities

The following section describes how the FOG sensors were used to measure the hip and lumbar angles of a group of subjects during everyday activities (standing, sitting, walking). These angles were subsequently used to characterise the activities and develop Interrogator activity detection software.

8.7.1) Observational procedure

Ten Physiotherapy students (6 female, 4 male, mean age: 20 years) from the University of Huddersfield were recruited for this study, and data collection took place on these premises. The compact flash (CF) card was programmed to log information for 8 minutes and then inserted into the datalogger. The FOGs were then attached to the subject in a laboratory environment, and both the datalogger and video camera were turned on. Subjects were first asked to stand, and then to flex and extend their lumbar spine and right hip. These movements provided a check that both FOG sensors were working, and later enabled the datalogger and video camera records to be synchronised. Subjects were asked to regularly alternate between activities (standing, sitting, walking) over the eight minute period. If subjects failed to alternate activities (at least once every 90 seconds), they were asked to adopt a new activity. A standard office chair and a sofa were made available, and each subject was asked to sit in both (if they didn't naturally), and were shown to adopt static, dynamic, kyphotic (slumped) and lordotic (upright) sitting postures. Subjects were also asked to walk at varying speeds.

8.7.2) Data analysis

Digital video camera data were used in the Noldus Observer software® (Noldus, New York, USA) to log changes in activity. This enabled the start and finish times of periods of standing, sitting and walking to be recorded. Using basic rules: standing (both feet on the floor with an erect trunk), sitting (gluteal contact with the support of a chair), and walking (minimum of two steps) activities were time-coded. Activities were only coded if two independent observers could agree on their occurrence at the same second, and movements between activities e.g. sit to stand, were coded as transitions. This enabled the mean, minimum, maximum and standard deviation (SD) of hip and lumbar angles to be calculated in Microsoft Excel® (Redmond, USA) for each activity. Visual analysis of each subject's datatrain (displaying FOG angles over time) also made it possible to view the characteristic motion profile of each activity (Figure 14), and to calculate hip gradients. For each subject, positive and negative gradients were calculated from three randomly selected periods of each activity. This analysis was undertaken with a view to discriminating between static and dynamic activities. Each gradient was measured by selecting three datapoints and their corresponding angles from the selected period of activity, and then calculating the change in hip angle over time. For example, if the angles 111.8° and 112.3° were separated by three datapoints (Figure 13), the positive gradient would be 0.5° (per 3 datapoints). Gradients were calculated over three datapoints rather than maximum and minimum values over a longer period of time because hip acceleration was not constant for any activity, and it was envisaged that this might help to make activity detection more sensitive.

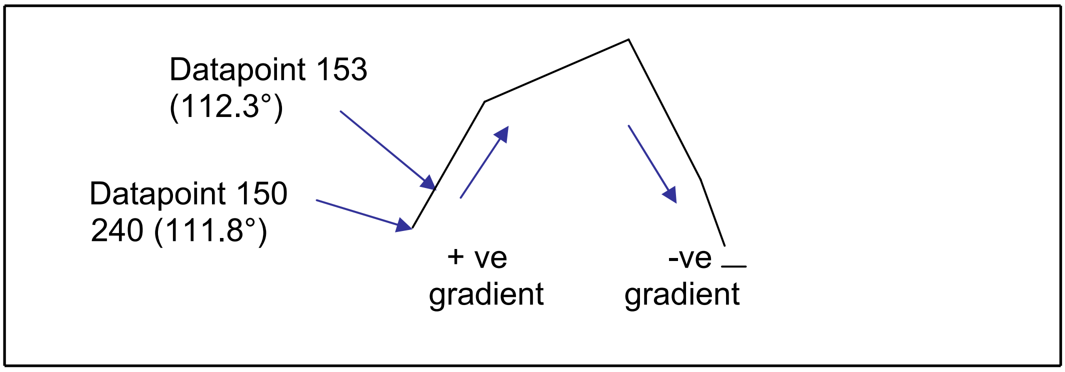

Figure 13: Illustration of a hip oscillation, depicting positive and negative gradients, and the values used to calculate the size of a positive gradient

8.7.3) Description of each activities movement characteristics

Displaying the FOG angles over time and using the time-coded activities from the Observer record it is possible to describe each activity's gross movement characteristics. In Figure 14, (A) represents the start of a period of standing, and the hip and lumbar angle are approximately 175° and 155°. Movement of the hip joint towards flexion results in the hip angle reducing, as demonstrated by the start of walking at 3 seconds (B), after which the hip angle starts to rise and fall in a reciprocal manner. These oscillations each have a negative (during hip flexion), and a positive (during hip extension) gradient. At 8 seconds there is an increase in lumbar spine and hip flexion, with angles settling well below those that might be expected for standing or walking. This illustrates a subject who is standing, bending forwards to move into sitting, and then remaining sitting (C).

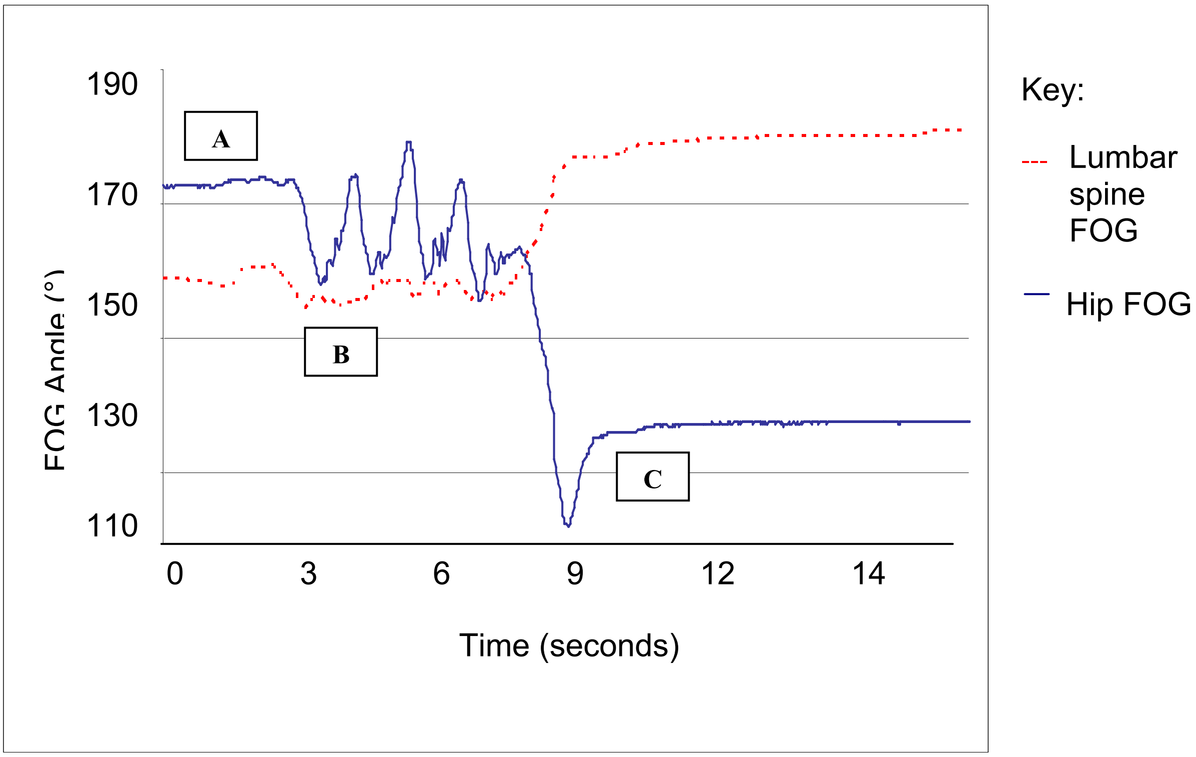

Figure 14: Datatrain of lumbar spine and hip FOG angles displayed over time during: (A) standing, (B) walking and (C) sitting

8.7.4 Activity characterisation using angular values

Analysis of the Excel data showed that during standing there was little change in the hip and lumber angles over time. For seven out of ten subjects, maximum deviation of the hip angle from the mean was <10° (Table 9, column 5). Subjects four (32°), eight (10.5°) and ten (10.3°) did appear to momentarily exceed 10°, but this was due to the first second of a transitions being detected (signifying an error during Observer activity classification). Similar results were obtained with the lumbar FOG; maximum deviation of the lumbar angle (lordosis) from the mean was <15° for nine out of ten subjects. The hip gradients calculated for standing did not exceed ±0.37° (per 3 datapoints) for any of the subjects. These findings support the view that standing, as defined by the parameters above, involves a relative lack of movement, and may be considered a 'static activity'.

Table 9: Hip and lumbar spine FOG angles measured during standing

	Hip				**Lumbar spine**			
Subject	**Mean**	**Max**	**Min**	**Max dev from mean**	**Mean**	**Max**	**Min**	**Max dev from mean**
1	170.8°	179.3°	163.6°	8.5°	147.4°	154.7°	139.2°	8.2°
2	188.8°	194.7°	181.6°	7.2°	130.7°	140.3°	124.3°	9.6°
3	176.4°	181.9°	168.3°	8.1°	154.2°	161.9°	143.9°	10.3°
4	190.7°	197.1°	158.4°	32.3°	144.5°	154.8°	137.3°	10.3°
5	177.6°	180.3°	169.6°	8°	149°	158°	144.3°	9°
6	175.9°	181.9°	168.3°	7.6°	142.1°	156.3°	132.5°	14.2°
7	172.2°	174.9°	167°	5.2°	138.1°	152.4°	130.6°	14.3°
8	175°	183.9°	164.7°	10.3°	153.6°	160°	148.9°	6.4°
9	182.6°	189.7°	174.3°	8.3°	155.2°	161°	152.5°	5.8°
10	183.9°	192.4°	173.6°	10.3°	164.1°	183.9°	139.1°	25°

Walking was defined by the characteristic oscillatory movements recorded when the right hip flexed and extended. For each subject, the ROM for any one hip oscillation ranged from 7° to 35°. The maximum and minimum values in Table 10 suggest that the range of hip movement during walking is actually much higher, but this is due to extreme values over a period of walking being detected, rather then during any one oscillation. The mean hip angles recorded for walking were lower than the mean angles recorded for standing (range: 5.8° to 17.4°) (column 5), due to the fact that the hip is further towards extension when standing, and walking predominantly involves flexion of the hip relative to standing. Compared to the mean lumbar angles for standing, the mean lumbar angles for walking generally increased (because the lumbar spine became more flexed), resulting in negative differences between these mean values for eight of the subjects (range: -1.5° to -15.3°) (column 9). Therefore, during walking the mean hip and lumbar angles generally remained within ±15° of standing values (table 11, columns 5 and 9). The hip gradients calculated for walking exceeded ±0.67° (per 3 datapoints) for all subjects

Compared to standing values, during sitting the mean hip angle reduced by a minimum of 38° (Table 11, column 5), and the mean lumbar angle increased by a minimum of 16° (column 9). The hip gradients calculated for sitting did not exceed ±0.37° (per 3 datapoints) for any subject. Movement from standing to sitting involved hip and lumbar spine flexion, the hip angle reducing and the lumbar angle increasing (Table 11). To provide an indication of the minimum amount of hip flexion that might be required to sit from the standing position, the maximum hip angle in sitting was subtracted from the mean standing hip angle (Table 11). For all subjects the reduction in the hip angle ranged from 19° to 43° (column 6).

Table 10: Hip and lumbar spine FOG angles measured during walking

	Hip				Lumbar spine			
Subject	**Mean**	**Max**	**Min**	**Stand mean – walking mean**	**Mean**	**Max**	**Min**	**Stand mean – walking mean**
1	156.9°	178.9°	132°	13.9°	147.5°	154.2°	140.6°	0.1°
2	177.6°	194.7°	138.3°	11.2°	135.2°	163.6°	127.4°	-4.5°
3	159°	184°	110.8°	17.4°	169.5°	196.5°	150°	-15.3°
4	179.4°	200.9°	142.5°	11.3°	146.2°	154.4°	133.1°	-1.7°
5	165.8°	190.3°	134.1°	12.2°	160.1°	171.4°	150.2°	-11.1°
6	168.5°	189°	137°	7.4°	150.5°	161.4°	138.6°	-8.4°
7	165.9°	185.6°	147.7°	6.3°	145.6°	158.3°	130.8°	-7.5°
8	169.2°	188.7°	145.4°	5.8°	155.1°	171.8°	146.7°	-1.5°
9	176.3°	190.7°	155.2°	6.3°	161.3°	172.2°	154.2°	-6.1°
10	176°	197.1°	156.1°	7.9°	162.2°	173.1°	152.9°	1.9°

Table 11: Hip and lumbar spine FOG angles measured during sitting, and the differences in angles from standing

	Hip					Lumbar spine			
Subject	**Mean**	**Max**	**Min**	**Standing mean – sitting mean**	**Standing mean – max sitting angle**	**Mean**	**Max**	**Min**	**Sitting mean - standing mean**
1	116.7°	140.3°	74.5°	54.1°	30.5°	180.3°	190.9°	153.1°	32.9°
2	134.7°	145.4°	99.8°	54.1°	43.4°	162.1°	186.4°	135.9°	31.4°
3	134.7°	147.7°	114.0°	41.7°	28.7°	188.4°	196.5°	177.9°	34.2°
4	142.9°	151.6°	129.6°	47.8°	39.1°	166.3°	188.9°	134.6°	21.8°
5	106.2°	154.2°	93.2°	71.4°	23.4°	171.0°	191.6°	149.3°	22.9°
6	112.9°	150.6°	96.6°	63.0°	25.3°	170.9°	197.4°	128.2°	28.7°
7	133.6°	153.6°	107.3°	38.6°	18.6°	172.6°	184.9°	152.1°	34.5°
8	133.1°	148.0°	119.4°	41.9°	27.0°	179.8°	183.9°	164.0°	26.2°
9	138.7°	143.4°	121.0°	43.9°	39.2°	179.5°	193.0°	163.7°	24.3°
10	145.7°	152.5°	130.9°	38.2°	31.4°	180.3°	185.5°	175.8°	16.2°

8.7.5) Summary

The two sensor FOG system was worn by ten subjects during 76 periods of standing, 50 periods of walking, and 34 periods of sitting, over a total period of 80 minutes. This enabled the sagittal movement characteristics of the hip and lumbar spine to be described for each activity.

8.8) Development and validation of the Interrogator software

This section describes the development of Interrogator software designed to identify activities and their lumbar movement characteristics. The origin of this custom built software has previously been described (see section 5.3.4)

8.8.1) Development of a prototype analytical algorithm

Using the FOG data collected from student subjects (n=10) whilst standing, sitting and walking, selected hip and lumbar angular characteristics for each activity were used to develop a prototype analytical algorithm. This contained parameters for activity detection that were written into the Interrogator software using Visual Basic (Table 12). It was decided to use the standing hip and lumbar spine angles recorded at the start of data collection as 'reference values', in order to help the software discriminate between different activities. This was anticipated to produce a flexible system that was able to take into account individual differences in standing position, and possible errors in sensor placement (especially for the hip FOG).

Table 12: Algorithm rules for the detection of activities

Activity	Hip Angle (HA)	Lumbar Angle (LA)	Hip Gradient	Hip Range
Standing	SHA*-HA <±10°	n/a	≤±0.37° per 3 datapoints	n/a
Sitting	SHA-HA >15°	n/a	≤±0.37° per 3 datapoints	n/a
Walking	MHA† <±15° from SHA	LA <±15° from SL≠	≥ ±0.68° per 3 datapoints	≥7° ≤35°

*SHA=reference standing hip angle, ≠ SL=reference standing lordosis. (see 8.8.2. for a description of how the reference angles were used in the software). †MHA=mean hip angle (measured over a 2 second buffer: see 8.9.2 for mechanism of action), Standing was defined by its static nature, allowing minimal variation from the reference hip angle, and minimal velocity of hip movement within this range. Sitting required a minimum reduction in the reference hip angle of 15°, also allowing for minimal velocity of hip movement.

In order to detect walking a large hip range and increased hip gradient (compared to sitting and standing) was used. Unlike for sitting and standing, where a fixed hip able was used to aid activity characterisation, the dynamic nature of walking meant that such this type of approach would be illogical to help define walking. Therefore, a method to calculate the mean hip angle over time (two seconds) was devised (see section 8.9.2). Since the lumbar angle deviated very little from standing values during walking, this was also added as an additional check. If the software failed to allocate an activity following analysis of hip and lumbar angles then a transition was detected (Appendix 1).

8.8.2) Software modification

Detection of each activity was dependant on how the angles measured by the FOG sensors related to reference standing values (Appendix 1). Therefore, the original Interrogator software was modified to enable reference values to be input (Figure 15: A). A 'predict activity' option was also added (B), which launched the data analysis routine (containing the analytical algorithm) that interrogated the hip and lumbar angles displayed on the datatrain, placing the results onto an Excel spreadsheet as an activity log. Because the mechanism of data interrogation changed as a result of these early software developments, its final mode of action is described later (see section 8.9.2). To help distinguish between activity during work and leisure time, an option was added that enabled these periods to be analysed separately (C).

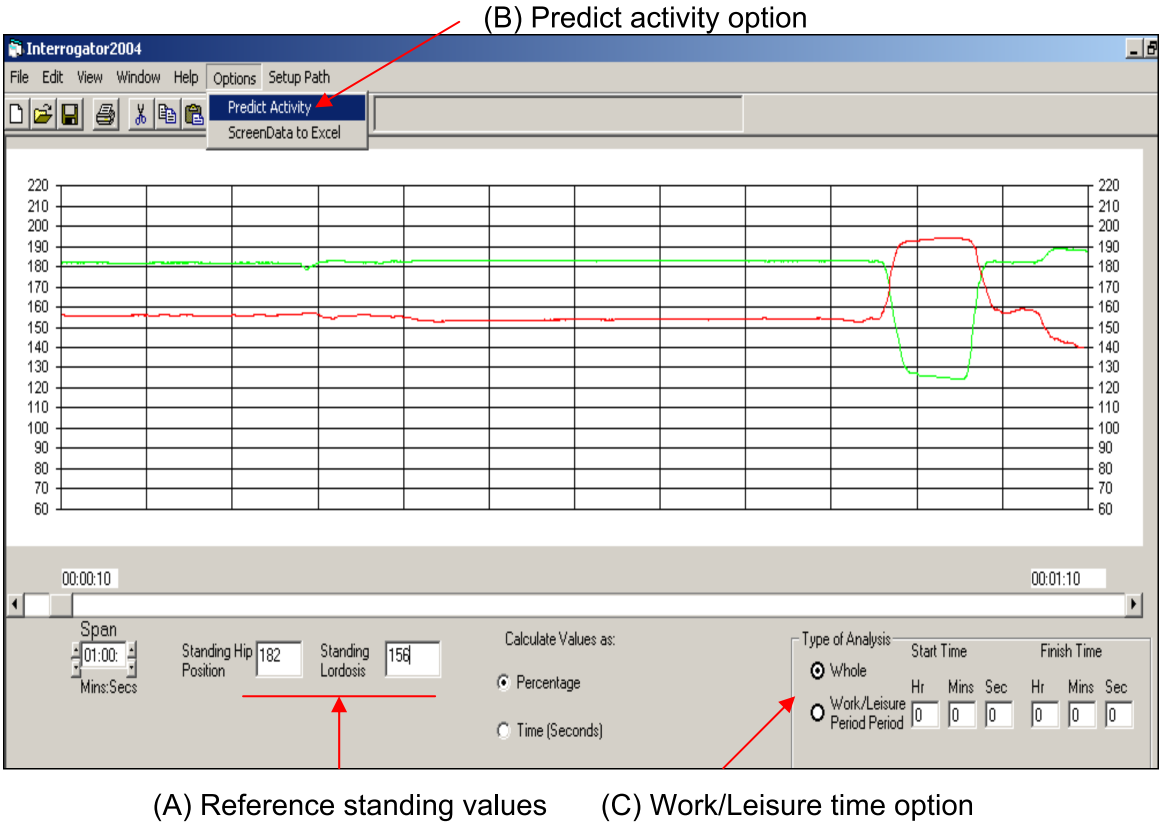

Figure 15: Visual display of the Interrogator software, illustrating a datatrain and its new options

8.8.3) Data analysis

Using the Observer record as an accurate reference, comparison with the activity log produced by the Interrogator software was undertaken. The sensitivity and predictive value of the Interrogator software was then calculated using previously described methods (Uiterwaall et al, 1988) (Appendix 2). For the purposes of this experiment, sensitivity was expressed as the percentage of activities that were identified by the Interrogator software, based on the Observer record. The predictive value was the percentage of these activities that were correctly identified by FOG system. Both calculations of sensitivity and predictive value were included because the validity of activity detection software depends on both features (Bussmann et al, 1998; Uiterwaal et al, 1998).

8.8.4) Results

A second per second comparison of the Interrogator and the Observer records demonstrated that detection of standing was the most sensitive (80%), followed by sitting (76%), and then walking (61%). Standing and sitting both demonstrated high predictive values of 92% and 99%, although walking was lower (80%). Some standing (20%) was not detected because cut-off points for the hip gradient or hip angle were exceeded during dynamic postural adjustments. The software also failed to detect some sitting (24%) because transitions were detected either at the same point in time that sitting occurred (due to a software coding error), or between periods of sitting. These latter periods of transition occurred when subjects moved their hips in sitting, generally towards flexion, and exceeded the set gradient. For walking, the sensitivity was poor (61%) because the hip and lumbar angles exceeded the algorithm rules. Changes in the speed of walking also reduced the sensitivity, because either the minimum gradient was not reached, or the hip range limit was exceeded. Overall, the sensitivity and predictive validity of the software was 73% and 79% respectively.

8.9) Improvements to the Interrogator software

8.9.1) Modification of the analytical algorithm

This section describes how the prototype algorithm was developed to produce an improved set of algorithm rules that were used in the main study (Table 13). At first, the prototype algorithm was modified by widening the cut-off points of exceeded parameters for each activity. However, this failed to improve the overall sensitivity and predictive values of the software, which both remained <80%. The prototype algorithm was based on an analysis of mean FOG angles and extreme values over the duration of data collection, thus explaining why these rules lacked sufficient sensitivity to detect particular periods of activity. Subsequently, there was a prolonged period of testing and re-testing in order to develop the algorithm. Improvements stemmed from a more in depth analysis of hip and lumbar angles over two second periods of each activity for each subject. This resulted in the design of a new set of algorithm rules.

Table 13 shows that the gradients originally used to help detect sitting and standing were removed, enabling sitting and standing to be identified more quickly and reliably (the start of these activities frequently involved considerable hip movement). Based on the data, a hip range was set for sitting and standing, and standing also had a lumbar range set. Tables 10 and 11 suggest that the hip ranges in Table 13 might be exceeded during activities, but these new ranges are based on an analysis of sitting and standing activities over two second periods, and not the total duration of time that these activities occurred. For sitting and standing, rather than using a specific lumbar angle, the mean hip angle over two seconds was used to provide a dynamic reference value (from the standing hip angle), thus making activity detection became more stable.

Table 13: Improved algorithm rules for the detection of activities

Activity	Hip Angle	Lumbar Range	Hip Range
Standing	*SHA-MHA† < 15°	≤ 25°	≤ 25°
Sitting	SHA-MHA ≥ 15°	n/a	≤ 40°
Walking	<3 seconds since the last hip peak Gap between last 2 peaks not <0.3 seconds or >2.4 seconds Difference in height of the last peak and present hip angle ≤15° Difference in depth of the last trough and present hip angle ≤25° Hip range not <5° or >60° Difference in height: any of the last 2 adjacent peaks must be ≤18° Difference in depth: any of the last 2 adjacent troughs must be ≤27°		

*SHA=standing hip angle,
†MHA=mean hip angle (analysed over a 2 second buffer, see 8.9.2),

Detection of walking was more difficult, because although involving reciprocal hip movement (shown as oscillations with characteristic peaks and troughs), the amplitude, gradient and distance between these oscillations varied according to walking speed and stride length. This lack of consistency meant that the prototype algorithm rules were often exceeded. The new set of rules used a sub-routine called 'peak detector' to scan for hip peaks and troughs in the datatrain, to help identify walking (see 8.9.2 for description of action). The rule '<3 seconds since the last peak' was used to detect the end of walking, with the rule 'gap between last 2 peaks not >2.7 sec or <0.3 sec' also helping to detect a change in activity from walking. Variability in the hip oscillations during a period of walking was accounted for by the differences between the respective height and depth of the last 2 peaks and troughs, and the present hip angle (see Appendix 3a for diagram). A large potential hip range was also set.

8.9.2) Mechanism of data interrogation and activity identification

On selection of the 'predict activity' option information on lumbar and hip angles is fed into the software. This builds the main array that stores lumbar spine and hip angles for each datapoint, which each represent 1/50th of a second. To analyse this data a 'sliding buffer' holds information about the angles and their corresponding datapoints over a two second period. The sliding buffer works by moving from left to right (with time), operating in parallel underneath the main array to calculate: (1) the hip range across the buffer; (2) the lumbar range across the buffer; and (3) the mean hip angle across the buffer. Having reached the right hand end of the buffer (datapoint 100 out of 1-100), the next datapoint (101) is entered into the array (far right), and the oldest (2 second old) datapoint (1) falls out of the buffer. The variables hip range, lumbar range and mean hip angle are calculated by keeping track of the maximum and minimum values in the sliding buffer, and also keeping a running sum of all the hip angles across the 2 second period, subtracting the exiting value from the sum before adding the replacement value. This helps to economise calculation of the mean (by not repeatedly calculating the sum of all hip angles). The results of these calculations are held in appropriately named variables, and can be tracked to a point in time or over a specified period because of the datapoints. A separate array (WP) holds information about the hip oscillations, notably the time, height and depth of the last two peaks and troughs. The height and depth of peaks and troughs were calculated using a sub-routine called ‘peak detector’. This identified when the hip angle was greater (peak) or smaller (trough) than the mean hip angle, enabling the highest and lowest angular values to be identified.

Once the 2 second sliding buffer is filled the software allows entry to the algorithm that contains sub-routines with rules governing activity detection (Appendix 3b). For each new datapoint running through the activity detection section of the software, the initial activity is changed to a transition. As the new datapoint and its characteristics over the past 2 seconds and the last two peaks and troughs passes through the activity detecting subroutines the activity allocation changes if sitting, walking or standing is recognised. If the activity allocation emerging at the end of the activity detection section is the same as the previous allocation (for the previous datapoint) then the software keeps a record of the activity allocation and a time is not entered. If during passage along the datatrain activity allocation changes, then a new activity is recorded. This procedure is controlled by a subroutine called ‘RecActy’ that records the datapoint at the start of a new allocation, and also codes this activity as a number. Therefore, detection of a new activity is used to signify the end of a previous activity, which is also recorded by ‘RecActy’.

8.9.3) Results

Compared to the Observer record the improved Interrogator software identified most standing (97%), sitting (99%), and walking (94%) activities. The predictive values were also high: 95% for standing, 98% for sitting and 96% for walking. For the overall detection of these activities the software exhibited sensitivity and predictive values of 97%.

8.9.4) Mechanism to analyse lumbar movement characteristics

This section describes how the activity detection algorithm was integrated with sub-routines designed to extract lumbar movement characteristics. Stigant (2001) has previously developed and validated sub-routines that calculate: (1) the standard deviation (SD) of lumbar angles; (2) mean lumbar angle; (3) overall time spent with a static or dynamic lumbar spine; and (5) the overall time spent in different portions of an individuals total lumbar range (see section 5.3.4 for an explanation of these calculations/terms). In the software, these analyses begin when the start of a new activity is recorded by 'RecActy' (Appendix 4). Therefore, these sub-routines were unchanged, and were used to analyse lumbar movement characteristics over the specific duration (calculated using datapoints) of a period of activity.

Additional new analysis routines were written to determine: (6) how long workers spent sitting with a lordotic or kyphotic lumbar posture; and (7) the mean lumbar angular velocity for each activity. The detection of different postures was relatively straightforward; the cumulative number of datapoints with lumbar angles $<180°$ (per sitting period and overall) were calculated, thus enabling periods of time spent sitting with a kyphotic lumbar posture (i.e. any remaining datapoints $\geq 180°$) to be determined. The mean angular velocity was calculated by keeping track of absolute changes in lumbar angles over time. Routines were also written that would rank periods of sitting according to their length, and calculate lumbar movement characteristics (1-7) over the duration of the three longest periods of sitting. For work, these periods were arbitrarily selected as a representative measure of exposure to prolonged sitting.

The raw values (datapoints, lumbar angles) used to calculate lumbar movement characteristics also feed into routines that are cumulative, in order to provide an overall summary for each activity (Appendix 4). Each of these subroutines operates in parallel to the activity detecting section of the software. Since the length of working shifts would vary, to standardise comparisons a routine was written that would display the amount of time spent in different activities and postures as percentages of total working time.

8.9.5) Results

To test that the Interrogator software accurately reported the overall amount of time spent in each activity, the sum of individual periods were compared to the overall amounts calculated by the software, and were found to be accurate. Similar procedures were undertaken to check the accuracy of the ranked periods of sitting, longest three periods of sitting, and the amount of time spent (for each activity) within different proportions of the lumbar range, and no errors were found. In order to check that the lumbar movement characteristics were accurately calculated, the values displayed in the Interrogator output for each activity and overall were compared to manual calculations. A stream of datapoints and their corresponding lumbar angles were generated from the datatrain, and using the datapoints displayed in the Interrogator output the SD, mean lumbar angle and mean angular velocity were calculated for two individual periods of each activity and overall. Datapoints <180° during a period of sitting were also used to establish the period of time spent with a lordotic lumbar posture. These values were then compared to those derived from the Interrogator output, and were found to be accurate (perfect agreement),

8.10) Testing the FOG system in a sedentary work environment

8.10.1) Procedure

To test the FOG system in a sedentary work setting, five call centre workers agreed to wear the system for 4 hours each during a working shift, their behaviour being simultaneously recorded on a digital video camera. Using this observational data activities during work (standing, sitting, walking) were time-coded, enabling comparison with the Interrogator activity log.

8.10.2) Results: activity detection

The workers were observed to adopt 57 periods of sitting, 129 periods of standing and 111 periods of walking. In comparison, the FOG system over-detected the occurrence of all activities: sitting (187 periods), standing (397 periods), and walking (172 periods). Analysis of the data showed that this was because during periods of sitting, standing and walking short transitions were detected, typically lasting <1 second. These transitions were due to any one of the parameters required for the detection of the occurring activity being exceeded, thus splitting the activity into two periods and increasing the number of separate periods of activity detected. Therefore, a filter was added to the software in order to remove transitions of short duration (<1 second) from periods of sitting, standing and walking. This reduced the tendency of the FOG system to over-detect the occurrence of activities: (78 sitting periods, 173 standing periods, 127 walking periods).

The Interrogator software's activity log showed that most movements into and out of sitting were detected as transitions (allocation: transition/sitting/transition). Whilst these transitions were not always detected before and after every sitting period, the FOG system detected at least one transition preceding or proceeding the majority of sitting periods identified using the Observer software (n=53, 93%). Where no 'transitions' were detected immediately before or after a period of sitting (n=4, 7%) subjects were shown to have moved from standing into and out of sitting without exceeding the set lumbar or hip range (allocation: standing/sitting/standing). These activity allocation sequences enabled the activity log to be manipulated in order to help overcome a problem with the detection of some periods of sitting. The activity log of three of the workers showed that on six separate occasions a prolonged period of standing was found between two periods of sitting (allocation: sitting/standing/sitting), without any transitions being detected between these activities. The data showed that on each occasion the subjects were sat and their right hip slowly extended to within 15° of the reference standing hip angle, thus triggering a change in activity from sitting to standing as a reclined sitting posture was adopted. Therefore, the filter was modified to remove periods of standing from between two periods of sitting, thus enabling prolonged periods of sitting to be identified.

8.10.3) Results: sensitivity and predictive value

Sensitivity and predictive values for the detection of sitting were high (99% each), but reduced for standing (96% and 91%), and walking (89% and 94%).

The results showed that some manually coded activities (based on visual interpretations of behaviour) were less sensitive to change than the Interrogator software. Indeed, postural sway during standing and hesitation during walking were not always identifiable during Observer coding, and resulted in the software splitting these activities into two, although the filter did help to limit these effects. Reductions in sensitivity and predictive value were also due to the algorithm that drives the Interrogator software failing to fully characterise or discriminate between different activities. For walking, the software had difficulty detecting a small number of steps (<2 right hip peaks), or very irregular sized peaks and troughs. Some of these periods were subsequently detected as standing, thus reducing the predictive values for standing. Furthermore, the algorithm could not discriminate between bending forwards and sitting, thus reducing the predictive value for sitting. Overall, the sensitivity and predictive values were high (97% each).

8.11) Summary of Chapter 8

This chapter has described how a lumbar FOG was modified to measure sagittal hip movement; both lumbar and hip FOGs were subsequently calibrated and found to be accurate. The repeatability of these sensors was then ascertained on a group of subjects, and lumbar and hip angles were measured during everyday activities. Using the angular characteristics of each activity an analytical algorithm for activity detection was written into custom built Interrogator software. This software was subsequently tested and modified to optimise activity detection. Compared to sensitivity and predictive values obtained in an experimental setting, for standing and walking the performance of the FOG system reduced in the field, these activities being detected with less sensitivity and predictive value. However, overall the FOG system identified sitting at work with greater sensitivity and predictive value than in an experimental setting. This reflects the nature of sedentary work; there were less frequent changes in activity, and proportionally less walking and standing. Analysis routines to extract lumbar movement characteristics (particularly for sitting) were also integrated into activity detection software, and were shown to be accurate. It is anticipated that the developments described in this chapter will usefully enable the FOG system to be used to investigate sedentary (biomechanical) risk factors for LBP.

METHODS 2

Questionnaire booklet development

9.1) Questionnaires

The relationship between psychosocial factors, LBP and sickness absence is complex (Davis and Heaney, 2000; Hoogendoorn et al, 2000; Hartvigsen et al, 2004). Therefore, a range of factors were measured using previously validated questionnaires. In order to investigate occupational psychosocial and symptom modifying factors new questionnaires were also developed. These questionnaires were presented to subjects in the form of a booklet rather than as single instruments, and the process of development is discussed below. The final booklet of questionnaires can be found in Appendix 5a.

9.1.1) Work-Related Causal Attributions Questionnaire

The attributions questionnaire was developed by Linton and Warg (1993) to measure: (1) work-related causal attributions (ATTRIBW), (2) individual causal attributions (ATTRIBI), and (3), preventative factors (ATTRIBP) associated with LBP. However, because this current study was interested in workers beliefs about the work-related causes of back discomfort, only the ATTRIBW scale was included. This consisted of 12 items that used a 10-point Likert scale where respondents rated attributions ranging from 1=never a cause to 10=always a cause.

Linton and Warg (1993) failed to state the psychometric properties of their questionnaire, although Bartys (2003) has validated the causal attribution sub-scales (ATTRIBW and ATTRIBI) on a sample of industrial workers. Principal Component Analysis (PCA) found three scales: attributions of psychosocial workplace factors, attributions of physical workplace factors and attributions of organisational factors. These components explained 58% of the variance, each had a Cronbach's Alpha score of 0.8 (showing a high degree of internal consistency), and no significant difference was found on test-retest analysis. Since the causal factors sub-scale was designed to measure the beliefs of industrial workers, it was modified for use on sedentary workers. The following statements were omitted: 'Lack of safety and assistive devices', 'Heavy lifts at work' and 'Lack of information about how work is to be done'. Instead, factors that have been reported by sedentary workers to cause/exacerbate discomfort: 'Poor chair', 'Prolonged sitting' and 'Hotdesking', were included. This new instrument, the Sedentary Work Causal Attributions Questionnaire (SWATTRIB) was found to be valid and reliable (see sections 10.2-10.3). Three constructs for work-related causes of LBP were found: (1) physical demands (PDEM), (2) work environment (WENV), and (3) work organisation (WORG) (see p261 for questionnaire). Each sub-scale is scored using a 5 point Likert scale ranging from; 1=never a cause to 5=always a cause. The WENV sub-scale contained 5 items, WORG 3 items, and PDEM 4 items, and Likert scores ranged from 5-25, 3-15 and 4-20 respectively.

9.1.2) Sitting and Symptom Modifying Factors Questionnaire

Symptom modifying factors (SMFs) are everyday activities or postures that alleviate or aggravate LBP symptoms (Biering-Sorenson, 1983). The Sitting and Symptom Modifying Factors Questionnaire (SSMQ) is a new instrument designed to measure reported symptom modifying factors in sedentary work environments. Its development was largely based on the authors' personal clinical experience and was designed because a suitable instrument had not previously been developed. Eleven statements were constructed, six were thought to aggravate symptoms, and five were thought to relieve symptoms. The SSMQ was found to contain three reliable sub scales (see section 10.4): (1) physical-aggravating (PHYAGG); (2) posture-relieving (POSREL); and (3) movement-relieving factors (MOVREL) (see p 262 for questionnaire). The questionnaire is scored using a 5 point Likert scale ranging from; 1=strongly disagree to 5=strongly agree. There are six items in the PHYAGG sub-scale, two in POSREL and three in MOVREL, and so Likert scores for each scale ranged from 6-30, 2-10 and 3-15 respectively. High scores indicate stronger symptom aggravating or relieving factors.

9.1.3) Psychological Demands Questionnaire

Psychological demand relates to "how hard workers work" (Meshkati et al, 1990), and the psychological demands questionnaire (PDQ) was originally developed as a scale for the Job Content Questionnaire (JCQ) (Karasek et al, 1998). High psychological demand has been reported as an important predictor of poor call handler well-being (Sprigg et al, 2003). Therefore, Karasek's psychological demand subscale was used in this current study and consists of five questions that use a four point Likert scale, ranging from; 1=strongly disagree to 4=strongly agree, producing a score between 12 and 48 (see

Appendix 6b for scoring system). A high score indicates high psychological strain, while a low score indicates low psychological strain. The instrument has been used for decades in a variety of occupational settings and has proven validity and reliability (Schechter et al, 1987; Brisson et al, 1998).

9.1.4) Social Support Questionnaire

The social support questionnaire (SSQ) was adapted from a sub-scale in the Psychosocial Aspects of Work questionnaire (PAW). This questionnaire also measures job satisfaction and mental stress, and has previously been validated in a variety of occupational settings (Burton et al, 1996; Burton et al, 1997; Bartys, 2003). The SSQ consists of four statements (e.g. I like most of my fellow workers), and uses a 5 point Likert scale ranging from; 1=strongly disagree to 5=strongly agree. Scores range from 4-20, a high score indicating a high level of perceived social support.

9.1.5) General Health Questionnaire

The General Health Questionnaire (GHQ) is widely regarded as providing an efficient measure of ‘strain’ or psychological distress (Goodchild and Duncan-Jones, 1985; Nelson, 2000). Several versions of the GHQ exist, and the 12 item version was chosen because it is the shortest version available, and is known to be valid and reliable (Winefield et al, 1989; Pevalin, 2000). The recommended scoring system uses a Likert scale 0-3, and the overall score ranges from 0-36, higher scores being indicative of higher levels of psychological distress.

9.1.6) Nordic Musculoskeletal Questionnaire

The Nordic Musculoskeletal Questionnaire (NMQ) is widely used in Europe and has been adapted by the National Institute for Occupational Safety and Health (NIOSH) for use in the United States (Salerno et al, 2002). The instrument measures the prevalence rates of self-reported musculoskeletal symptoms at several anatomical sites (Kuorinka et al, 1987), and has been used in a wide diversity of workplaces (Dickinson et al, 1992). Several authors have demonstrated that the NMQ is a valid and reliable tool for occupational research (Baron et al, 1996; Salerno et al, 2002). This current study was concerned with measuring symptoms that may be associated with LBP, so the NMQ was shortened, measuring symptoms reported in eight body areas in the past 12-months and 7-days.

9.1.7) Fear Avoidance Beliefs Questionnaire – Physical Activity

To measure the fear associated with physical activity and work the fear avoidance beliefs questionnaire (FABQ) was developed (Waddell et al, 1993). This instrument has two sub-scales that relate to physical and work activities. The work activities sub-scale could not be used because it was developed for manual workers and its items might confuse sedentary workers (e.g. ‘My work is too heavy’). Therefore, only the fear avoidance beliefs physical activity sub-scale (FAB-phys) was chosen. FAB-phys consists of four statements that use a six point Likert scale ranging from; 0=completely disagree to 5=completely agree (Waddell et al, 1993), a high score identifying individuals who are fearful of pain on movement. This sub-scale has shown to be valid and reliable using a 5 point Likert scale (Symonds, 1995), and so has a range of possible scores (4-20). This scoring method was chosen because it conformed with most of the other scales used in the booklet.

9.2) Individual questions

9.2.1.) Low back discomfort scale

A new low back discomfort scale was developed to measure workers symptoms whilst sitting at work. The scale was designed to enable a wide range of symptoms to be reported (Appendix 5a). The visual appearance of the scale was based on a 100mm visual analogue scale, and these are widely accepted as a sensitive, reliable and valid measure of symptom intensity (Jensen et al, 1986; Melzack, 1987; Collins et al, 1997). Subjects were asked to mark on the scale the intensity of any discomfort they had experienced whilst sitting at work ‘today’. For LBP, symptoms are also known to fluctuate over time (Jensen et al, 1996; Bolton, 1999), so a second scale rating discomfort experienced whilst sitting at work in the ‘past week’ was used. Subjects were also asked how frequently they experienced discomfort when sat at work in the past week; never; occasionally; quite a lot; or all the time.

9.2.2) Job satisfaction

Due to the large number of questionnaires that would be distributed to subjects a concise measure of overall job satisfaction was chosen. Therefore, the question “If you take into consideration your work routines, management, salary, promotion possibilities, and work mates, how satisfied are you with your job?” was used. Job satisfaction was rated on a 5 point Likert scale with anchors of 1=not at all satisfied, through to 5=completely satisfied. This measure was originally validated by Kunin (1955), and has since been used in industrial studies (Linton, 1991; Linton and Warg, 1993), and in yellow flag screening questionnaires (Linton and Hallden, 1998; NZ Guidelines, 2002). Therefore, this measure has good content validity, and statistical reports of its construct validity or structure are not pertinent given that it comprises one statement.

9.2.3) Symptom bothersomness, function and disability

LBP is a complex phenomenon and Deyo et al (2003) have suggested using 6 core questions to measure its multiple dimension (symptoms, function, general health, disability (work and social), and satisfaction with care). These standardised questions were developed by a team of internationally respected LBP experts (Deyo et al, 1998), and have been used in several different studies (Gross and Battie, 2002; UK Beam Team., 2004). Due to their short length and excellent content validity these items were included in the questionnaire booklet.

9.2.4) Additional self-report items

As a crude measure of previous occupational exposure, subjects were asked if their previous job involved spending a lot of time sitting with four choices; never; occasionally; quite a lot; and all the time. Subjects were also asked if their previous job had involved any manual work or heavy lifting. Items were also included to measure previous experience of LBP.

9.3) Questionnaire booklet design and presentation

The aim of this booklet was to present questionnaires to subjects in a way that was user-friendly and encouraged a high response rate. Therefore, the front cover was designed to attract as much interest as possible, with the Spinal Research Unit’s logo in the top right hand corner and the title *‘Understanding Back Trouble – Your Chance to Help’* in the centre. Each booklet also had a unique subject ID number, making it possible to link questionnaire responses to individuals. The first page sought general information about sex, age, job type and activity. The next section related to the measurement of low back discomfort, its perceived causes (SWATTRIB), and symptom modifying factors (SSMQ). These were placed at the front of the booklet because the measurement of discomfort whilst sitting at work was integral to a number of hypotheses. Indeed, the order of the questionnaires in the booklet was carefully considered, since questionnaires placed at the front are more likely to be completed, and in a more consistent manner (Beam Team., 2004)). Subsequent sections focused on the subjects work situation (PDQ, SSQ), life in general (GHQ), and experience of musculoskeletal symptoms (NMQ), before reaching a cut-off point where only individuals who had previously experienced LBP >24 hours were asked to continue. Information was then sought about LBP history and fear avoidance beliefs. Subjects who had experienced LBP in the past week were also asked to complete the six questions proposed by Deyo et al (1998).

9.4) Pilot study procedure

The booklet of questionnaires was distributed to call centre workers at Job Centre Plus, Clydesbank (n=92), and office workers at Hall Mead School, Upminster (n=12). In both samples the questionnaires were given to a 'neutral' employee to distribute amongst the workforce. Each questionnaire had a covering letter that outlined the nature of the study and explained that participation was voluntary. Completed questionnaires were returned to the 'neutral' employee in a supplied sealed envelope. Each questionnaire had a final section that asked respondents to indicate what they thought about its content and wording. The total response rate was 38% (n=39), although when a reminder message was placed on staff notice boards this improved to 47% (n=49). The pilot study identified that most respondents felt that the booklet was too lengthy, were uncertain if they needed to complete all of the questions, and were concerned that their employer may see the results. Several booklets were not fully completed, and some items were reported as ambiguous. For instance, in SWATTRIB respondents were unsure what was meant by 'hotdesking'.

9.4.1) Changes to the questionnaire booklet

A sentence was added to the introduction page making subjects aware that they should try and complete all of the questions, and that confidentiality was assured. To encourage completion, halfway through the booklet a statement was added encouraging subject's to continue completing the questionnaires. A comment was also added to the hotdesking statement in SWATTRIB to clarify its meaning, e.g. 'sharing your chair with other people'. The length was reduced by excluding three questions proposed by Deyo et al (1998); for the purposes of this study general health was already being measured by the GHQ, work disability could be measured by absence, and satisfaction with care was not considered pertinent. In its lengthiest form the response rate to the booklet was 48%, and because shorter questionnaire surveys generally have better response rates (Krosnic, 1999), the final shortened questionnaire booklet might improve the response rate in the main study (Appendix 5a). A high response rate (>70%) is generally regarded as desirable for sample representativness (Passmore et al, 2002), although lower response rates do not necessarily indicate lower representativness (Krosnic, 1999).

9.5) Development of a follow-up booklet

To collect prospective data a follow-up booklet was developed (Appendix 6). This had an ID number on the first page box so that baseline and follow-up questionnaires could be matched. To ensure that each subject's level of exposure to sitting had not changed during the follow-up period, there was a question to check that the total number of hours worked in a typical week remained unchanged. The next section was about the measurement of low back discomfort, after which there was a cut-off point for subjects who had not experienced LBP lasting more than 24 hours. Respondents who continued were asked questions about LBP and absence in the past 6-months, with a further questionnaire measuring fear avoidance beliefs. The follow-up booklet was not extensively tested prior to its use in the main study, because it was shorter than the baseline booklet and its contents were worded and presented in a similar way. Response rates usually reduce at follow-up, and so to minimise non-response bias reminders would be issued (Weinstein and Deyo, 2000).

9.6) Justification of the questionnaires

Whilst the previous sections in methods 2 have established the reliability and validity of the measures that were used in the questionnaire booklet, their inclusion also requires justification in light of the hypotheses. Based on the evidence presented in the literature review (*see Chapters 1, 4, and 5*), symptoms and psychosocial factors are known to influence the development of disability amongst patients and workers with LBP (Linton, 2000; Truchon and Fillion, 2000; Waddell and Burton, 2001; Hartvigsen et al, 2004; Pincus et al, 2006). However, in relation to workers, most evidence relates to industrial or manual jobs, so there was a perceived need to use previously validated measures on a cohort of sedentary workers. This would enable researchers to draw comparisons between different occupational groups, and for the purposes of this thesis, allow investigation of predictors of sickness absence due to LBP amongst sedentary workers. Whilst no 'standardised' symptom or psychosocial measures appear to exist in the literature, widely recognised questionnaires (described earlier in Methods 2) were considered appropriate for the purposes of this study.

Despite this thesis having a definite occupational focus, certain 'clinical' psychosocial factors were also measured (psychological distress; fear avoidance beliefs), since there is a purported need to better understand how these relate to occupational outcomes (alongside occupational psychosocial factors) (Main, 2000) (*see sections 5.3 and 5.5 for further discussion*). Psychological distress was measured using the 12-point general health questionnaire. This measure has shown to be just as useful as longer questionnaires, and is referred to as an important predictor of disability in numerous systematic reviews (Truchon and Fillion, 2000; Pincus et al, 2002; Pincus et al, 2006). The fear avoidance beliefs questionnaire was also selected due to its recognised psychometric properties (related to physical activity), and its perceived importance in clinical models of disability (Vlaeyen et al, 1995; Pincus et al, 2002).

Numerous reports and systematic reviews have shown occupational psychosocial factors to play a significant role in the development of chronic disability (Waddell and Burton, 2001; Waddell et al, 2003; Hartvigsen et al, 2004), albeit mainly amongst non-sedentary occupational groups. Therefore, questionnaires were chosen that would enable widely recognised 'psychosocial aspects of work' (job satisfaction, social support, psychological demand) to be measured. As shown earlier (*see section 1.7*), causal beliefs about work are highly prevalent amongst the general population, although their role in explaining sickness absence is unknown. To investigate this area a new questionnaire had to be developed (due to the absence of a tool for use in sedentary jobs), and is described earlier in Methods 2. Overall, a large number of psychosocial measures were included in the questionnaire booklet, thus enabling predictors of sickness absence to be determined using multivariable models. To date, few studies have measured a wide range of influences, although recent literature suggests that measuring multiple risk factors is important (Burton et al, 2005; Shaw et al, 2007), due to interrelationships between variables. The wide range of psychosocial factors measured in this study was therefore deemed relevant to test aspects of the main hypothesis, the cross-sectional components of sub-hypotheses 1 and 3, and part of sub-hypothesis 7.

In order to measure back discomfort whilst sitting at work and symptom modifying factors, new instruments had to be developed. This was because similar tools could not be found amidst the literature. The justification for measuring symptom modifying (aggravating) factors is that whilst thought to be important to sedentary workers (Dankaerts, 2006), their influence on sickness absence does not appear to have been investigated (*this links to sub-hypothesis 5*). The rationale for measuring back discomfort is that existing measures may not be sensitive enough to account for the symptoms experienced by sedentary workers (*see sections 4.3 and 4.4. for further justification*). This was an important measure since it would help to explain associations between work-relevant symptoms, psychosocial factors (*sub-hypothesis 1*) and biomechanical factors (*sub-hypotheses 2 and 4*). It should be made clear that whilst unrelated to most of the hypotheses, the NMQ was included within the questionnaire booklet primarily to control for the potential confounding effect of other musculoskeletal symptoms (in multivariable models). In summary, the questionnaire measures used in this thesis were justified in light of the hypotheses, which were designed to further understanding about LBP and related sickness absence amongst sedentary workers.

METHODS 3

Validation of the questionnaires

10.1) Pilot studies using sedentary workers

In order to test the psychometric properties of the SWATTRIB, SSMQ and FAB-phys questionnaires, the booklet containing these instruments was distributed to an experimental sample of sedentary call centre workers from Job Centre Plus, Grimsby, (n=128), and O2, Arlington (n=71). The response rate was 68% and 135 workers were recruited (Job Centre Plus n=97, O2 n=38).

10.2) Validity of the Sedentary Work Causal Attributions Questionnaire (SWATTRIB)

The construct validity or structure of the SWATTRIB was analysed using PCA. Construct validity occurs where an instrument behaves in a way that can be predicted by an underlying theory (Rick et al, 2001).

10.2.1) Principal Components Analysis (PCA)

This statistical technique analyses the total variance among questionnaire items and identifies underlying factors that explain the correlations among a set of variables (Afshinnia and Afshinnia, 2004) in order to construct sub-scales. Ideally the sample size should exceed four times the number of items in any one scale, and 100 is the minimum ideal required sample for PCA (Norman and Streiner, 1999). Factors were extracted on the magnitude of their eigenvalues, and only factors with eigenvalues >1 were extracted (Rick et al, 2001). Varimax rotation was then used to help identify patterns in the data, and a lower limit of <.03 was set to reject variables with weak factor loading. PCA was performed on the whole cohort (n=135), and 3 components were extracted explaining 58% of the total variance (Table 14). The first factor accounted for 32% of the variance, with the second and third factors accounting for 10% and 16% respectively. One limitation of PCA is that naming the component products of analysis is arbitrary (Norman and Streiner, 1999). However, the extracted components did make conceptual sense as work-related causes of back discomfort (work environment; work organisation; physical demands).

Table 14: Sub-scales, variance (%) and Item loading for SWATTRIB

Work environment (WENV) (32%)	***Work organisation (WORG)(10%)***	***Physical demands (PDEM) (16%)***
Rapid work pace (0.68)	Lack of work organisation (0.69)	Poor work posture (0.62)
Long working hours (0.67)	Lack of interest from company's management (0.87)	Poor chair (0.79)
Too few breaks (0.65)	Lack of interest from unions (0.63)	Hotdesking (0.62)
Monotonous work (0.76)		Prolonged sitting (0.71)
Workplace's physical environment (0.76)		

The PCA was repeated for each of the call centres (Job Centre Plus and O2), to check whether the same results would be produced from different sedentary groups. Results confirmed the findings from the whole sample.

10.3) Reliability of the SWATTRIB

The reliability of the SWATTRIB was determined using Cronbach's alpha and test-retest analysis.

10.3.1) Cronbach's alpha

Internal consistency relates to the interrelatedness of a set of items (Schmitt, 1996), and is typically measured using Cronbach's alpha (Cronbach, 1947; Cronbach, 1951). The minimum value considered to be internally consistent is widely regarded as 0.70 (Loewenthal, 1996; Rick et al, 2001; Norusis, 2003). Based on analysis of the combined sedentary sample (n=135), the WENV (0.79) and WORG (0.72) sub-scales were internally consistent, although the PDEM sub-scale was less consistent (0.65). However, a scale with reliability >0.60 but <0.70 can still be considered to have acceptable internal consistency (Cicchetti and Sparrow, 1981; Rick et al, 2001), particularly when a test contains a small number of items (Schmitt, 1996).

10.3.2) Test-retest reliability

Test-retest reliability is used to demonstrate the stability of an instrument over time (Dimitrov et al, 2001). The procedure involves respondents completing an instrument twice, with a time lapse between the two attempts. This time period should be of sufficient length to ensure that respondents are unable to remember their initial responses to the questionnaire when completing it for the second time. However, if the time lapse is too long this increases the possibility that external factors may influence workers responses. A two week test-retest time lapse has been reported as optimum in the literature (Armitage and Berry, 1998; Rick et al, 2001) and was used for this study The first questionnaire was completed by 135 workers, although only 47% of the second batch of questionnaires were returned (n=64). The response rates at Job Centre Plus (48%) and O2 call centres were similar (46%). Having distributed the questionnaire on two occasions the mean test score for each sub-scale and the mean shift (difference between the two scores for each individual) was calculated (Table 15). There were no statistically significant differences ($P>0.05$) between the test-retest means scores, which correlated strongly.

Table 15: Test and retest mean score, mean shift, standard deviation (SD), and Pearson's correlation coefficient (r) for each sub-scale of SWATTRIB

Subscale	Test mean score	Retest mean score	Mean shift	*r*
WENV	16.90 (4.46)	16.17 (4.05)	-0.73 (3.64)	0.63
WORG	7.75 (2.78)	7.93 (2.97)	0.18 (1.85)	0.79
PDEM	15.98 (3.33)	15.70 (3.22)	-0.28 (2.61)	0.68

10.4) Validity of the Sitting and Symptom Modifying Factors Questionnaire (SSMQ)

The SSMQ was placed second in the order of the questionnaires, and two subjects failed to complete this instrument (n=133).

10.4.1) Principal Components Analysis

The structure of this new questionnaire was investigated using PCA and three components were found that explained 62% of the total variance between the items (Appendix 8a). One component related to physical-aggravating factors (PHYAGG), and the remaining components were relieving factors related to posture (POSREL), and movement (MOVREL) (Table 16).

Table 16: Sub-scales, variance (%) and Item loading for SSMQ

Physical-aggravating (PHYAGG) (32%)	***Posture-relieving (POSREL)) (19%)***	***Movement-relieving (MOVREL) (12%)***
Prolonged sitting makes my back feel worse (0.80)	Sitting upright or leaning backwards when I am sat eases my back (0.87)	Moving around in my seat relieves my back ache (0.62)
Sitting in a slumped position aggravates my back (0.78)	Adjusting the position of my chair makes my back feel better (0.89)	Having a break from sitting always makes my back feel better (0.87)
Having to 'hotdesk' aggravates my back (0.72)		Exercising at break times eases my back (0.85)
After sitting for a while standing up makes my back feel worse (0.65)		
Sitting at break times makes my back feel worse (0.74)		
Being at work aggravates my back (0.57)		

10.4.2) Cronbach's alpha

Cronbach's alpha was used to test the internal consistency of responses from the Job Centre Plus and O2 samples. Results indicated that PHYAGG, POSREL and MOVREL sub-scales had alpha scores of 0.80 0.78 and 0.72 respectively. Therefore, each sub-scale was internally consistent.

10.4.3) Test-retest reliability

The mean shift between test and re-test SSMQs was calculated for each sub-scale (Table 17), and there were no statistically significant differences ($P>0.05$). Using the limits suggested by Swiscow and Campbell (2002), correlation between test and re-test sub-scale scores varied from strong (PHYAGG, POSREL) to very strong (MOVREL).

Table 17: Test and retest mean score, mean shift, standard deviation (SD), and Pearson's correlation coefficient (r) for each sub-scale of SSMQ

Subscale	**Test mean score**	**Retest mean score**	**Mean shift**	***r***
PHYAGG	21.96 (4.54)	21.84 (4.40)	-0.12 (3.91)	0.62
POSREL	7.38 (2.14)	7.18 (1.96)	0.20 (1.55)	0.72
MOVREL	10.62 (2.83)	10.38 (2.85)	0.24 (1.07)	0.92

10.5) Reliability of the Fear Avoidance Beliefs Questionnaire - FAB-phys

This questionnaire has been used widely in a range of industrial and clinical studies and was considered valid, so only its reliability was tested.

10.5.1) Cronbach's alpha

Workers with a previous experience of LBP completed FAB-phys (n=41), which had a high level of internal consistency (Cronbach's alpha: 0.83).

10.5.2) Test-retest reliability

Although fear avoidance beliefs may change over time, short-term test-retest analysis seems appropriate. Therefore, test-retest analysis was undertaken using sedentary workers with a previous history of LBP. Mean test (12.73), and retest (11.36) scores on the FAB-phys failed to demonstrate a statistically significant change over a two week period (t=1.705; df=18; p=0.105).

10.6) Validity and test-retest reliability of the low back discomfort scale

Test-retest reliability was established using 41 sedentary workers in administrative roles. A time-lapse of two weeks between completion of the first and second low back discomfort (today) scale showed that there was no statistically significant difference (P>0.05) between test (28mm) and retest (21mm) mean scores. Only nineteen workers returned the second low back discomfort scale, and any differences between test and retest mean scores could reflect changes in subjects' levels of discomfort, or the instruments stability.

WORKFORCE SURVEY AND EXPERIMENTAL INVESTIGATION

i. Call centre study

A convenience sample of call centres workers were recruited for this study. This type of work is though to be characterised by exposure to multiple risks for LBP (Flaspoler et al, 2005), making it an ideal environment to target for research.

i.i. Research design

A quasi-experimental research design employing baseline and follow-up procedures was used (Krosnic, 1999). At baseline, a large cross-sectional survey was distributed to workers to collect data on the prevalence of LBP (and other musculoskeletal symptoms), psychosocial and symptom modifying factors. The FOG system was attached to a sub-sample of these workers to measure activities (sitting, standing, walking) and lumbar movement characteristics over 24-hours. A follow-up questionnaire was subsequently distributed at 6-months, to collect data on LBP and sickness absence over this period. The reliability of the self-reported absence data was not assumed, so company-recorded data were also collected for comparison.

iii. Validity of the study

One of the difficulties of conducting research with a quasi-experimental design is that internal and external factors can have an adverse effect on the validity of the study (Cook and Campbell, 1979, Campbell and Stanley, 1979)

iii.i.i. Threats to internal validity

Internal validity refers to the extent to which a relationship between two factors can be considered causal, and the factors listed here are regarded as potential threats to establishing such relationships (Cook and Campbell, 1979):

- *History* accounts for the conditions or events in the subject's working environment that may have changed during the period of study.
- *Maturation* takes place when the measured effect is due to a change over time, e.g. respondents ageing, rather than the experimental conditions.
- *Instrumentation* explains how changes in subjects behavior during the course of a study (e.g. baseline to follow-up) may influence the results.
- *Selection* of groups with different baseline characteristics makes it difficult to determine if group differences at follow-up are due to the experiment.

- *Mortality* explains how there is likely to be some attrition in respondents for any study taking place over a period of time.
- *Time* or seasonal variations may be problematic in studies that take place over a sustained period of time.

iii.i.ii. Threats to external validity

External validity or 'generalisability' are terms used to describe the extent to which the results from an experimental sample can be extrapolated to the wider population (Zaccai, 2003). Cook and Campbell (1979) suggest that the following can threaten external validity:

- *Recruitment bias* can be introduced if some subjects interacted with the researcher during recruitment and other did not. This can influence the questionnaire responses.
- *Selection-procedure interaction* describes the importance of ensuring that the study sample represents the wider (intended) population, if they do not then any changes attributed to exposure to an experimental condition may not be found if the wider population was studied.
- *Reactivity: i.e.* subjects can alter their behaviour in response to a study.

iv. Company size

A sufficiently large number of workers were required in order to collect self-reported data on LBP and related sickness absence. To estimate the number of workers required for the workforce survey it was assumed that an optimal 60% response rate would be achieved. Based on the literature and approximating the number of workers who would have experienced LBP, it was considered that the respondent group would consist of about 60% workers with a history of LBP (Walsh et al, 1992). Using this figure of 60% and a desirable response rate of 60% (Krosnic, 1999), companies comprising 1600 call handlers were estimated to provide enough sedentary workers who had (n=576) and had not (n=384) experienced LBP. This would enable the total number of respondents to be sub-classified by group (e.g. by gender, age). Based on the literature and a 6-month follow-up period it was assumed that at least 10% (n=96) of respondents would experience LBP (Hillman et al, 1996), and that 5% (n=48) would take sickness absence (Walsh et al, 1992), thus providing enough data for subsequent statistical analyses to take place.

v Ethics

The basic right of every human research participant is to be treated with dignity and respect, and the safety and well-being of the participants in this study was of utmost importance at all times. Whilst ethical issues are formally addressed in the application and approval processes related to clinical (NHS) based research, the industrial nature of this study meant that it was not possible to follow recognised procedures. However, the ethical dimensions of research involving human participants were duly considered at every stage of the research process. For instance, although none of the companies included in the study had a formal ethics committee, two companies (West Yorkshire Police and First Direct plc) did employ health professionals (nurses) with experience of undertaking health research (who read through the proposal and agreed that the study could take place). At Job Centre Plus the absence of health professionals meant that approval was granted by senior management, who regarded the study as being ‘low risk’. Furthermore, the Research Ethics Panel at the School of Human and Health Sciences at the University of Huddersfield also confirmed that the study could take place (decision dated: Wednesday 12th February 2003), and that LREC approval was not required.

Using the expertise of members of the supervisory team, widely recognised measures were taken to ensure that the dignity and rights of the research participants: (1) guidelines suggested by the Central Office for Research Ethics Committees (COREC) were used to structure patient information and consent forms; (2) all participants were offered the opportunity to ask the researcher questions and discuss the study if they so wished; (3) date were coded so that individuals’ responses remained confidential; and (4) all data were securely stored, and were only accessible by the researcher. The overarching ethical principles that the study complied with include: *non-malificence* (the duty to do no harm); *respect for persons* (embodied in informed consent); *beneficence* (low risk and perceived benefit for the population studied, and the wider community); and *justice* (ensuring that the data was collected from sedentary workers; the occupational group most likely to benefit from the results).

METHODS 4

Selection of experimental samples

11.1) Recruitment of call centre companies

Many different methods were used to try and recruit companies. The successful approach involved contacting occupational health or health and safety managers by telephone to: (1) outline the aim of the study and its benefits; (2) find out if the manger was interested; and (3) ask if additional study information could be posted. If agreed, an introductory letter was sent with a document describing the proposed investigation (Appendix 7a and 7b). Managers were then contacted 3 weeks later to determine if collaboration might be agreeable.

11.1.1) West Yorkshire Police

A meeting was held with the Director of 'Health Matters', a private occupational health company contracted to manage musculoskeletal pain in the West Yorkshire Police (WYP) call centres. There were three call centres run 24 hours a day by 430 call handlers, with the largest central call centre (180 call handlers), at WYP headquarters directly receiving 999 calls. These calls were then redirected to either the call centre in Dudley Hill, Bradford (129 call handlers), or Killinbeck, Leeds (121 call handlers). Following discussions about the study a meeting was arranged with the Chief Inspector of Call Centre Operations, where the study was outlined and then successfully approved. Subsequently, an administrator was assigned to help plan subject recruitment.

11.1.2) First Direct

The proposed study was presented to the Health and Safety Manager of First Direct (FD) at their Stourton, Leeds site. However, formal approval was required from their Central office in London, so working with the Health and Safety Manager a business case was proposed. Following approval, an administrator was assigned to help establish the study. FD at Leeds was a large and complex organisation, with 620 call handlers working in customer and financial services.

11.1.3) Job Centre Plus

Job centre plus (JCP) had sites throughout the country, with no occupational health managers. So, through a senior manager six sites were contacted, and four agreed to take part: Southend on Sea (120 call handlers), Exeter (115 call handlers), Liverpool (100 call handlers) and Telford (93 call handlers).

11.2) Recruitment of sedentary workers

The common feature of all the companies recruited for this study is that they employed call handlers exposed to prolonged periods of sitting. However, the location of these organisations varied, as did the nature and patterns of their work. Therefore, although a standardised information sheet and consent form were used (Appendix 8a and 8b), the dissemination of this information varied to fit in with logistical requirements. Since part time workers would have a lower level of exposure to sitting only full time workers were recruited.

11.2.1) West Yorkshire Police

Call handlers typically worked three different shifts, each lasting two days: 7.00am-4.00pm; 11.00am-9.00pm and 9.00pm-7.00am. Workers were then allowed four rest days. Each call centre had five call handling teams with three teams working at any one time, the remaining two taking rest days. To maximise recruitment the researcher introduced himself to all workers and gave them each a copy of the information sheet. Workers were asked not to indicate if they wished to participate whilst the researcher was present. The information sheet was completed later, placed in the sealed envelope provided and posted into a box left by the researcher at the call centre exit for later collection.

11.2.2) First Direct

FD did not allow the researcher to individually contact workers because it was thought that this would disrupt working practices. Therefore, because workers each had their own e-mail addresses, copies of the information sheet were sent electronically from the University of Huddersfield. Workers were asked to place the completed information sheet in a sealed envelope addressed ‘Jamie Bell - LBP Researcher’. These envelopes were made freely available to workers, and were returned via internal mail for later collection by the researcher.

11.2.3) Job Centre Plus

Due to the location of the JCP sites recruitment had to take place by post. Information sheets were sent to a ‘neutral’ call handler for distribution amongst the workforce. Each of the information sheets had an envelope attached, and following completion these were placed in the envelope and returned to the ‘neutral’ call handler. To assist recruitment, each site made 15 minutes available at the start of their bi-monthly team briefing for workers to complete the information sheets. Once collected, the information sheets were bound securely in a box and posted to the researcher by next day recorded delivery.

11.3) Representative nature of the experimental samples

The UK call centre sector is characterised by high female labour force participation (66%-72%) (Belt, 2002)), and call handlers aged 26-35 years and 36-45 years constitute 34% and 16% of the workforce respectively, with a mean age of 33 years (Datapoint, 2004). Retention of staff is difficult in the call centre industry, with 70% of call centre managers reporting this as a problem (TOSCA, 1999). Absenteeism is another widely reported problem (Callaghan and Thompson, 2001; Taylor, 2002), and surveys suggest that the mean annual number of days absence per call handler ranges from 7.8-15 days (IDS, 2001; Jenkins and Brown, 2001). Information provided by the recruited companies helped to determine if their demographics were representative of 'typical call centres' (Table 18). On balance, the experimental samples appeared to be broadly representative of call handlers in this sector. However, WYP had fewer females than the sector average. The mean age of workers at each company was also higher than the sector average. FD appears to be most typical of the sector. Training package content showed little variation (all workers received HSE advice, and were shown how to adjust their chair).

Table 18: Demographic data for the three recruited companies (n=1537)

Company	***Size of company (worker n)***	***% of female call handlers***	***Mean age***	***Mean (annual) number of days sickness absence (per call handler)***
WYP	*430*	57%	40	8 days
FD	*620*	70%	34	9 days
JCP	*487*	65%	36	12 days

11.4) Summary

Three companies comprising 8 call centres were recruited for this study. This enabled a broad range of workers to be included from several different organisations, all of whom were thought to be exposed to prolonged periods of sitting. No attempts were made to coerce subjects, so they might be considered to be a self-selecting sample. Each workplace environment will likely have its own unique influence on workers behaviour, thus provided an opportunity to investigate the combined effects of these influences on LBP, and related sickness absence.

METHODS 5

Data collection

12.1) West Yorkshire Police

For convenience, data collection took place during the 7.00am-4.00pm shift. On arrival at the call centre the inspector was informed which workers had volunteered for the study to confirm that they could be made available to meet the researcher. The volume of calls, emergencies, and the absence of other members of the team all influenced worker availability.

The meeting took place in a quiet private room adjacent to the call centre. The subject was offered another information sheet, given the opportunity to ask questions, and then presented with a consent form. The booklet of questionnaires was then completed and the FOG system was attached. When the FOG system was attached to female subjects a female chaperone was present from within the call centre. Each worker was shown how the FOGs should be removed, asked to try and wear the system for 24 hours, and informed to remove the device at the end of their working shift or any time if it became uncomfortable. Upon removal, FOGs were placed in a collection tray marked ‘Posture Device’ at the entrance to the call centre. Following collection, the information stored on the compact flash card was downloaded and the datalogger was recharged. Each datalogger took 12 hours to fully recharge, and due to the availability of 8 FOG systems data was collected at a rate of 4 subjects per day. The follow-up booklets were distributed to subjects in re-sealable envelopes six months later, and completed questionnaires were sealed and posted into a box at the call centre for collection. Company absence data were obtained 6-months following baseline measures.

12.2) First Direct

Data collection at FD could not take place at a set time because individual shift patterns varied. Two weeks prior to data collection an e-mail was sent to a random cross-section of 130 workers for an appointment with the researcher. Meetings were held in one of the companies first aid rooms, and the same standardised survey and FOG data collection procedures used for the WYP were followed (Table 21). Those workers who were not selected for an appointment were sent a copy of the questionnaire booklet in a re-sealable envelope. When completed these were returned to ‘Jamie Bell: LBP Researcher’ via internal mail. Follow-up questionnaires were distributed to all workers who completed the baseline questionnaires and were also collected in sealed envelopes via internal mail. Human resource managers at FD were not prepared to release company sickness absence data.

12.3) Job Centre Plus

Due to the location of the JCP sites it was not feasible to collect data using the FOG system (Table 19). However, named re-sealable envelopes containing consent forms and questionnaire booklets were sent to a designated 'neutral' worker at each of the call centres. This worker had responsibility for distributing the envelopes to workers, and then collecting and returning them to the researcher via recorded mail. Sickness absence data was made available from three of the JCP sites.

Table 19: Data collection procedure for each company in the main study

Company and baseline no. of subjects	***Baseline method of data collection***	***6-month follow-up method of data collection***
WY Police *n=130*	1st Booklet of questionnaires FOG data	2nd booklet of questionnaires Company sickness records
First Direct *n=183*	1st booklet of questionnaires FOG data	2nd booklet of questionnaires No company sickness records
Job Centre Plus *n=287*	1st booklet of questionnaires No FOG data	2nd booklet of questionnaires Company sickness records (provided by 3 sites, n=173)

SUMMARY: EXPERIMENTAL METHODS

Methodological procedures have been developed and tested to reliably collect a range of self-reported and physical data from a sample of sedentary call centre workers. Although attempts were made to limit errors, some aspects of the measurement were difficult to control. These aspects will be considered when discussing the results. On balance, the experimental methods documented in this chapter were considered sufficiently robust to answer the hypotheses related to this thesis.

RESULTS

Data analysis

13.1) Structure of the analysis

The process of data analysis was hypotheses driven, and the purpose of this section is to demonstrate how the analysis of the results explicitly relates to the hypotheses. There a number of reasons why data analysis should be hypotheses driven, most notably: (1) to produce meaningful *p*-values (reducing the risk of finding chance associations); and (2) to objectively test rationale '*a priori'* hypothesis, thus reducing the risk of identifying and explaining subjective phenomenon.

The proposed hypotheses were designed to address gaps in the literature (see page 59), and were complex in nature. Certain sub-hypotheses (*1,2,3*) required separate cross-sectional and prospective analyses in order to be tested, and any significant associations identified would be used to inform the development and testing of prospective models (*main hypothesis and sub hypothesis 7*). Many sub-hypotheses (*2,3,4,6,7*) also required different types of data (self-reported and biomechanical), collected by different methods, to be separately analysed before being considered together. Some of the variables used in the analyses were also new (designed to test novel ideas), and so some degree of 'exploration' was first required in order identify patterns in the data and select logical cut-off points for these variables. Whilst not included in the hypotheses, there was a perceived need to examine some of the basic aspects of sedentary work commonly described in the literature, e.g. is back discomfort whilst sitting at work highly prevalent? Were the workers studied exposed to prolonged sitting? Such descriptive analyses were necessary in order to provide confirmation that the study sample was broadly representative, in certain respects, of sedentary worker cohorts previously described in the literature. Therefore, the results were carefully structured to reflect the hypotheses and different aspects of the thesis, and followed a similar format to previous occupational studies (Symonds et al, 1995; Burton et al, 2005), that have collected cross-sectional and follow-up data.

The first section of the results provides a descriptive analysis of the profile of respondents to the baseline (workforce) survey, thus helping to establish the homogeneity of the company samples (in terms of demographics, psychosocial and symptom data), and the psychometric properties of the newly developed questionnaires. Results section two subsequently presents analyses of patterns amongst the psychosocial and symptom data, for the combined companies' sample (*testing the cross-sectional component of sub hypothesis 1*). Results section three relates to the experimental investigation, and provides a descriptive analysis of the activities and lumbar movement characteristic of the workers involved in this study, and estimates the accuracy of the FOG system. In results section four the biomechanical data were combined with the self-reported psychosocial and symptom data from the workforce survey (*testing the cross-sectional component of sub-hypotheses 2, and sub-hypothesis 4*).

Results section five presents the results of analyses to predict 'future LBP' *(testing the prospective component of sub-hypothesis 2, sub-hypothesis 7, and the first part of the main hypothesis.* Finally, results section 6 presents the results of analysis to predict 'future sickness absence' *(testing the prospective component of sub-hypothesis 1, 3, and 5, and the latter part of the main hypothesis*).

Within the results sections, where hypothesis are tested this is highlighted (*except for the cross-sectional component of sub-hypothesis 3, and hypothesis 6, which both related to 'walking outside of work', and could not be tested: see section 20.2.5 for explanation*). There is specific discussion on whether or not the hypotheses were accepted or rejected in section 20.5.

13.2) General procedures

13.2.1) Data storage and input

Raw physical data such as questionnaires were stored in a locked office, and FOG data were stored on a password protected computer as raw CSV files. For the purposes of data analysis, all data were input onto spreadsheets manually, checked twice, and then saved as SPSS files.

13.2.2) Significance levels and confidence intervals

The significance level indicates the level at which a hypothesis is accepted or rejected (Hicks, 1998). If the significance level is set at a minimum of *P=0.05* this indicates that if the probability of an event occurring by chance alone is less than 5%, then the null hypothesis can be rejected (Robson, 2002). For the purposes of this study a 5% significance level was used to reject the null hypothesis. Confidence interval are perhaps more informative than the results of hypothesis tests that are rejected or accepted based on significance levels, since they are used to express the degree of uncertainty in a quantity being estimated (Polgar and Thomas, 1995). For this study, the confidence interval was set at 95%, indicating that if a population mean were 15-20 there would be 95% confidence that the true mean score lies between these lower (15) and upper (20) limits.

13.3) Statistical analysis

The data were analysed using SPSS for Windows (Statistical Package for the Social Sciences, version 14.0), and where appropriate statistical tests included: *t*-tests, analysis of variance (ANOVA), correlation coefficients, chi-square tests (χ^2), Mann Whitney U tests, and logistic regression. Widely published assumptions about each statistical test needed to be met in order for analysis to take place. For multivariable (stepwise) logistic regression analysis, more varied practices seem to exist, so the following parameters were set for this study:

- In order to prevent multicollinearity, the inter-correlations between independent variables were checked. Among variables with a Spearman's correlation of 0.75 or higher, variables with the lowest *P*-value (as found in univariate regression analyses) were dropped from multiple regression models.
- The standard errors for variables included in models were screened for high values (>5), as a check of the models stability.
- The omnibus test of model coefficients had to demonstrate a significant difference ($P<0.01$), and the Hosmer-Lemeshow statistic had to be insignificant ($P>0.05$), thus suggesting that the model had an acceptable fit.
- A minimum of 8 subjects per predictor variables has been arbitrarily recommended by statistical advisors to prevent 'overfitting'. In this context the risk of overfitting will be considered in the discussion.

Cross-sectional analyses

Differences between company and respondent demographics were tested to determine the homogeneity of the sample. Univariate and bivariate associations were then explored between self-reported musculoskeletal symptoms; psychosocial and symptom modifying factors; activities and lumbar sagittal movement characteristics. The relative ability of these data to explain LBP and discomfort were explored using multivariable models.

Prospective analyses

Univariate statistics were used to explore associations between self-reported cross-sectional data; future LBP, and the occurrence and extent (>7 days) of future sickness absence due to LBP. In order to explore the relative influence of a range of variables on these outcomes, multivariable models were used.

RESULTS: CROSS-SECTIONAL

<u>WORKFORCE SURVEY</u>

RESULTS 1

Profile of the respondents to the first booklet of questionnaires

14.1) Total response rate

From the 1,537 full time workers invited to take party in this study at the West Yorkshire Police (WYP), First Direct (FD), and Job Centre Plus (JCP), 39% (n=600) completed and returned the first booklet of questionnaires.

14.2) Company response rates

The company response rates varied (Table 20), and only JCP achieved a high response rate. Potential non-response bias could explain these findings, and is discussed in section 20.2.5.

Table 20: Total number of employees and respondents from each company, with survey response rates expressed as a percentage

Company	Employees (n)	Respondents (n)	Response rates (%)
West Yorkshire Police (WYP)	430	130	30.2%
First Direct (FD)	620	183	29.5%
Job Centre Plus (JCP)	487	287	58.9%

14.3) Demographic representation

14.3.1) Gender and age

Demographic information on the proportion of male to female permanent full time call centre workers was provided by each company. Based on gender proportions for the whole sample (Table 21), survey respondents were not significantly different from the company workforce ($P>0.05$). WYP was the only company where a significant difference was found, significantly more males and less females taking part in the study ($P<0.01$). Company records showed that the mean age of workers at WYP was 40 years, compared to 34 years at FD, and 36 years at JCP. The mean age of respondents closely matched company records: WYP (39 years), FD (37 years) and JCP (36 years). For the whole respondent sample the mean age was 37 years (range 18-65 years).

Table 21: Numbers of workforce and survey respondents from each company based on gender, expressed as a % of total numbers

Company	Sex	Company workforces (n)	%	Survey respondents (n)	%
WYP	Male	185	43%	82	63%*
	Female	245	57%	48	37%*
FD	Male	186	30%	55	30%
	Female	434	70%	128	69.9%
JCP	Male	170	35%	100	34.8%
	Female	317	65%	187	65.1%
Whole Sample	Male	541	35.2%	237	39.5%
	Female	995	64.7%	363	60.5%

[Statistically significant difference between company workforce and survey respondents for WYP, $\chi^2(1, n= 560)=16.09, P<0.01$].*

Splitting the respondent sample at the mean age, younger (18-37 years), and older (38-65 years) age categories were constructed, and the gender proportions in each company were compared (Table 22). Significant differences existed for WYP, a larger proportion of older males and younger females taking part in the study (*P<0.01*). When the age categories were considered without sex, there were no significant differences between the companies (*P>0.05*). For the whole sample, the largest group of respondents were young females, and there were no significant differences between the proportion of young and old respondents for either gender (*P>0.05*).

Table 22: Numbers of respondents from each company, split by gender and expressed as a % of age categories

Company	Sex	Younger (n)	Older (n)
WYP	Male	44.4% (24)	75.7% (56)*
	Female	55.6% (30)*	24.3% (18)
FD	Male	33% (31)	27.6%(24)
	Female	67% (63)	72.4% (63)
JCP	Male	36.2% (55)	32.8% (43)
	Female	63.8% (97)	67.2% (88)
Whole Sample	Male	36.7% (110)	42.1% (123)
	Female	63%.3 (190)	57.9% (169)

[Statistically significant difference between age categories for WYP, $\chi^2(1, n= 128)=12.99, <0.01$].*

14.4) Self-reported occupational history

Respondents were asked to categorise: (1) their previous job in order to provide a crude estimate of exposure to heavy lifting and sitting, and (2) how long they had been employed in their present job (job tenure), since these data might both impact on the results.

14.4.1) Heavy lifting and sitting

Most respondents' previous job did not involve heavy lifting (67%, n=397), although for a third it did (33%, n=192). When asked about how much time was spent sitting in their previous job, responses ranged from: never (13%, n=80), occasionally (25%, n=151), through to quite a lot (39%, n=236), or all the time (21%, n=127). Proportions based on a previous job involving heavy lifting and varying amounts of sitting were not significantly different between the companies ($P>0.05$).

14.4.2) Job tenure

Both FD and WYP appear to have employed a small proportion of new (<1 year) and relatively new (1-3 years) staff, and a large proportion of respondents had remained with these companies for >3 years (Table 23). This trend was reversed for JCP, who were significantly different to FD and WYP. For the whole sample, the majority of respondents had been in post for 3 years (n=323, 56%). Present job length was related to age; a significantly larger proportion of younger (18-37 yrs) respondents had been employed for <1 year (72%), and 1-3 years (55%), than older (38-65 yrs) respondents ($P<0.05$). The significant majority (61%) of job lengths >3 years were held by older respondents. Therefore, these results suggest that self-reported occupation history is possibly of little importance

Table 23: Job tenure, expressed as a percentage for each company

Company	**Job tenure (time in present job)**		
	<1 year (n)	**1-3 years (n)**	**>3 years (n)**
WYP	7% (9)	29% (36)	64% (80)
FD	5% (9)	14% (25)	81% (144)
JCP	29% (80)*	58% (164)*	13% (37)*
Whole Sample	17% (98)	39% (225)	45% (261)

[Statistically significant difference from WYP and FD, $\chi^2(4,n=584)=228.88$, $P<0.001$].*

14.5) Self-reported physical activity

Workers were asked in a typical week how many days they would participate in sport, exercise in a gym, or go for a walk. Mean scores indicated that respondents from WYP reported being active on significantly more occasions (3.07 days, SD 2.11), than at FD (2.53 days, SD 1.78) or JCP (2.53 days, SD 2.01) (*P>0.05*). On a typical weekday 43% (n=258) of respondents reported spending 3-4 hours sitting in their leisure time, with 29% (n=171) and 27% (n=160) reporting to sit for 1-2 hours and >5 hours respectively. These proportions were not significantly different between the companies (*P>0.05*).

14.6) Prevalence of self-reported LBP

For the whole respondent sample, the lifetime, 12-month and 7-day self-reported LBP prevalence rates were: 63% (n=377), 54% (n=323) and 43% (n=255) respectively. Based on the proportions shown in Figure 16, there were significant differences in the lifetime and 7-day prevalence of LBP between the companies (*P<0.05*). Notably, compared to WYP and JCP there was a higher proportion of respondents at FD (75%) who had previously experienced LBP. FD also had the highest 12-month and 7-day LBP prevalence rates. The lowest prevalence of LBP for all periods was reported by WYP respondents. Overall, Figure 16 shows that LBP was reported by a high proportion of respondents at each company.

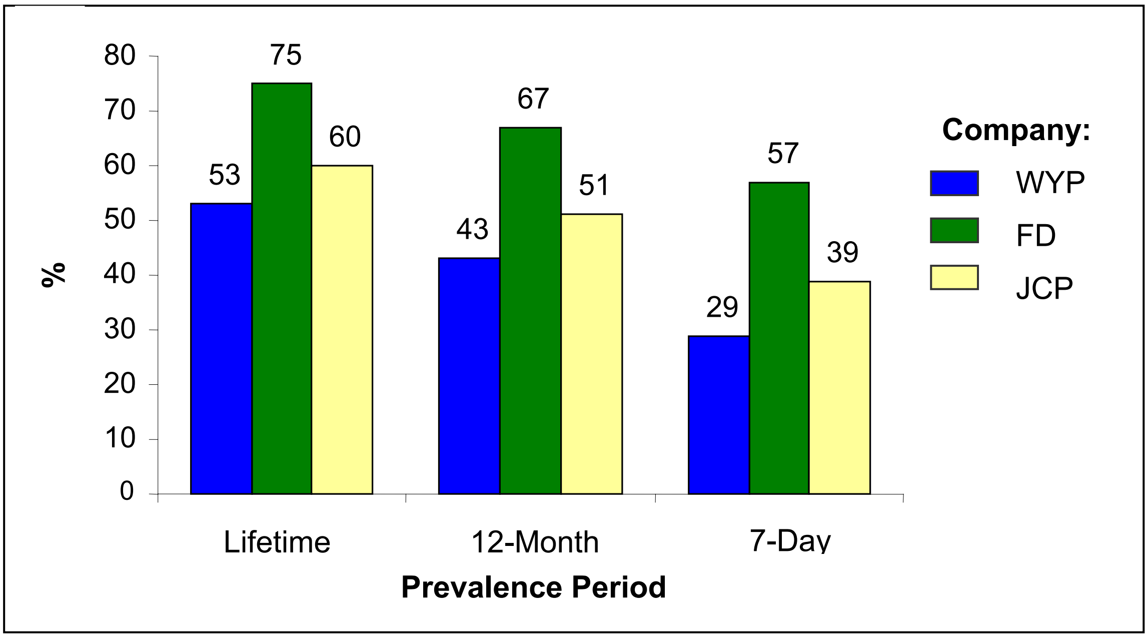

Figure 16: Percentage of survey respondents at each company who reported LBP for different prevalence periods

Using the 12-month LBP prevalence rate the relationship between LBP and age was explored. For the whole sample, the 12-month prevalence of LBP for different age categories varied from: 14% (<30 years), 19% (30-39 years), 14% (40-49 years), and 7% (>50 years). Therefore, LBP prevalence tended to increase with age, peak around 30-39 years, and then decrease, particularly in the 5th decade.

14.6.1) Frequency of LBP episodes

Only 8.8% (n=33) of respondents with a previous history of LBP reported experiencing an isolated episode of LBP during their life, with 31.8% (n=120) reporting a few (2-4), and 59.4% (n=224) reporting many (>4) episodes. The number of LBP episodes were similarly distributed across the companies (*P>0.05*), with most respondents reporting >4 previous episodes (Figure 17).

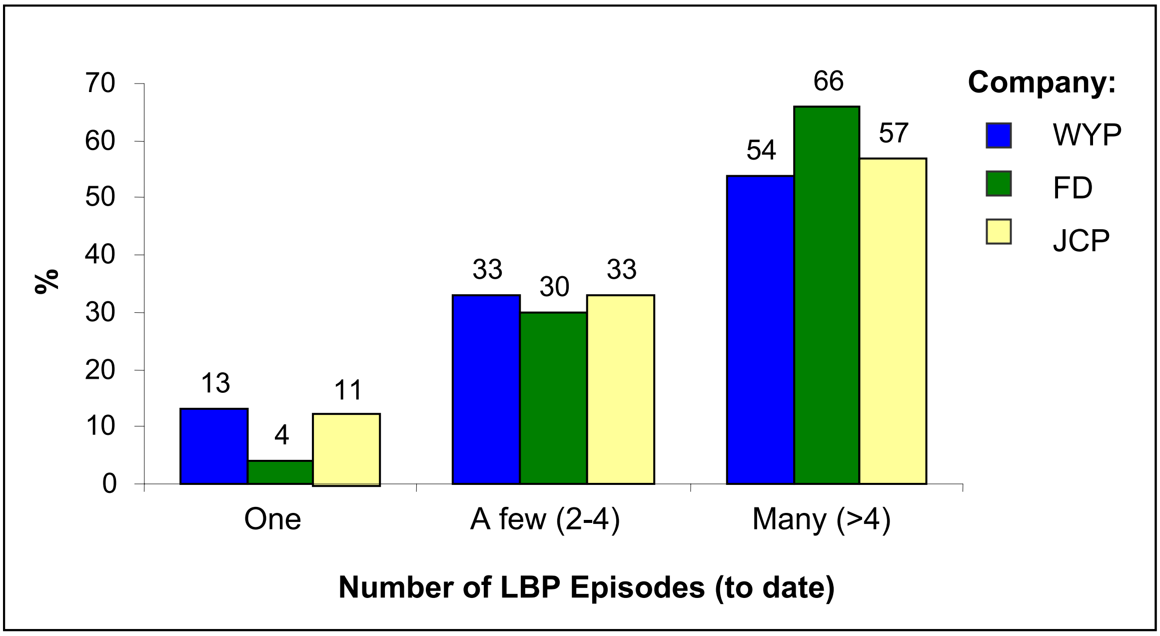

Figure 17: Percentage of survey respondents at each company who reported different numbers of previous LBP episodes

For the whole sample, younger respondents aged <30 years (n=89) reported the highest proportion of isolated LBP episodes (Figure 18). Respondents in this age category reported far less recurrent LBP, and proportions reduced as the number of LBP episodes increased. This trend was reversed for respondents aged 30-39 years (n=126); proportionally there were few isolated episodes of LBP, and proportions increased as the number of recurrent episodes increased (albeit only by 1%). For the age category 40-49 years (n=105) the proportions of respondents reporting different numbers of LBP episodes were fairly evenly spread. Overall, episode recurrence peaked at around 30-39 years, and then reduced during the 4th decade, but remained more prevalent than for younger (<30 years) workers. For respondents aged >50 years, recurrent LBP episodes were more prevalent than isolated ones, and the low proportions evident for this age group may reflect its small size (n=54). The patterns in Figure 18 will also be influence by respondents' ability to accurately recall LBP episodes.

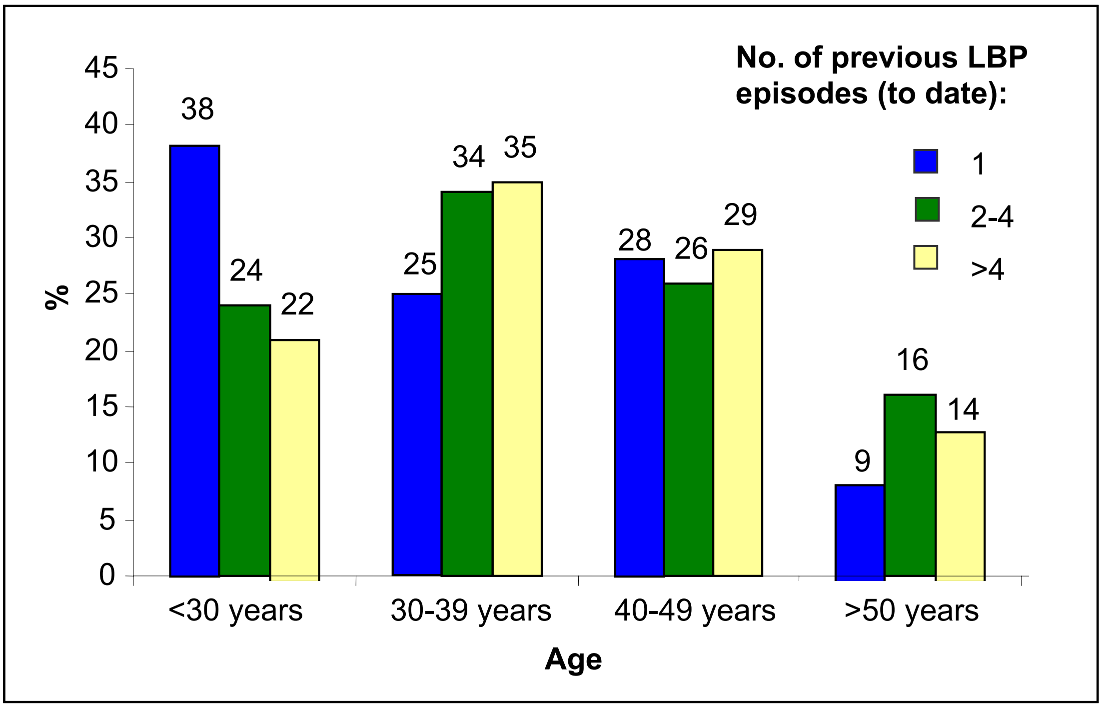

Figure 18: Percentage of survey respondents who reported different numbers of previous LBP episodes, expressed for age categories

14.7) Disability and function

Overall, 37.5% (n=94) of respondents reported some degree of LBP disability in the past month. Mean disability scores (measured by the number of days in the past month that respondents cut down on doing things they would normally do due to LBP) were higher at FD (3.4 days), than at WYP (1.7 days) or JCP (1.9 days), although this difference was not significant (*P>0.05*). Respondents were also asked: During the past week how much did pain interfere with your normal work? (including both work outside the home and housework). Responses ranged from not at all (33%, n=85), a little bit (34%, n=87), moderately (15%, n=39), quite a bit (16%, n=40) or extremely (2%, n=5). These proportions were similarly distributed between the companies *(P>0.05).*

14.8) Sickness absence due to LBP

In the previous 12-months, 13.7% (n=82) of respondents reported taking sickness absence due to LBP. The mean period of absence was 13.8 days (SD 25.2), ranging from 1 to 150 days. The mode and median durations of absence were much lower, 1 and 5 days respectively. The majority of LBP absence was for 1-6 days (58%, n=47), although a high proportion of respondents reported being absent >7 days (42%, n=34). The proportions of total sickness absence taken due to LBP in the past 12-months (no absence, 1-6 days, >7 days) were not significantly different between the companies (*P>0.05*).

14.9) Low back discomfort whilst sitting at work

14.9.1) Prevalence and intensity

The majority of respondents reported some discomfort whilst sitting at work in the 'past week' (68%, n=409), and 'today' (53.8%, n=323). The proportion of respondents who had experienced some discomfort 'today' was broadly similar between the companies: FD (62%), JCP (54%), WYP (48%), (*P>0.05*). Although proportions based on discomfort in the 'past week' were significantly different between the companies: FD (79%), JCP (67%), WYP (62%) *(P<0.05)*, the pattern of responses was the same as for discomfort 'today'.

Mean discomfort intensity scores whilst sitting at work (past week and today) were significantly higher at FD (24.4 and 17.4) and JCP (23.9 and 17.3), than at WYP (16.9 and 9.1) (*P<0.05*). The mean discomfort intensity scores for the whole sample were also significantly higher in the 'past week' (22.61, SD 23.98), than 'today' (15.62, SD 22.07) (*P<0.01*). The frequency of discomfort experienced whilst sitting at work (past week) varied from never (29%, n=170), occasionally (52%, n=299), quite a lot (15%, n=85), to all the time (4.5%, n=26).

14.9.2) Mean symptom modifying scores

The mean scores and variances for all three sub-scales of the sitting and symptom modifying factors questionnaire (SSMQ) were similar between the companies *(P>0.05*) (Table 24).

Table 24: Mean SSMQ sub-scale scores and standard deviations (SD) for each company and the whole sample

	Physical-aggravating Range: 6-30	Posture-relieving Range: 2-10	Movement-relieving Range: 3-15
WYP	17.4 (4.67)	7.45 (1.99)	9.92 (2.46)
FD	18.6 (5.01)	7.56 (1.62)	10.21 (2.52)
JCP	17.9 (4.67)	7.37 (1.88)	10.38 (2.72)
Whole Sample	18.03 (4.78)	7.44 (1.83)	10.23 (2.61)

[No statistically significant differences between companies (5% level)]

14.10) Prevalence of self-reported musculoskeletal symptoms

Using self-report data from the Nordic Musculoskeletal Questionnaire, excluding LBP the majority of respondents reported some musculoskeletal symptoms (i.e. ache, pain, discomfort or numbness) in at least one other part of their body (e.g. neck, shoulder, elbow, wrist/hands, upper back, hips, knees, ankles/feet). The 12-month and 7-day prevalence rates were 83% (n=493) and 70% (n=413) respectively. Upper limb symptoms, defined as pain anywhere in the upper limb and/or neck were highly prevalent (12-month rate: 78%, n=462; 7-day rate: 60%, n=354). The prevalence of musculoskeletal and upper limb symptoms were significantly higher at FD than at WYP or JCP, both for the past 12-months and 7-days ($P<0.05$).

14.11) Patterns of mean psychosocial scores

The mean scores and standard deviations (SD) for each psychosocial questionnaire are shown for each company and the whole sample (Tables 25 to 32). One-way ANOVA with Scheffe post hoc tests were used to identify significant differences between company mean scores.

Table 25: Beliefs about work organisation as a cause of low back discomfort (range 3-15)

Company	Mean Score (SD)
WYP	6.62 (2.64)
FD	6.08 (2.52)
JCP	6.28 (2.66)
Whole Sample	6.16 (2.61)

[No statistically significant differences between companies (5% level)]

Table 26: Beliefs about the work environment as a cause of low back discomfort (range 5-25)

Company	Mean Score (SD)
WYP	14.17 (3.98)
FD	14.40 (4.37)
JCP	14.44 (4.50)
Whole Sample	14.37 (4.34)

[No statistically significant differences between companies (5% level)]

Table 27: Beliefs about physical demands at work as a cause of low back discomfort (range 4-20)

Company	Mean Score (SD)
WYP	15.38 (3.51)
FD	15.05 (3.36)
JCP	14.74 (3.76)
Whole Sample	14.98 (3.59)

[No statistically significant differences between companies (5% level)]

Table 28: Psychological demand at work (range 12-48)

Company	Mean Score (SD)
WYP	35.9 (4.42)
FD	35.0 (4.93)
JCP	35.2 (5.22)
Whole Sample	35.3 (4.98)

[No statistically significant differences between companies (5% level)]

Table 29: Social support at work (range 5-20)

Company	Mean Score (SD)
WYP	15.53 (2.94)*
FD	16.25 (2.50)
JCP	16.66 (3.07)
Whole Sample	16.29 (2.91)

[Statistically significant difference from JCP $F(2, n=578)=6.64$, $P<0.01$].*

Table 30: Job satisfaction (range 1-5)

Company	Mean Score (SD)
WYP	3.42 (0.96)
FD	3.52 (0.89)
JCP	2.88 (1.05)*
Whole Sample	3.19 (1.03)

[Statistically significant difference from FD and WYP $F(2, n=583)=27.32$, $P<0.01$].*

Table 31: Psychological distress (range 0-36)

Company	Mean Score (SD)
WYP	10.52 (4.64)*
FD	12.42 (5.02)
JCP	13.0 (6.04)
Whole Sample	12.28 (5.53)

[Statistically significant difference from FD and JCP $F(2, n=587)=9.18$, $P<0.01$].*

Table 32: Fear avoidance beliefs – physical activity (range 4-20)

Company	Mean Score (SD)
WYP	10.71 (4.32)
FD	11.79 (3.85)
JCP	11.30 (4.61)
Whole Sample	11.37 (4.30)

[No statistically significant differences between companies (5% level)]

14.12) Construct validity and internal consistency of new questionnaires

The construct validity and internal consistency of the questionnaires developed for this study were tested on the main data set (Appendix 9 and 10). For the Sitting and Symptom Modifying Factors Questionnaire (SSMQ) construct validity and internal consistency was confirmed for each of its sub-scales. Whilst sub-scales of the Sedentary Work Causal Attributions Questionnaire (SWATTRIB) were internally consistent, one of the items from the physical demands sub-scale (prolonged sitting) loaded more strongly onto the work environment sub-scale. The original questionnaire (as validated in Methods 3) has been used throughout the main results.

RESULTS 2

Patterns of responses between different groups of respondents

15.1) Mean psychosocial scores for gender and age

For the combined companies' sample, mean psychosocial scores were compared across gender and age categories. Males reported significantly less social support and job satisfaction than females (Table 33), and there were no significant differences in psychosocial scores for different age groups (Table 34). When analyses for gender were conducted with the level of statistical significance set at 1% only social support remained significant. Thus, the small mean difference evident for job satisfaction at the 5% level was possibly due to the studies large sample size.

Table 33: Patterns of mean psychosocial scores and standard deviations (SD) for males and females

Psychosocial factor	Males n=237	Females n=363
Work organisation (3-15)†	6.2 (2.71)	6.0 (2.54)
Work environment (5-25)†	14.4 (4.26)	14.3 (4.40)
Physical demands at work (4-20)†	14.7 (3.79)	15.1 (3.44)
Job satisfaction (1-5)	3.08 (1.06)*	3.26 (1.0)
Psychological demand (12-48)	35.2 (4.94)	35.3 (5.01)
Social support (5-20)	15.8 (2.92)*	16.5 (2.87)
Psychological distress (0-36)	11.9 (5.17)	12.5 (5.76)

[Statistically significant difference between males and females, (5% level)]*
[† Sub-scale measuring beliefs about the causes of low back discomfort]

Table 34: Patterns of mean psychosocial scores and standard deviations (SD) for different age categories

Psychosocial factor	<30 yrs n=149	30-39 yrs n=185	40-49 yrs n=176	>50 yrs n=82
Work organisation (3-15)†	5.95 (2.55)	6.11 (2.77)	6.2 (2.47)	6.62 (2.58)
Work environment (5-25)†	14.3 (4.48)	14.1 (4.33)	14.5 (4.28)	14.4 (4.32)
Physical demands at work (4-20)†	14.8 (3.57)	15.0 (3.60)	15.0 (3.57)	14.7 (3.57)
Job satisfaction (1-5)	3.04 (1.06)	3.2 (0.97)	3.35 (0.96)	3.05 (1.17)
Psychological demand (12-48)	35.4 (5.30)	34.8 (4.72)	35.4 (5.11)	35.5 (4.63)
Social support (5-20)	16.8 (2.61)	16.2 (2.81)	16.0 (3.13)	16.0 (3.12)
Psychological distress (0-36)	11.7 (5.05)	12.7 (6.07)	12.4 (5.70)	11.9 (4.62)

[† Sub-scale measuring beliefs about the causes of low back discomfort]

15.2) Mean psychosocial scores and self-reported LBP

15.2.1) Lifetime, 12-month and 7-day prevalence of LBP

The mean psychosocial scores of respondents who did and did not report LBP were similar for different prevalence periods, except for psychological distress and fear avoidance beliefs; LBP respondents had significantly higher psychological distress scores for each prevalence period, and significantly higher fear avoidance scores for the past 12-months and 7-days (Table 35).

Table 35: Mean psychosocial scores and standard deviations (SD) for respondents who did and did not report LBP for different prevalence periods

Psychosocial factor	LBP Prevalence					
	Lifetime		Past 12-months		Past 7-days	
	Yes n=377	No n=223	Yes n=323	No n=277	Yes n=255	No n=345
Work organisation (3-15)	6.27 (2.60)	5.98 (2.61)	6.27 (2.58)	6.04 (2.64)	6.30 (2.65)	6.06 (2.58)
Work environment (5-25)	14.55 (4.45)	14.06 (4.15)	14.61 (4.47)	14.09 (4.18)	14.64 (4.54)	14.17 (4.19)
Physical demands at work (4-20)	15.01 (3.47)	14.92 (3.79)	15.06 (3.41)	14.89 (3.79)	14.94 (3.38)	15.00 (3.74)
Job satisfaction (1-5)	3.15 (1.05)	3.27 (0.98)	3.15 (1.03)	3.24 (1.02)	3.10 (1.05)	3.26 (1.01)
Psychological demand (12-48)	35.3 (5.05)	35.1 (4.86)	35.5 (5.05)	35.0 (4.48)	35.3 (5.22)	35.3 (4.79)
Social support (5-20)	16.28 (2.84)	16.31 (3.02)	16.26 (2.72)	16.32 (3.12)	16.10 (2.66)	16.44 (3.07)
Psychological distress (0-36)	12.77** (5.63)	11.44 (5.26)	12.89* (5.54)	11.82 (5.49)	13.05** (5.81)	11.78 (5.05)
Fear avoidance beliefs: physical (4-20)	11.36 (4.32)	-	11.72** (4.29)	10.01 (3.83)	11.80* (4.43)	10.47 (3.90)

[Statistically significant difference between respondents who did and did not report LBP, at the 5% level, ** at the 1% level].*

15.2.2) Frequency of LBP episodes

The general pattern of results suggests that more frequent LBP episodes are associated with more negative psychosocial scores (Table 36). Analysing the differences in mean scores between the three episode groups shows that respondents who reported > 4 episodes of LBP had significantly higher fear avoidance beliefs and levels of disability, and lower levels of function (*P<0.01*).

Table 36: Mean psychosocial scores and standard deviations (SD) for respondents who reported different numbers of LBP episodes (to date)

	Number of episodes		
Psychosocial factor	**1**	**2-4**	**>4**
Previous LBP respondents:	*n=33*	*n=120*	*n=224*
Work organisation (3-15)	5.65 (2.50)	6.38 (2.54)	6.27 (2.64)
Work environment (5-25)	13.2 (4.26)	14.6 (4.38)	14.6 (4.56)
Physical demands at work (4-20)	14.1 (3.99)	15.3 (3.24)	15.0 (3.50)
Job satisfaction (1-5)	3.3 (1.11)	3.2 (1.11)	3.1 (1.00)
Psychological demand (12-48)	34.8 (6.01)	35.5 (5.38)	35.4 (4.83)
Social support (5-20)	17.2 (2.35)	16.3 (2.94)	16.1 (2.83)
Psychological distress (0-36)	11.8 (5.68)	11.5 (5.03)	13.3 (5.78)
Fear avoidance beliefs - physical (4-20)	9.40 (4.18)	10.4 (4.03)	12.0 (4.27)**
Current LBP respondents:	*n=16*	*n=57*	*n=182*
Function (1-5)	1.03 (1.40)	0.84 (1.09)	1.82 (1.36)*
Disability (1-28)	0.7 (1.06)	0.7 (1.71)	3.1 (6.01)**

[Statistically significant difference from other groups at the 5% level, ** at the 1% level]*

15.3) Mean symptom modifying scores and self-reported LBP

For the Sitting and Symptom Modifying Factors Questionnaire (SSMQ), no significant differences in either posture-relieving or movement-relieving sub-scale scores were found between respondents with different LBP histories (*P>0.05*). However, respondents who reported LBP in the past week or 12-months had a significantly higher physical-aggravating mean score than respondents reporting a lifetime prevalence (but not in the past 12 months), or no history of LBP. *(The mean scores and standard deviations can be found in Appendix 11a).*

15.4) Low back discomfort whilst sitting at work and self-reported LBP

15.4.1) Discomfort prevalence

Respondents who reported a previous episode of LBP were significantly more likely to report discomfort whilst sitting at work than respondents who reported no previous LBP (Table 37). Notably, more recent LBP and increased episode frequency (>4) were each associated with an increase in the proportion of respondents who reported discomfort. However, low back discomfort was also reported by a high proportion of respondents without an apparent history of episodic LBP, suggesting that some discomfort whilst sitting is a common feature of call centre work. Separate analyses showed that sex and job tenure were unrelated to discomfort prevalence, although a greater proportion of younger workers (<38 yrs) reported discomfort, compared to older workers (≥38 yrs) (Appendix 11b).

Table 37: Respondents who reported low back discomfort whilst sitting at work 'today', expressed as a % for LBP prevalence periods and episodes

LBP prevalence			**Low back discomfort whilst sitting at work 'today' (n=323)**	***P* (χ^2)**
Lifetime:	**Yes**	**n= 377**	62.3% (235)	*P<0.01*
	No	**n=222**	39.6% (88)	
12-month:	**Yes**	**n=323**	69.7% (225)	*P<0.01*
	No	**n=277**	35.4% (98)	
7-day:	**Yes**	**n=255**	74.9% (191)	*P<0.01*
	No	**n=345**	38.3% (132)	
Number of episodes:	**1**	**n=30**	53.3% (16)	*P<0.01*
	2-4	**n=122**	48.4% (59)	
	>4	**n=227**	71.4% (162)	

15.4.2) Discomfort Intensity

One-way ANOVA with Scheffe post-hoc tests were used to analyse the differences between mean discomfort scores 'today' for respondents with different self-reported histories of LBP (Table 38). Mean discomfort scores were higher for respondents reporting previous LBP, and discomfort scores increased for each more recent experience of LBP.

Table 38: Respondents mean low back discomfort scores whilst sitting at work 'today', categorised for different LBP histories.

LBP Histories	**Mean Score (SD)**
No previous history	5.4 (13.44)
Lifetime history (but not in the past 12-months)	7.6 (15.40)
12-month history (but not in the past week)	13.3 (18.6)
7-day history	26.2 (25.5)*

[Statistically significant difference from other groups, (5% level)].*

15.5) Mean psychosocial scores and low back discomfort

This section relates to the cross-sectional component of sub-hypothesis 1.The mean psychosocial scores of respondents who did and did not report low back discomfort whilst sitting at work were significantly different for causal beliefs (work organisation, work environment), job satisfaction, psychological distress and function (Table 39). Respondents who experienced discomfort tended to believe that their symptoms were caused by certain aspects of work, had less job satisfaction, higher levels of psychological distress and lower levels of daily function than workers who reported no discomfort.

Table 39: Mean psychosocial scores and standard deviations (SD) for respondents who did and did not report low back discomfort whilst sitting at work 'today'

Psychosocial factor	**Discomfort whilst sitting at work 'today'**	**No discomfort whilst sitting at work 'today'**
All respondents:	*n=323*	*n=261*
Work organisation (3-15)	6.5 (2.78)**	5.8 (2.31)
Work environment (5-25)	14.9 (4.32)**	13.7 (4.25)
Physical demands at work (4-20)	15.1 (3.50)	14.8 (3.62)
Job satisfaction (1-5)	3.0 (1.02)*	3.3 (1.02)
Psychological demand (12-48)	35.5 (4.85)	35.1 (5.10)
Social support (5-20)	16.1 (2.68)	16.4 (3.17)
Psychological distress (0-36)	13.3 (5.71)**	11.0 (5.09)
Previous LBP respondents:	*n=235*	*n=128*
Fear avoidance beliefs – physical (4-20)	11.7 (4.23)	10.6 (4.25)
Current LBP respondents:	*n=191*	*n=56*
Function (1-5)	2.4 (1.13)**	1.7 (0.90)
Disability (1-28)	2.80 (5.25)	1.81(5.43)

[Statistically significant difference between respondents who did and did not report discomfort at the 5% level, ** at the 1% level]*

Associations between psychosocial factors and low back discomfort scores 'today' were investigated using Spearman's Rho. Positive and negative associations were found for a range of psychosocial factors (*P<0.05*), although the strength of these relationships was generally weak (Appendix 11c). Placing the psychosocial factors in Table 39 into a logistic regression (stepwise) model resulted in psychological distress (OR 1.09, 95% CI 1.02-1.17), and function (OR 1.84, 95% CI 1.26-2.68) being retained, explaining 15% of the variance in discomfort whilst sitting at work 'today'. Thus, clinical rather than occupational factors were most important in explaining work-relevant discomfort.

To explore the relationship between psychosocial factors and the frequency of discomfort whilst sitting at work in past week, odds ratios (ORs) with 95% confidence intervals were calculated (Table 40). Apart from the work-relevant factors: social support, physical demands, and psychological demands, all psychosocial factors were significantly associated with at least one discomfort frequency category. However, associations (measured using Nagelkerke R^2) were generally weak, except for function and the discomfort categories: quite a lot (R^2 0.27) and all the time (R^2 0.42).

Table 40: Association between psychosocial factors and discomfort frequency, expressed as odds-ratios with 95% confidence intervals (CI)

Psychosocial factor	**Frequency of low back discomfort (yes/no: each category)**			
	never n=170	**occasionally n=229**	**quite a lot n=85**	**all the time n=36**
Work organisation (3-15)	0.96 (0.9-1.0)	0.97 (0.9-1.0)	1.1* (1.01-1.2) *R^2 0.02*	1.0 (0.92-1.2)
Work environment (5-25)	0.99 (0.9-1.0)	0.96 (0.9-0.99)	1.1* (1.03-1.2) *R^2 0.03*	1.0 (0.98-1.2)
Physical demands - work (4-20)	0.98 (0.9-1.0)	1.0 (0.9-1.03)	1.0 (0.9-1.1)	1.0 (0.92-1.1)
Job Satisfaction (1-5)	1.0 (0.8-1.2)	1.1 (0.9-1.3)	0.75* (0.6-0.9) *R^2 0.02*	0.95 (0.65-1.4)
Psychological demand (12-48)	1.0 (0.9-1.1)	0.99 (0.97-1.0)	1.0 (0.9-1.02)	1.0 (0.9-1.05)
Social support (5-20)	0.98 (0.9-1.0)	1.0 (0.9-1.1)	1.0 (0.9-1.08)	1.0 (0.89-1.1)
Psychological distress (0-36)	0.92 (0.9-1.0)	0.98 (0.95-1.0)	1.1* (1.07-1.1) *R^2 0.04*	1.1* (1.06-1.2) *R^2 0.09*
FAB - phys (4-20)	0.95 (0.8-1.0)	0.96 (0.91-1.0)	1.0 (0.9-1.08)	1.2* (1.0-1.3) *R^2 0.06*
Function (1-5)	0.33* (0.1-0.7) *R^2 0.16*	0.44* (0.34-0.58) *R^2 0.03*	1.8* (1.4-2.3) *R^2 0.27*	4.3* (2.6-7.2) *R^2 0.42*
Disability (1-28)	0.7* (0.5-0.9) *R^2 0.05*	0.94* (0.9-0.97) *R^2 0.02*	1.0 (0.9-1.07)	1.1* (1.04-1.2) *R^2 0.09*

[ORs statistically significant, (5% level)] [Nagelkerke R^2 expressed for significant associations]*

15.6) Mean symptom modifying scores and low back discomfort

Respondents who experienced low back discomfort whilst sitting at work (past week) also reported significantly higher physical-aggravating, movement-relieving and posture-relieving factor scores than respondents without any discomfort (*$P<0.05$*) (Appendix 11d). Similar results were obtained for discomfort whilst sitting 'today', except posture-relieving scores were no longer significantly different between respondents with and without back discomfort (*$P>0.05$*).

Using Spearman's Rho, associations were investigated between discomfort scores 'today' and: (1) physical-aggravating factors (*$r=0.44$, $P<0.01$*); (2) movement-relieving factors (*$r=0.18$, $P<0.01$*); and (3) posture-relieving factors (*r =0.01, P>0.05*). When the symptom modifying factors were placed together in a logistic regression (stepwise) model only physical-aggravating factors were retained, explaining 24% of the variance in discomfort. (A*ssociations between SMFs and discomfort frequency were unremarkable: see Appendix 11e).*

15.7) Association between musculoskeletal symptoms, LBP and low back discomfort

The proportion of reported musculoskeletal symptoms (in at least one body region) was significantly different between respondents who did and did not report histories of LBP and discomfort whilst sitting at work (Table 41). Notably, a history of LBP and low back discomfort were each significantly associated with an increased prevalence (12-month/7-day) of other symptoms, particularly affecting the upper limb.

Table 41: Prevalence rates of self-reported musculoskeletal symptoms for respondents who did and did not report previous LBP and discomfort 'today'

Prevalence of musculoskeletal symptoms	**Previous LBP episode**		**Discomfort whilst sitting at work 'today'**	
	Yes n=377	**No n=223**	**Yes n=323**	**No n=261**
12-Month prevalence:				
At least 1 body region	87%* (327)	74% (166)	89%* (287)	75% (195)
2 regions	26% (97)	21% (46)	29%* (93)	17% (45)
3 regions	22%* (81)	14% (32)	24%* (78)	13% (33)
4 or more regions	20%* (77)	8% (18)	23%* (74)	8% (20)
Upper limb	83%* (311)	68% (152)	85%* (273)	69% (179)
7-Day prevalence:				
At least 1 body region	74%* (279)	60% (134)	78%* (253)	58% (152)
2 regions	20% (76)	24% (53)	23% (73)	20% (51)
3 regions	20%* (77)	11% (25)	20%* (66)	13% (34)
4 or more regions	15%* (57)	5% (11)	14%* (45)	8% (22)
Upper limb	66%* (244)	51% (110)	72%* (228)	47% (119)

[Statistically significant difference from the 'no' group, (5% level)]*

EXPERIMENTAL INVESTIGATION

RESULTS 3

Activities and lumbar movement characteristics measured during work

16.1) Introduction

This section of the results presents the activity data (standing, sitting, walking) and lumbar movement characteristics (lumbar postures and movements) collected from sedentary workers by the FOG system during work.

16.2) Participation and compliance

From the 240 full time workers invited to wear the FOG system at work (120 each from WYP and FD), 75% (n=181) agreed to participate in the experimental investigation. However, only FOG data from 140 workers (n=72 WYP, n=68 FD) could be used because: (1) 4 workers each broke a sensor; (2) 21 workers removed the system soon after attachment; (3) 11 workers reattached the hip sensor; and (4) a corrupted compact flash card was mistakenly used to collect data from 5 workers.

16.3) Demographic characteristics

The experimental sample were representative of respondents to the workforce survey (for their respective companies) in terms of age, gender, job tenure and low back discomfort at work. However, there was a significantly greater proportion of workers who reported a previous history of LBP in the experimental sample ($P<0.05$).

16.4) Duration of FOG data collection

For the whole sample, activity data were collected for a mean duration of 5.8 hours continuously during work. The mean duration of data collection was longer at FD (6.6h) than at WYP (5h), because the FOG system could generally be attached earlier at FD (emergency telephone calls at WYP meant that it was not always possible for call handlers to immediately leave their workstation).

16.5) FOG angles measured in standing

16.5.1) Lumbar lordosis and hip angle

The Interrogator software required the lumbar lordosis and hip angle measured at the start of data collection to be input for each individual, since these 'reference' values were used by the software's algorithm to automatically detect sitting, standing and walking. The mean reference standing lordosis for all workers was 147°, and was significantly different between males (152°) and females (142°) (*P<0.01*). Therefore, females were found to have a larger standing lordosis. The mean reference hip angle measured whilst standing was 166°, and was not significantly different between males (165.5°) and females (167°). For all workers, when the mean reference lordosis in standing (measured at the start of data collection) was compared to the mean lordosis calculated from the software's allocation of standing (i.e. for all periods of standing detected during work), the lumbar angle significantly increased (158°) signifying a reduction in the lumbar lordosis (*P<0.05*). This demonstrates that the reference standing lordosis was not always representative of the standing lordosis during work (perhaps due to worker behaviour or spinal shrinkage over time), thus supporting the use of a wide lumbar range (≤25°) in the algorithm for detection of standing.

16.5.2) Range of lumbar sagittal movement

At the start of data collection, immediately after the FOG system had been attached, each subject was asked to fully flex and then extend their lumbar spine. From the standing position, workers exhibited a mean flexion range of 48° and a mean extension range of 20°, producing a total mean range of 68°. Females had a larger mean range of flexion and extension (50° and 21°) than males (47° and 19°), and thus a larger total range of lumbar sagittal movement (71°) compared to males (66°). There were no significant differences between gender or age (younger/older) categories (*P>0.05*). However, there was a trend for older workers (aged 38-65) to be stiffer; exhibiting less flexion, extension and total ROM than younger workers (aged 18-37).

16.6) Activities during work

Since the duration of data collection varied between workers, the activity data were normalised (by being expressed as a percentage of total work-time) to produce proportions of use for each activity, thus enabling activities during work to be compared (Table 42). The single longest and the cumulative total of the 3 longest periods of sitting were chosen as arbitrary measures of prolonged sitting, in order to determine what proportion of work-time was spent sitting for these uninterrupted periods. The data confirmed that overall (column 4) workers spent the majority (83%) of their working day sitting, with the single longest period and the three longest periods comprising 20.2% and 45% of the total sitting time. The proportion of time spent standing was small (typically 12.1%), and even less time was spent walking (typically 4.3%). There were some differences between the companies with respect to the mean proportion of time spent sitting; WYP workers spent significantly more time sitting overall (all periods), and the single longest and 3 longest periods were also longer than at FD (*P<0.01*). Accordingly, WYP workers spent significantly less time standing compared to FD workers, although the proportions of time spent walking were similar.

Table 42: Mean proportions of time spent sitting, standing and walking during work, expressed for each company and the combined sample

Activities during work		**WYP n=72**	**FD n=68**	**Combined Sample n=140**
Sitting:	**all periods**	85.7%**	80.4%	83.1%
	single longest period†	23.6%**	16.6%	20.2%
	longest 3 periods†	52.3%**	37.0%	45%
Standing:	**all periods**	9.6%**	14.6%	12.1%
Walking:	**all periods**	4.2%	4.5%	4.3%

*[** Statistically significant difference between WYP and FD (1% level)]*
[†Single longest period represents the maximum recorded period, the longest 3 periods is a cumulative measure of the longest period and the 2nd and 3rd 'ranked' longest periods]
[Cumulatively the proportions do not add up to 100%, due to unexplained 'transitions']

16.6.1) Exposure to prolonged sitting

Whilst the single longest period of sitting provides a measure of maximum exposure to prolonged sitting for one instance during a working shift, it may not be typical of the duration of most prolonged sitting periods. Therefore, the average duration of the three longest periods was arbitrarily selected as a more representative measure. In order to determine the proportion of workers exposed to different length prolonged sitting periods, 60 minutes was selected as a cut-off point to define low (<60 mins) and high (≥60 mins) exposures. Small worker numbers limited analysis of additional high exposure (e.g. ≥90 mins) groups. The mean number of sitting periods (per hour) was calculated as a measure of changes in activity from sitting during work (higher values indicating more frequent changes).

Whilst 45.7% of workers spent <60 minutes sitting during their single longest period (Table 43: combined sample), it is clear that many workers (54.3%) were exposed to more prolonged sitting periods; a higher proportion at FD had longest periods ≥60 minutes (column 3). Considering the average duration of the 3 longest sitting periods, 69% of all workers sat for <60 minutes, and 31% sat for ≥60 minutes, and this pattern was consistent for WYP and FD. The mean number of sitting periods (per hour) was also similar between WYP and FD. Overall, there were no significant differences between the companies (*P>0.05*).

For the combined sample, the average duration of the single longest period of sitting was 66 minutes, although the individual maximum period greatly exceeded this (215 minutes). The mean duration of the three longest periods of sitting was 50 minutes, with some workers spending up to 125 minutes sitting during these periods.

Table 43: Proportion of workers exposed to prolonged sitting periods of different durations and the average number of sitting periods per hour, expressed for each company and the combined sample

	WYP (n=72)	**FD (n=68)**	**Combined Sample (n=140)**
Single longest period:			
< 60mins	48.6% (35)	42.6% (29)	45.7% (64)
≥ 60mins	51.4% (37)	57.4% (39)	54.3% (76)
Mean (3 Longest periods):			
< 60mins	70.8% (51)	66.2% (45)	68.6% (96)
≥ 60mins	28.2% (21)	33.8% (23)	31.4% (44)
Mean no. of sitting periods (per hour):	3.6 (72)	4.2 (68)	3.9 (140)

[No statistically significant differences between WYP and FD (5% level)]

16.7) Lumbar movement characteristics measured whilst sitting

This section will consider the lumbar movement characteristics of all workers (with and without LBP) measured continuously whilst sitting at work: (1) over the course of a shift (all sitting periods), and (2) during prolonged sitting (3 longest periods). This will help to determine if workers lumbar movement characteristics are different during prolonged periods of sitting, compared to sitting in general. Lumbar movement characteristics will first be explored for variables that describe different postures (e.g. lordotic and kyphotic shaped lumbar curves, time spent at the extremes of range), and then for variables that describe movement of the lumbar spine (e.g. changes in posture: regardless of shape).

16.7.1) Lordotic and kyphotic postures

Using the mean lumbar angle formed by the shape of the FOG, workers were classified as sitting with a predominantly lordotic (<180°) or kyphotic (≥180°) lumbar posture. The mean lumbar angle of all workers whilst sitting at work was 182.2° (2.2° of kyphosis), and was not significantly different between males (183°) and females (181.3°) (Table 44, column 3). Since data for the variable % of sitting time with a lordotic posture was negatively skewed, the median was used to characterise workers postures (columns 4 and 6). Males spent proportionally less time sitting with a lordotic posture than females, and younger workers spent proportionally more time in a lordotic posture than older workers, both for all and the 3 longest sitting periods. There were some company differences; lordotic lumbar postures were more evident at WYP than at FD.

Regardless of gender, age or company type, the proportion of sitting time spent with a lordotic lumbar posture reduced for the three longest periods (column 6), compared to all periods (column 4). However, these differences were small, and overall there was little change in the mean lumbar angle (columns 3 and 5). Overall, workers maintained a lordotic lumbar posture for only a small proportion (26%) of the total sitting time.

Table 44: Average lumbar angle and % of sitting time with a lordotic posture, expressed for different sitting periods and categories

Categories	n	Sitting – all periods		Sitting – 3 longest periods	
		Mean lumbar angle (SD)	Median % of sitting time lordotic (IR)	Mean lumbar angle (SD)	Median % of sitting time lordotic (IR)
Sex:					
Male	71	183.0° (16.3)	18.6% (55.2)	183.3° (17.9)	15.0% (68.8)
Female	69	181.3° (15.6)	35.8% (72.4)	182.3° (16.5)	27.3% (78.8)
Age:					
< 37 yrs	60	183.9° (13.1)	31.5% (48.4)	184.4° (14.5)	25.3% (61.7)
≥ 38 yrs	76	180.9° (18.1)	23.4% (71.8)	181.9° (19.3)	18.1% (80.6)
Company:					
WYP	72	179.8° (16.4)	29.8% (70.4)	180.0° (17.4)	26.4% (84.3)
FD	68	184.6° (15.2)	20.1% (48.2)	185.8° (16.5)	16.8% (57.0)
Whole sample:	140	182.2° (15.9)	26.4% (65.4)	182.8° (17.2)	24.1% (17.2)

[No statistically significant differences within or between sitting period groups (5% level)]
[SD= standard deviation, IR = interquartile range]

16.7.2) Time spent at the extremes of range

Since the range of lumbar movement varied between individuals, these data were normalised to explore lumbar postures adopted at the extremes of range. Using the minimum and maximum angles recorded over the course of data collection (total ROM) a range of 0-100% was set, and the amount of time spent in 10% portions of this range was calculated for each individual. The total ROM (mean: 75°) was considered preferable to using the lumbar ROM measured in standing at the start of data collection (mean: 70°), because many workers (62%) achieved a larger ROM whilst sitting during work. Cut-off points for the extremes of total ROM were set at ≤40% and ≥80%. The mean lumbar angles at these points were 156° and 194° respectively. Therefore, the time spent at the extremes of lumbar range represents extreme lordotic and kyphotic sitting postures for most individuals.

Table 45 shows the mean lumbar ROM achieved whilst sitting (column 3), and the percentage of sitting time spent in lumbar postures at the extremes of range (determined using minimum and maximum angles recorded over the course of data collection) (columns 4 and 5). Females and younger workers had a larger ROM in sitting than males and older workers (column 3). For all sitting periods, the proportions of time spent in extreme postures were similar for different gender and age categories. However, younger workers spent a significantly greater proportion of time with a lumbar posture ≤40% of the total ROM, compared to older workers (column 5).

For the 3 longest periods, females and older workers spent proportionally more time with a lumbar posture ≥80% of the total ROM, although these differences were not significant. For the whole sample, during the 3 longest sitting periods workers spent significantly more time with a lumbar posture ≥80% of the total ROM, used a significantly smaller lumbar ROM, and spent significantly less time with a lumbar posture ≤40% of the total ROM, compared to all sitting periods.

Table 45: Average lumbar ROM and % of sitting time with a lumbar posture at the extremes of range, expressed for different sitting periods and categories

	Categories		n	Mean lumbar ROM (SD)	Median % of sitting time ≥ 80% total ROM (IR)	Median % of sitting time ≤ 40% total ROM (IR)
All periods	**Sex:**	**Male**	71	71.2° (21.6)	17.6% (24.0)	2.4% (4.6)
		Female	69	78.9° (26.9)	17.3% (44.3)	2.5% (3.8)
	Age:	**< 37 yrs**	60	80.8° (28.5)	16.2% (24.6)	3.0% (9.0)
		≥ 38 yrs	76	71.0° (19.7)	18.5% (46.4)	2.0% (10.1)*
	Whole Sample:		140	74.9 (24.6)	17.5% (28.0)	2.3% (4.4)
3 longest	**Sex:**	**Male**	71	52.6° (24.2)**	15.8% (25.0)	1.4% (1.6)
		Female	69	56.0° (24.3)**	23.4% (62.0)	0.8% (0.8)
	Age:	**< 37 yrs**	60	56.8° (26.5)**	12.2% (32.6)	1.5% (1.7)
		≥ 38 yrs	76	52.5° (22.7)**	25.2% (42.3)	1.0% (1.0)
	Whole Sample:		140	54.3° (24.2)**	19.9% 37.6)**	1.19% (1.1)**

*[** Statistically significant difference between 'all' and '3 longest periods' (1% level)]*
[Statistically significant difference between age categories (5% level)]*
[SD= standard deviation, IR = interquartile range]

16.7.3) Movement and changes in posture

In order to explore different aspects of lumbar movement-in-sitting the following variables were calculated for all periods and the 3 longest periods of sitting: (1) mean angular velocity; (2) mean proportion of time spent static; and (3) mean variation. For each individual, lumbar angular velocity was measured as absolute changes in lumbar angles (per second) whilst sitting; the proportion of sitting time spent static was measured as the percentage of time spent accruing 5° of total lumbar movement; and variation was measured using the standard deviation of lumbar angles in sitting.

Table 46 shows that there were minimal differences in lumbar movement variables for sex and age categories, both within and between different sitting periods. For the whole sample, during the 3 longest sitting periods workers changed their lumbar posture significantly less than during all sitting periods; there was a lower mean angular velocity, more time spent accruing 5° of movement, and less variation in movement.

Table 46: Mean lumbar movement variables and standard deviations (SD), expressed for different sitting periods and categories

Categories	**n**	**Mean angular velocity (°sec^{-1})** Sitting periods: All	Sitting periods: 3 Longest	**Mean % of sitting time spent static** Sitting periods: All	Sitting periods: 3 Longest	**Mean variation (SD°)** Sitting periods: All	Sitting periods: 3 Longest
Sex:							
Male	**71**	4.26 (2.3)	4.05 (2.3)	65.1% (16.0)	69.1% (16.2)	10.1 (5.1)	8.4 (3.8)
Female	**69**	4.26 (2.4)	3.95 (2.3)	66.7% (13.3)	70.1% (15.6)	10.2 (4.6)	8.3 (4.6)
Age:							
< 37 yrs	**60**	4.47 (2.5)	4.18 (2.4)	65.6% (15.4)	68.8% (17.0)	10.7 (5.5)	8.8 (4.8)
≥ 38 yrs	**76**	4.15 (2.9)	3.92 (2.3)	5.8% (14.5)	70.9% (14.2)	9.7 (4.1)	7.9 (3.5)
Whole Sample:	**140**	4.26 (2.3)	2.98** (2.9)	65.9% (14.7)	69.9%** (15.6)	10.1 (4.8)	8.3** (4.2)

*[** Statistically significant difference between 'all' and '3 longest periods' (1% level)]*

16.8) Lumbar movement characteristics measured whilst standing and walking

Lumbar movement characteristics recorded whilst standing and walking during work will now be considered; little is known about these characteristics or how they vary from those measured in sitting. Table 47 shows the mean lumbar lordosis, mean angular velocity (AV) and mean variation in lumbar angles for all standing and walking periods. Although gender differences for the mean standing lordosis were evident, they were only significant for the mean walking lordosis (column 6). No other significant differences based on gender or age groups were apparent, although females and younger workers had a higher mean AV than males or older workers when standing and walking.

Comparing the results in Table 47 with those in Tables 45 and 46 (all periods of sitting) shows that standing involved more changes in lumbar posture (mean AV 6.9°sec^{-1}) compared to sitting (4.26°sec^{-1}). Walking also had a higher mean AV (18.2°sec^{-1}) than during sitting, and there was less variation in lumbar movement when walking (SD 6.4°) compared to sitting (SD 10.1°). Standing involved a similar amount of variation in lumbar movement to sitting (SD: 10.8°).

Table 47: Mean lumbar posture and movement variables for all periods of standing and walking at work, expressed for different categories

Categories		Activity during work					
		Standing - all periods			Walking – all periods		
	n	Mean lordosis (SD)	Mean AV °sec^{-1} (SD)	Mean variation (SD)	Mean Lordosis (SD)	Mean AV °sec^{-1} (SD)	Mean variation (SD)
Sex:							
Male	71	160.7° (18.9)	6.69 (3.0)	10.6° (5.4)	160.8°* (17.5)	16.32 (7.5)	6.6° (3.5)
Female	69	154.9° (18.8)	7.20 (3.4)	10.9° (3.9)	152.6° (25.4)	20.28 (11.8)	6.1° (2.7)
Age:							
<37 yrs	60	158.8° (17.7)	7.36 (3.5)	10.8° (5.2)	158.7° (16.5)	19.74 (12.1)	6.5° (3.3)
≥38 yrs	76	156.4° (20.2)	6.66 (1.1)	10.7° (4.3)	154.7° (25.6)	17.07 (7.8)	6.2° (2.8)
Whole sample:	140	157.8° (19.0)	6.94 (6.94)	10.8° (4.7)	158.0° (22.0)	18.24 (10.01)	6.4° (3.1)

[Statistically significant difference between males and females (5% level)]*
[SD= standard deviation]

16.9) Accuracy of the FOG system

16.9.1) Percentage agreement with identified activities

To provide a check that the FOG system was accurately detecting sitting, standing and walking, 4.8% (n=7) of datatrains were randomly selected for analysis. The author viewed the datatrain graph of both FOG sensors over time and periods of sitting, standing and walking were identified by eye. Agreement was confirmed if activities within the activity log (derived from the Interrogator software) occurred within two seconds of the authors own estimate. Overall, sitting (86 periods), standing (243 periods) and walking (140 periods) were detected 98%, 96%, and 93% of the time respectively.

16.9.2) Drift in the FOG sensors

The FOG sensors were calibrated the day prior to the start of data collection, and activity and lumbar movement data were subsequently collected over a 49 day period. Since the accuracy of the FOG sensors is known to reduce over time, after 24-days data collection they were re-tested in the calibration jig using the original calibration equation obtained on day 0. The overall mean difference (from each of the jig angles) for all lumbar sensors (from measures on day 0) was 1.37°, and the mean LoA (differences) were -0.9° to +3.64°. Therefore, drift in the lumbar FOGs was sufficiently small to have a negligible impact on the results. Nonetheless, the lumbar FOGs were re-calibrated to collect data for the remaining 25 days. Due to sizable attachment errors involving the hip FOG, these sensors were not re-calibrated. This did not impact on the results because the hip FOGs were used to measure changes in the hip angle between different activities.

RESULTS 4

Activities and seated lumbar movement characteristics measured during work: associations with self-reported data

17.1) Introduction

This section of the results will explore associations between activities and seated lumbar movement characteristics measured during work, and self-reported symptom data.

17.2) Factors associated with activities during work:

17.2.1) Self-reported LBP

Workers reporting previous or current LBP spent a similar proportion of work-time sitting, standing and walking to workers reporting no LBP (Table 48). Differences in the mean number of sitting periods per hour (providing an indication of changes in activity from sitting) were also similar between workers who did and did not report previous or current LBP (Table 48).

Table 48: Mean proportion of time spent in different activities during work for workers with did and did not report previous and current LBP

Activities during work (all periods)	Previous LBP (not past 7-days)		Current LBP (past 7-days)	
	Yes n=26 (SD)	No n=114 (SD)	Yes n=64 (SD)	No n=76 (SD)
Sitting	83.2% (10.7)	83.1% (11.4)	82.7% (10.8)	83.4% (11.5)
Standing	11.1% (8.2)	12.3% (9.9)	12.7% (9.5)	11.5% (9.6)
Walking	5.2% (3.7)	4.2% (3.4)	4.2% (3.0)	4.4% (3.8)
Mean no. of sitting periods (per hour)	4.4 (1.8)	3.8 (1.8)	4.0 (1.7)	3.8 (2.0)

[No statistically significant difference between 'yes' and 'no' groups (5% level)]

Table 49 shows that for the average length of the three longest periods of sitting (chosen as a representative measure of prolonged sitting), a greater proportion of workers who reported previous or current LBP sat for shorter durations than workers who reported no previous or current LBP (*P>0.05*). This indicates that workers reporting LBP generally did not sit for long uninterrupted periods. Column 4 indicates that workers with current LBP tended to sit for longer durations compared to workers with previous LBP (column 2). This finding might be explained by the smaller number of workers who reported previous LBP (n=26). Based on reported LBP history, the average duration of the three longest periods of sitting varied: previous LBP (43mins, SD 23.2); no previous LBP (53mins, SD 16.9); current LBP (50mins, SD 21.3); and no current LBP

(52mins, SD 31.9). There were no significant differences within previous and current LBP groups (*P>0.05*).

Table 49: Proportion of workers exposed to prolonged sitting during work who did and did not report previous and current LBP

Mean duration: 3 longest periods of sitting	**Previous LBP (not past 7-days)**		**Current LBP (past 7-days)**	
	Yes (n=26)	**No (n=114)**	**Yes (n=64)**	**No (n=76)**
< 60mins	80.8% (21)	65.8% (75)	71.9% (46)	65.8% (50)
≥ 60mins	19.2% (5)	34.2% (39)	28.1% (18)	34.2% (26)

[No statistically significant differences between 'yes' and 'no' groups (5% level)]

17.2.2) Self-reported low back discomfort

Workers who reported discomfort whilst sitting at work 'today' spent a greater proportion of time sitting and a smaller proportion of time standing and walking during work, compared to workers who reported no discomfort (Table 50). These differences were small (<1.2%), and the mean number of sitting periods (per hour) were also similar between workers who did and did not report discomfort. Therefore, low back discomfort whilst sitting at work did not significantly influence the proportions of time spent in activities during work.

Table 50: Mean proportions of time spent in different activities during work for respondents with did and did not report discomfort whilst sitting at work

Activities during work (all periods)	**Discomfort whilst sitting at work 'today' n=68 (SD)**	**No discomfort whilst sitting at work 'today' n=66 (SD)**
Sitting	83.6% (11.37)	82.5% (11.28)
Standing	11.9% (10.1)	12.2% (9.1)
Walking	4.1% (2.9)	4.7% (4.1)
Mean no. of sitting periods (per hour	3.7 (2.0)	4.1 (1.7)

[No statistically significant differences between 'yes' and 'no' groups (5% level)]

Table 51 shows that workers who reported low back discomfort whilst sitting at work tended to sit for longer uninterrupted periods than workers reporting no discomfort. The average duration of the three longest periods of sitting varied from 56mins (SD 25.8) for workers reporting discomfort, to 47mins (SD 18.6) for workers who reported being discomfort free, and these differences were significant (*P<0.05*).

Table 51: Proportion of workers exposed to prolonged sitting during work who did and did not report discomfort whilst sitting at work 'today'

Mean duration: 3 longest periods	Low back discomfort whilst sitting at work (n=68)	No low back discomfort whilst sitting at work (n=66)
< 60 mins	60.3% (41)	74.2% (49)
≥ 60 mins	39.7% (27)	25.8% (17)

[No statistically significant differences between discomfort groups (5% level)]

The reported intensity of discomfort 'today' was also considered. Workers reporting a high level of discomfort (>25pts, n=23) spent a similar proportion of work-time sitting (85.3%) and standing (11.8%) to workers reporting a lower level of discomfort (≤25pts, n=43) (sitting: 81.5%, standing: 9.7%). However, workers reporting high discomfort spent significant less work-time walking (3.2%) compared to workers reporting a lower level of discomfort (4.9%) (*P<0.05*), although the differences in proportions were small.

17.2.3) Symptom modifying scores

To determine if physical-aggravating, posture-relieving and movement-relieving factors influenced the proportion of time spent sitting, standing and walking during work, associations were investigated using Spearman's Rho. No significant bivariate correlations were found. Using the mean to dichotomise sub-scale scores into high/low groups, the independent *t*-test also found no significant differences in the proportions of time spent sitting, standing and walking during work. Thus, symptom modifying factors did not significantly influence the proportion of time spent adopting activities during work.

17.3) Factors associated with seated lumbar movement characteristics during work:

17.3.1) Self-reported low back pain

Average lumbar posture and movement variables measured whilst sitting at work were explored over the course of a working shift (all periods) and during prolonged sitting (3 longest periods), in order to identify associations with self-reported LBP (Table 52). Workers reporting previous and current LBP had a higher mean lumbar angle (rows 1 and 7), spent a smaller proportion of sitting time with a lordotic lumbar posture (rows 2 and 8), and a greater proportion of time sat with a posture ≥80% of the total ROM (rows 3 and 9), compared to workers who reported no LBP. For current LBP, these differences were significant for the mean lumbar angle and the proportion of sitting time spent with a lordotic posture, both for all and the three longest periods (*P<0.05*). The proportion of sitting time spent with a lumbar posture ≥80% of the total ROM was also significantly different, but only for the 3 longest periods (*P<0.05*). Therefore, workers reporting current LBP adopted a significantly more kyphotic lumbar sitting posture than workers who were pain free.

For the group of workers reporting current LBP, where there were similar numbers of workers who did and did not report symptoms, workers reporting LBP developed a more kyphotic lumbar posture during prolonged sitting periods, compared to workers who reported no LBP. The mean differences in postural variables (recorded during the 3 longest periods) from all periods of sitting (which included the 3 longest periods) for the LBP group were: +1.3° (lumbar angle), -4.9% (sitting time spent lordotic), +6.9% (sitting time spent ≥80% total ROM); compared to +0.1° (lumbar angle), +5.5% (sitting time spent lordotic), and +1.7% (sitting time spent ≥80% total ROM) for the no symptom group. There were no within group differences (*P<0.05*).

The lumbar movement variables 'total ROM in sitting' and 'percentage of sitting time spent accruing 5° of movement' were not used to investigate associations with LBP, because these measures were highly correlated with other variables (SD and angular velocity). Using the variable 'mean angular velocity' (rows 5 and 11), workers reporting previous LBP were found to change their lumbar posture (per second) more than workers reporting no LBP. This pattern was reversed for workers reporting current LBP (past 7-days), who changed lumbar posture less than workers reporting no LBP. These differences were not significant (*P>0.05*). All workers reporting previous or current LBP used less variety of lumbar movement whilst sitting than workers reporting no LBP (rows 6 and 12). These differences were small and consistent for different sitting periods. Overall, the movement variables recorded show that during the course of a working shift workers changed lumbar posture less during prolonged sitting, although this trend was similar for all workers, regardless of reported LBP.

Table 52: Average lumbar posture and movement variables for different sitting periods at work, expressed for respondents who did and did not report previous and current LBP

	Variables (range)	Previous LBP (not past 7-days)		Current LBP (past 7-days)	
		Yes n=26 (SD/IR)	**No n=114 (SD/IR)**	**Yes n=64 (SD/IR)**	**No n=76 (SD/IR)**
All periods	**Mean lumbar angle° (143-219)**	183.3 (12.5)	181.9 (16.7)	185.5* (15.0)	179.5 (16.3)
	Median % of sitting time lordotic (0-100)	19.3 (43.2)	20.4 (56.8)	15.7* (40.6)	32.0 (66.6)
	Median % of sitting time ≥80% total ROM (0-99)	26.2 (9.4)	18.6 (28.7)	19.7 (33.1)	12.0 (26.9)
	Median % of sitting time ≤40% total ROM (0-58)	3.7 (5.0)	2.1 (3.6)	1.5 (2.0)	3.7 (5.8)
	Mean angular velocity $°sec^{-1}$ (1-12)	4.37 (2.4)	4.24 (2.2)	4.01 (2.3)	4.48 (2.4)
	Mean Variation – SD° (2-25)	9.2 (4.3)	10.4 (5.6)	10.1 (4.5)	10.3 (5.1)
3 longest periods	**Mean lumbar angle° (143-219)**	184.5 (12.7)	182.4 (18.1)	186.8* (16.4)	179.7 (17.2)
	Median % of sitting time lordotic (0-100)	24.1 (77.2)	26.4 (74.3)	10.8* (42.8)	37.5 (84.4)
	Median % of sitting time ≥80% total ROM (0-99)	23.1 (39.1)	13.8 (50.7)	26.6* (51.7)	13.7 (35.9)
	Median % of time ≤40% total ROM (0-58)	1.0 (1.0)	0.3 (2.8)	0.6 (0.5)	1.5 (1.8)
	Mean angular velocity $°sec^{-1}$ (1-12)	4.1 (2.4)	3.9 (2.3)	3.7 (2.2)	4.2 (2.4)
	Mean Variation – SD° (2-25)	7.6 (3.7)	8.5 (4.3)	8.1 (4.2)	8.5 (4.2)

[Statistically significant difference between 'yes' and 'no' groups (5% level)]*
[SD= standard deviation for mean, IR = interquartile range for median]

17.3.2) Self-reported low back discomfort

This section addresses the cross-sectional component of sub-hypothesis 2, and sub-hypothesis 4. There were no significant associations between the presence of discomfort and lumbar postural variables (all/3 longest periods), although workers reporting discomfort had a higher mean lumbar angle (Table 53: rows 1 and 7) and spent a smaller proportion of sitting time with a lordotic lumbar posture (rows 2 and 8). For the proportion of sitting time spent with lumbar postures at the extremes of normalised range, workers reporting discomfort spent proportionally more time with postures ≥80% (rows 3 and 8) and proportionally less time with postures ≤40% (rows 4 and 10). In terms of lumbar movement (mean angular velocity), workers reporting discomfort changed lumbar posture a similar amount to workers reporting no discomfort (rows 5 and 11), both for all and the 3 longest periods of sitting. The only significant difference was for mean variation in lumbar angles during all periods of sitting (row 6); workers reporting discomfort used less variety of lumbar movement than workers reporting no discomfort.

Table 53: Average lumbar posture and movement variables for different sitting periods at work, expressed for respondents who did and did not report discomfort

	Variables (range)	**Low back discomfort whilst sitting at work 'today'**	
		Yes n=68 (SD/IR)	**No n=66 (SD/IR)**
All periods	**Mean lumbar angle° (133-219)**	184.4 (15.2)	180.2 (16.7)
	Median % of sitting time lordotic (0-100)	13.8 (56.6)	28.3 (57.0)
	Median % of sitting time ≥80% total ROM (0-99)	19.3 (27.0)	15.1 (27.2)
	Median % of sitting time ≤40% total ROM (0-58)	1.6 (2.1)	3.0 (5.0)
	Mean angular velocity °sec^{-1} (1-12)	4.09 (2.4)	4.38 (2.3)
	Mean Variation – SD° (2-25)	9.2 (4.7)*	11.0 (4.8)
3 longest periods	**Mean lumbar angle° (133-219**	184.5 (12.7)	182.4 (18.1)
	Median % of sitting time lordotic (0-100)	11.6 (76.9)	28.6 (78.4)
	Median % of sitting time ≥80% total ROM (0-99)	24.7 (39.1)	15.3 (38.4)
	Median % of sitting time ≤40% total ROM (0-58)	0.5 (0.6)	1.9 (3.3)
	Mean angular velocity °sec^{-1} (1-12)	4.1 (2.4)	3.9 (2.3)
	Mean Variation – SD° (2-25)	7.6 (3.7)	8.5 (4.3)

[Statistically significant difference between 'yes' and 'no' group (5% level)]*
[SD= standard deviation for mean, IR = interquartile range for median]

In order to determine if workers who maintained a lumbar lordosis in sitting and changed their posture regularly reported less discomfort whilst sitting at work than workers who adopted more kyphotic and static lumbar postures, four posture and movement variables were selected for analysis (Table 54). Workers were then categorised as having 'high' or 'low' values for each variable using the sample mean or median value as a cut-off point. The pattern of the results was largely consistent for all periods and the three longest periods of sitting; workers who maintained a lordotic lumbar posture for longer (% sitting time lordotic) and changed lumbar posture more regularly (angular velocity, variation) reported less discomfort.

The only significant difference was for variation in lumbar movement during the 3 longest sitting periods; workers who changed posture less reported significantly more discomfort. Overall, the differences in discomfort scores between 'high' and 'low' groups were small.

Table 54: Mean low back discomfort scores whilst sitting at work 'today', expressed for workers with high/low lumbar posture and movement variables

Variables	**Mean discomfort score (SD)**	
	High [a]	**Low [b]**
All sitting periods:		
% of sitting time lordotic (median: 26%)	11.3 (19.3)	14.5 (22.9)
% of sitting time ≥80% total ROM (median: 17.5%)	13.0 (20.7)	15.8 (24.0)
Angular velocity (mean: 4.26 °sec^{-1})	11.1 (19.0)	13.7 (22.1)
Variation – SD (mean: 10.1°)	9.2 (18.3)	15.3 (22.6)
3 longest sitting periods:		
% of sitting time lordotic (median: 24%)	12.1 (19.7)	13.5 (22.4)
% of sitting time ≥80% total ROM (median: 17.5%)	12.7 (20.5)	13.0 (31.9)
Angular velocity (mean: 2.9 °sec^{-1})	11.8 (21.0)	13.8 (21.3)
Variation - SD (mean: 8.3°)	8.1 (17.1)*	15.5 (22.7)

[n=140] [[a] ≥ mean or median, [b] < mean or median]
[Statistically significant difference in discomfort scores (5% level)]*
[Conducting the same analyses exclusively for workers with current LBP yielded N.S. differences, with a maximum mean score difference of 12pts between 'high' and 'low' groups for % of sitting time >80% total ROM]

Spearman's Rho was also used to explore significant correlations (*P<0.05*) between the lumbar movement characteristics in Table 54, and discomfort intensity. The only significant (weak) associations were for variation in lumbar movement for all periods of sitting (*r=-.210*), and the 3 longest periods of sitting (*r=-.217*); workers with higher levels of back discomfort moved less.

17.3.3) Symptom modifying scores

To determine if reported symptom aggravating and relieving aspects of sitting at work related to biomechanical factors, Spearman's Rho was used to investigate associations between sub-scales of the SSMQ and seated lumbar movement characteristics. Only one significant weak association was found, between variation in lumbar movement during the 3 longest periods of sitting and physical-aggravating factors ($r=-.205$).

17.4) Univariate and multivariable explanation of self-reported current LBP

The independent and combined ability of variables to explain current LBP will now be considered. Four different types of factors were explored: (1) lumbar movement characteristics; (2) clinical psychosocial factors; (3) occupational psychosocial factors; and (4) work-relevant symptoms (including symptom modifying factors - SMFs). Associations with current LBP were investigated for individual variables, then within each group of factors, and finally between different groups of factors. It was anticipated that this approach might help to better understand the influence of variables at different levels, some of which are new. For analysis within and between different groups of factors, a stepwise procedure was used to identify variables that made a statistically significant contribution to models. Since continuous data with different sized scales were investigated, Nagelkerke R^2 (%) was used to estimate the strength of association, both for individual variables and multivariable models.

At univariate level (Table 55, column 4), the crude ORs (which were generally small due to large sized scales) show that the lumbar movement characteristics associated with current LBP were: lumbar angle and % of sitting time with a lordotic posture (all/3 longest periods). The % of sitting time with a posture ≥80% ROM was also associated with LBP (3 longest periods only). Thus, workers who spent more time sitting with a lordotic posture were significant less likely to report current LBP. However, the amount of variance in current LBP explained by each variable was rather small (maximum 7%).

The clinical psychosocial factors (psychological distress, fear avoidance beliefs) each explained more of the variance in current LBP (7% and 10% respectively) than any of the occupational psychosocial factors. The strongest univariate association with current LBP was found for work-relevant symptoms and SMFs: discomfort whilst sitting at work (7%), and physical-aggravating factors (18%).

Prior to conducting within-group stepwise analysis of lumbar movement characteristics the mean lumbar angle was dropped, due to its high inter-correlation (*r=-.948*) with the % of sitting time spent with a lordotic posture. Controlling for all other lumbar movement characteristics measured whilst sitting at work showed that only the % of sitting time spent with a lordotic posture was retained as a significant factor, explaining 6% (all periods) and 9% (3 longest periods) of the variance in current LBP (column 7). Thus, this postural variable dominated other biomechanical variables in explaining current LBP.

When clinical and occupational psychosocial factors were considered in separate multivariable models they explained 10% and 1% of the variance in current LBP. Fear avoidance beliefs dominated psychological distress, although no occupational psychosocial factors were significantly associated with current LBP. The notion that social support was associated with other occupational psychosocial factors was thus explored in separate (univariate) logistic regression analysis, to identify this variables possible 'buffering' effects. Social support was weakly (R^2 <5%) significantly associated with high (>mean: yes/no) levels of job satisfaction (OR 1.13, 95% CI 1.06-1.20), causal beliefs about: work organisation (OR 0.94, 95% CI 0.89-0.99), and physical demands (OR 0.96, 95% CI 0.91-0.99). Thus, there was some evidence for the positive influence of social support on other occupational psychosocial factors.

As a group of factors, work-relevant symptoms (back discomfort whilst sitting) and SMFs (physical-aggravating factors) explained most of the variance in current LBP (32%), 22% more than the next best group (clinical psychosocial factors).

Table 55: Univariate and multivariable associations with self-reported current LBP (yes/no)

	Variables (range)	Mean (SD) Yes n= 64	Mean (SD) No n= 76	Crude OR (95%CI)	R^2 (%)	Adjusted OR (95%CI)‡	R^2 (%)
	Lumbar movement characteristics:						
Sitting: all periods	**Lumbar angle° (133-219) [a]**	185.5 15.0)	179.4 (16.3)	1.02 (1.01-1.05)*	5		
	% of sitting time lordotic (0-100)	15.7[m] (40.6)	32.0[m] (66.6)	0.98 (0.97-0.99)*	5	0.98 (0.96-0.99)*	
	% of sitting time ≥ 80% ROM (0-99)	19.7[m] (33.1)	12.0[m] (26.9)	1.01 (1.00-1.02)	2		
	% of sitting time ≤ 40% ROM (0-58)	1.5[m] (2.0)	3.7[m] (5.8)	0.96 (0.91-1.01)	0.3		
	Angular velocity °sec^{-1} (1-12)	4.01 (2.3)	4.48 (2.4)	0.92 (0.76-1.06)	1		
	Variation – SD° (2-25)	10.1 (4.5)	10.3 (5.1)	0.99 (0.92-1.06)	0.1		**6**
Sitting: 3 longest periods	**Lumbar angle° (133-219) [a]**	186.8 (16.4)	179.5 (17.2)	1.02 (1.01-1.06)*	6		
	% of sitting time lordotic (0-100)	0.8[m] (42.8)	47.5[m] (84.4)	0.98 (0.93-0.99)**	7	0.98 (0.97-0.99)**	
	% of sitting time ≥ 80% ROM (0-99)	26.6[m] (51.7)	13.7[m] (35.9)	1.01 (1.00-1.02)*	6		
	% of sitting time ≤ 40% ROM (0-58)	0.6[m] (0.5)	1.5[m] (1.8)	0.98 (0.95-1.02)	0.9		
	Angular velocity °sec^{-1} (1-12)	3.7 (2.2)	4.2 (2.4)	0.91 (0.79-1.06)	1		
	Variation – SD° (2-25)	8.1 (4.2)	8.5 (4.2)	0.97 (0.90-1.06)	2		**9**
	Clinical psychosocial factors:						
	Psychological distress (0-36)	12.2 (5.28)	10.0 (4.24)	1.10 (1.02-1.19)*	7		
	Fear avoidance beliefs- phys (4-25)	12.1 (3.91)	9.7 (4.16)	1.16 (1.02-1.31)*	10	1.16 (1.02-1.31)**	**10**
	Occupational psychosocial factors:						
	Work organisation (3-15)	5.88 (2.34)	5.84 (2.71)	1.01 (0.88-1.15)	0.1		
	Work environment (5-25)	15.0 (4.43)	13.8 (4.38)	1.06 (0.98-1.15)	2		
	Physical demands at work (4-20)	15.3 (2.84)	15.1 (3.80)	1.01 (0.91-1.11)	0.1		
	Job satisfaction (1-5)	3.41 (0.89)	3.55 (0.89)	0.83 (0.57-1.22)	0.8		
	Psychological demand (12-48)	35.3 (5.22)	35.3 (4.69)	0.96 (0.93-0.99)	0		
	Social support (5-20)	15.9 (2.5	15.3 (3.0	1.07 (0.94-1.21)	1		**1**
	Work-relevant symptoms and symptom modifying factors -SMFs:						
	Discomfort – sitting 'today' (0-100)	22.5 (25.9	4.7 (10.7)	1.06 (1.03-1.1)**	7	1.04 (1.01-1.08)**	
	Physical-aggravating SMFs (6-30)	19.7 (4.6)	16.1 (4.5	1.19 (1.09-1.30)**	18	1.15 (1.05-.127)**	
	Movement-relieving SMFs (3-15)	10.3 (2.39	9.7 (2.38	1.13 (0.97-1.31)	2		
	Posture-relieving SMFs (2-10)	7.80 (1.51)	7.81 (1.98)	1.22 (1.01-1.49)*	4		**32**

[* ORs statistically significant at the 5% level, ** at the 1% level] [R^2 = proportion of variance in current LBP explained]
[[m] = median and interquartile range (IR)] [‡after controlling for all group variables using a stepwise procedure]
[[a] Due to high inter-correlation with % of sitting time lordotic, lumbar angle is dropped from group analysis]

In order to reduce the number of variables input into the final multivariable model (including different groups of factors), lumbar movement characteristics measured over the course of work (all periods) were dropped. These variables were also measured during prolonged sitting (3 longest periods), were thus highly correlated ($r \geq .75$), and explained more of the variance in current LBP when measured during prolonged sitting.

Including the significant univariate variables from different groups of factors (7 in total: excluding lumbar movement characteristics for all periods, and the mean lumbar angle: 3 longest periods), stepwise analysis was undertaken. Two significant variables were retained: % of sitting time with a lumbar posture ≥80% total ROM (OR 1.01, 95% CI 1.00-1.05), and discomfort whilst sitting at work (OR 1.18, 95% CI 1.02-1.36), explaining a modest amount of the variance in current LBP (40%). Thus, different types of work-relevant factors (sitting biomechanics and symptoms) provided the best explanation of the variance in current LBP.

17.5) Multivariable explanation of low back discomfort

The association between low back discomfort whilst sitting 'today' (yes/no) and the variables in Table 55 were explored using multivariable (stepwise) regression, analysis taking place with the addition of each group of factors. In the first step (that included lumbar movement characteristics only), the sole variable retained was variation in lumbar movement (OR 0.87, 95% CI 0.79-0.97), accounting for 8% of the variance in discomfort. The addition of occupational psychosocial factors resulted in two variables being retained: causal beliefs about the work environment (OR 1.16, 95% CI 1.05-1.28) and variation in lumbar movement (OR 0.88, 95% CI 0.79-0.99), explaining 18% of the variance. However, the inclusion of clinical psychosocial factors resulted in fear avoidance beliefs having a dominant effect (OR 1.23, 95% CI 1.06-1.41), explaining 20% of the variance in discomfort. The best model was found when symptom modifying factors were also included: physical-aggravating factors (OR 1.16, 95% CI 1.01-1.34) and fear avoidance beliefs (OR 1.21, 95% CI 1.03-1.42) were retained, explaining 30% of the variance in discomfort.

SUMMARY POINTS: CROSS-SECTIONAL RESULTS:

Workforce survey: profile of respondents

- Respondents were largely representative of their respective company's workforce in terms of gender and age.
- The 12-month prevalence of self-reported LBP was high but similar for respondents at each company, and there were no significant differences in the frequency of LBP episodes, levels of disability or function, or previous sickness absence due to LBP. FD respondents did report a significantly higher lifetime and 7-day prevalence of LBP.
- FD and JCP respondents reported significantly greater low back discomfort whilst sitting at work than respondents at WYP, although the mean differences were small, and may have been detected due to the studies large sample size.
- Mean psychosocial scores were significantly different between the companies, except for work-related causal beliefs, psychological demands at work and fear avoidance beliefs. Significant differences were not substantial, and variances in the scores between the companies were similar (<1 point), except for psychological distress.
- The combined sample comprised a cohort of sedentary workers (61% female, mean age: 37 years) with similar demographic and individual characteristics.

Patterns of responses between different groups of respondents

- Respondents reporting previous or current LBP had significantly higher levels of psychological distress, and more low back discomfort whilst sitting at work than respondents reporting no LBP.
- Respondents who reported discomfort whilst sitting at work had significantly stronger beliefs about its work-related causes (work organisation, work environment), higher levels of psychological distress, and lower levels of job satisfaction and function than respondents without discomfort.
- Psychosocial and symptom modifying factors were variously significantly associated with the intensity and frequency of low back discomfort whilst sitting at work, although the strength of these relationships was generally weak.
- Self-reported LBP and back discomfort whilst sitting at work were significantly associated with an increased prevalence of other musculoskeletal symptoms.

Experimental investigation: activities and lumbar movement characteristics measured during work

- Participants that wore the FOG system were representative of workforce survey respondents in terms of age, gender, job tenure and low back discomfort, yet more workers who reported previous LBP were in the experimental investigation
- Workers spent 83% of their working day sitting, although workers at WYP spent a significantly larger proportion of work-time sitting and for more prolonged periods compared to workers at FD.
- The average duration of the three longest sitting periods was 50 minutes, and 31% of workers sat for >1 hour (on average); exposure to prolonged periods of sitting was not a common feature of call centre work in this study.
- Workers adopted a predominantly kyphotic lumbar sitting posture at work, a trend that was most pronounced during prolonged sitting periods.
- Workers used a smaller range of lumbar movement and changed their lumbar posture significantly less during prolonged sitting periods, compared to all sitting periods over the course of a working shift.

Activities and seated lumbar movement characteristics measured during work: association with self-reported data

- Current LBP and discomfort whilst sitting at work did not significantly influence the proportion of time workers spent sitting, standing or walking during work
- Self-reported current LBP was weakly significantly associated with the adoption of kyphotic lumbar sitting postures, although changes in lumbar posture were not significantly associated with LBP.
- Physical-aggravating factors and low back discomfort whilst sitting at work were more strongly associated with current LBP than biomechanical aspects of sitting (lumbar posture and movement variables), or psychosocial factors.
- Multivariable analysis showed that workers who spent more sitting time with a lumbar posture ≥ 80% total ROM, and reported high levels of discomfort whilst sitting at work were significantly more likely to report current LBP.
- Low back discomfort whilst sitting at work was not significantly related to lumbar postures, although a lack of variation in lumbar movement was associated with discomfort. However, physical-aggravating factors and fear avoidance beliefs dominated in their modest explanation of low back discomfort.

RESULTS: PROSPECTIVE

RESULTS 5

Prediction of future LBP using lumbar movement characteristics, demographic, psychosocial and symptom data

18.1) Introduction

Six months following the collection of baseline data, a follow-up survey was used to identify workers that reported future LBP. The combined ability of baseline data from the workforce survey (demographics, psychosocial factors, symptoms) and experimental investigation (activities and seated lumbar movement characteristics) to predict future LBP will now be considered.

18.2) Profile of the follow-up respondents

The response rate to the follow-up survey was 61% (n=367), and there were no significant differences between respondent and non-respondent groups based on age or reported LBP history (Table 56). However, significantly more workers who were male and who had been employed for >3 years responded to the follow-up survey. In relation to the psychosocial and symptom modifying factor scores (*see Appendix 12a*) there was only one significant difference; non-respondents had higher levels of psychological distress at baseline than respondents. Therefore, whilst some sub-group differences were evident, overall the respondents to the follow-up survey were considered broadly representative of respondents at baseline (Table 56). Therefore, follow-up data were used in subsequent analysis.

Table 56: Follow-up respondent status, expressed as a % for baseline demographic and individual categories

Categories	Respondents (n=367)	Non-respondents (n=233)	χ^2
Gender	Male 43.3% (159) Female 56.7% (208)	Male 33.5% (78) Female 66.6% (155)	*P<0.05*
Age	≤ 37 yrs 50.1% (182) >37 yrs 49.9% (181)	≤ 37 yrs 51.5% (118) >37 yrs 48.5% (111)	*n.s.*
Job length	<1 year 11.7% (42) 1-3 years 37.2% (133) >3 years 51.2% (183)	<1 year 24.9% (56) 1-3 years 40.4% (91) >3 years 34.7% (78)	*P<0.05*
Previous LBP	Yes 63.5% (233) No 36.5% (134)	Yes 61.9% (143) No 38.1% (88)	*n.s.*
Current LBP	Yes 42.5% (156) No 57.5% (211)	Yes 42.5% (99) No 57.5% (134)	*n.s.*
No. of episodes	1 episode 8.1% (19) 2-4 episodes 31.3% (73) 4+ episodes 60.7% (142)	1 episode 7.6% (11) 2-4 episodes 33.3% (48) 4+ episodes 59% (85)	*n.s.*

18.3) Prediction of future LBP

During the six month follow-up period, 33% (n=122) of respondents reported experiencing LBP lasting >24 hrs. These reports of ‘future LBP’ conceal different LBP outcomes (incidence, recurrence, and persistence). Prediction of these separate outcomes was undertaken in order to explore contributory mechanisms, and minimise the confounding effects of dominating risk factors, which may depend on previous or current experiences of LBP.

The analysis will first explore univariate (baseline) influences on future LBP incidence, recurrence and persistence, since using multivariable models may result in small risk factors being dominated by associated larger risk factors. Finally, where appropriate, the results of multivariable analyses will be presented. Results section five therefore tests the prospective component of sub-hypotheses 2, sub-hypothesis 7, and part of the main hypothesis.

18.3.1) Univariate analysis

For the purposes of predicting incident LBP in logistic regression analysis, respondents reporting no history of LBP at baseline but LBP at follow-up were identified. None of the baseline variables considered relevant in explaining incident LBP were found to be statistically significant predictors (*see Appendix 12b for variables, ORs and 95% CIs*). Analysis was, however, limited by the small number of respondents reporting first-onset LBP (n=20), particularly when lumbar movement characteristics were used (n=5). In order to predict recurrence, respondents who reported a previous history of LBP but no current symptoms at baseline were identified. From this group, respondents who reported LBP that started >1 month after the first workforce survey were identified (n=26). Table 57 shows univariate associations between baseline data and recurrent LBP during the 6-month follow-up period. The sole significant (weak) predictor was low back discomfort whilst sitting at work (columns 4 and 5); respondents reporting high levels of discomfort were more likely to subsequently experience recurrent LBP. The small number of workers that wore the FOG system again limited analyses involving lumbar movement characteristics (n=6), although the pattern of results the tentatively suggests that workers who change lumbar posture less (angular velocity, variation) might be more likely to experience recurrence.

Table 57: Univariate associations with future recurrent LBP (yes/no)

Baseline variables (range)	Recurrence [a]		Crude OR 95% (CI)	R^2%
	Yes	No		
Lumbar movement characteristics: [b]	*n=6*	*n=26*		
% of sitting time lordotic (0-100)	25.6 (27.0) [m]	23.2 (83.9) [m]	0.97 (0.93-1.02)	7%
% of sitting time ≥ 80% ROM (0-99)	15.68 (24.3) [m]	14.97 (40.2) [m]	0.98 (0.93-1.04)	3%
% of sitting time ≤ 40% ROM (0-58)	0.46 (3.95) [m]	1.55 (2.71) [m]	1.12 (0.75-1.65)	2%
Angular velocity °sec^{-1} (1-12)	2.41 (0.81)	4.85 (2.78)	0.41 (0.10-1.62)	3%
Variation – SD° (2-25)	5.79 (3.32)	7.89 (3.84)	0.79 (0.47-1.30)	8%
Symptoms and SMFs:	*n=26*	*n=52*		
Discomfort whilst sitting 'today' (0-100) [ǂ]	16.4 (21.2)	6.79 (14.1)	1.03 (1.01-1.06)*	9%
Physical-aggravating (6-30) [ǂ]	18.9 (4.88)	17. 1 (4.73)	1.08 (0.96-1.21)	4%
Movement-relieving (3-15) [ǂ]	11.1 (2.63)	10.1 (2.76)	1.15 (0.95-1.40)	1%
Posture-relieving (2-10) [ǂ]	7.5 (1.65)	7.5 (1.87)	1.02 (0.77-1.35)	0.1%
MSK symptoms: [c] **>2 regions**	28.5% (8)	23% (12)	1.90 (0.64-5.62)	3%
Clinical psychosocial factors:	*n=26*	*n=52*		
Psychological distress (0-36)	11.7 (5.29)	11.7 (5.25)	1.00 (0.91-1.10)	0%
Fear avoidance beliefs (4-25)	10.54 (3.83)	10.42 (3.64)	1.01 (0.87-1.15)	0%
Occupational psychosocial factors:	*n=26*	*n=52*		
Work organisation (3-15)	5.22 (2.09)	6.52 (2.78)	0.80 (0.64-1.01)	0.8%
Work environment (5-25)	13.5 (4.91)	14.7 (4.33)	0.94 (0.84-1.05)	2%
Physical demands at work (4-20)	16.2 (2.91)	15.3 (3.6)	1.08 (0.92-1.27)	2%
Job satisfaction (1-5)	3.18 (1.09)	3.45 (1.02)	0.78 (0.48-1.26)	2%
Psychological demand (12-48)	37.9 (4.21)	36.3 (6.50)	1.04 (0.96-1.14)	2%
Social support (5-20)	17.5 (2.95)	16.3 (3.30)	1.16 (0.95-1.41)	5%

[Unless stated variables expressed as mean scores, with standard deviations (SD) for 'yes' and 'no' groups
[[m] = median and interquartile range (IR)]
[[a] all workers reported previous LBP but no current LBP (episode)]
[[b] measured during the 3 longest periods of sitting]
[[c] not including LBP, reported in the past 7-days]
[[ǂ] work-relevant factor]
[* ORs statistically significant at the 5% level, ** at the 1% level]
[R^2 = proportion of variance in LBP explained]

The influence of baseline variables on the persistence of LBP will now be considered. Only workers with current LBP at baseline were included in analyses, and persistent LBP was defined as LBP also reported during the follow-up period (n=64). Exposure to prolonged sitting (average of the 3 longest periods ≥60mins: yes/no) was not a predictor of persistence (OR 4.0, 95% CI 0.80-20.5, R^2 0.08, *P=0.090)*. Table 58 shows that the only lumbar movement characteristic associated with persistent LBP was 'variation in lumbar movement whilst sitting'; workers who changed posture less were significantly more likely to report persistent LBP (column 4). This explained more of the variance in persistence than any other variable (13%).

Symptom variables were variously significantly associated with persistent LBP; higher levels of symptom bothersomness and low back discomfort whilst sitting at work each increased the likelihood of reporting persistence (column 4). Symptom modifying factors were not significant, although workers who reported musculoskeletal symptoms (co-existing with LBP) in more than 2 body regions were at increased risk of reporting persistence. Overall, symptom variables and symptom modifying factors were generally weak predictors of persistent LBP (column 5); bothersomness was the strongest predictor and explained 12% of the variance in persistent LBP. Clinical and occupational psychosocial factors were not generally associated with persistent LBP, although respondents reporting lower levels of function and job satisfaction were more likely to report persistence (column 4). The results suggest that the influence of these variables is somewhat small; function and job satisfaction explained 8% and 3% of the variance in persistent LBP.

In order to maximise statistical power, all LBP reported during the follow-up period was included under the outcome 'future LBP' to explore univariate predictors. Exposure to prolonged sitting (average of 3 longest periods ≥60mins: yes/no) was associated with future LBP (OR 8.2, 95% CI 1.86-26.4, R^2 0.13, *P<0.01)*. The same significant variables in Table 58 were also identified (with similar effect sizes: ±3%). Finally, demographics were considered: previous LBP: yes/no (OR 3.4, 95% CI 2.0-5.8*,* R^2 *0.10*), current LBP: yes/no (OR 2.7, 95% CI 1.6.-4.3, R^2 *0.07*), and ≥38 yrs: yes/no (OR 1.2, 95% CI 0.7-1.9, R^2 *0.003*), with previous and current LBP being significant predictors (*P<0.01*).

Table 58: Univariate associations with future persistent LBP (yes/no)

Baseline variables (range)	Persistence [a]		Crude OR 95% (CI)	R^2%
	Yes	No		
Lumbar movement characteristics: [b]	***n=22***	***n=42***		
% of sitting time lordotic (0-100)	7.6 (49.2) [m]	10.8 (39.9) [m]	0.99 (0.98-1.01)	0.6%
% of sitting time ≥ 80% ROM (0-99)	28.9 (75.7) [m]	25.7 (44.9) [m]	1.01 (0.99-1.02)	3%
% of sitting time ≤ 40% ROM (0-58)	0.15 (0.22) [m]	1.05 (1.84) [m]	0.82 (0.58-1.15)	6%
Angular velocity °sec^{-1} (1-12)	4.40 (3.07)	3.40 (1.65)	1.20 (0.96-1.51)	6%
Variation – SD° (2-25)	6.60 (3.03)	9.03 (4.55)	0.80 (0.66-0.98)**	13%
Symptoms and symptom modifying factors:	***n=64***	***n=93***		
Discomfort whilst sitting 'today' (0-100) [ǂ]	31.9 (28.1)	19.8 (21.8)	1.02 (1.01-1.03)**	7%
Physical-aggravating (6-30) [ǂ]	19.8 (4.22)	19.0 (3.96)	1.04 (0.96-1.13)	1%
Movement-relieving (3-15) [ǂ]	10.6 (2.62)	10.1 (2.61)	1.06 (0.94-1.21)	1%
Posture-relieving (2-10) [ǂ]	7.22 (1.84)	7.47 (1.56)	0.83 (0.68-1.01)	2%
Bothersomness (1-5)	2.7 (1.07)	2.0 (0.95)	1.88 (1.34-2.64)**	12%
MSK symptoms: [c] **>2 regions**	58.4% (38)	38.7% (36)	2.22 (1.16-4.25)*	5%
Clinical psychosocial factors:	***n=64***	***n=93***		
Psychological distress (0-36)	13.0 (4.89)	11.8 (4.87)	1.05 (0.98-1.12)	2%
Fear avoidance beliefs (4-25)	12.1 (4.36)	11.6 (4.36)	1.02 (0.95-1.10)	0.4%
Disability (1-5)	2.56 (4.80)	1.65 (4.27)	1.04 (0.97-1.12)	1%
Function (0-25)	2.46 (1.13)	1.89 (1.03)	1.61 (1.19-2.18)**	8%
Occupational psychosocial factors:	***n=64***	***n=93***		
Work organisation (3-15)	6.60 (2.92)	6.25 (2.54)	1.04 (0.93-1.18)	0.6%
Work environment (5-25)	14.8 (4.35)	14.9 (4.40)	0.99 (0.92-1.07)	0.1%
Physical demands at work (4-20)	14.3 (3.19)	15.4 (3.17)	0.90 (0.81-0.99)	4%
Job satisfaction (1-5)	2.98 (0.92)	3.31 (1.06)	0.72 (0.52-0.99)*	3%
Psychological demand (12-48)	34.5 (5.56)	35.7 (4.96)	0.99 (0.89-1.09)	0.1%
Social support (5-20)	15.8 (2.49)	16.1 (2.84)	0.95 (0.84-1.07)	0.5%

[Unless stated variables expressed as mean scores, with standard deviations (SD) for 'yes' and 'no' groups]
[[m] = median and interquartile range (IR)]
[[a] all workers reported a current LBP episode at baseline]
[[b] measured during the 3 longest periods of sitting]
[[c] not including LBP, reported in the past 7-days] [[ǂ] work-relevant factor]
[* ORs statistically significant at the 5% level, ** at the 1% level]
[R^2 = proportion of variance in LBP explained]

18.3.2 Multivariable analysis

This section will first justify the factors included in the theoretical model used to predict future LBP, and then present the results of the analysis. A variety of lumbar movement characteristics were included in the multivariable model to provide measures of 'exposure' to different degrees of lumbar posture (so called lumbar lordosis or kyphosis), and movement (see Table 58 for variables). These aspects of sitting were chosen due to their perceived importance (as risk factors for LBP) in the clinical (Williams et al, 1990) and biomechanical literature (Adams and Hutton, 1986; Ishihara et al, 1996; Hedman and Fernie, 1997). Such factors do not, however, appear to have been measured in real life occupational settings. Therefore, analysis might help to identify biomechanical (occupational) risk factors for future LBP, thus helping to add to the existing evidence base.

A range of demographic factors were included in the multivariable model to control for potentially relevant influences. A history of LBP has been shown to be the strongest predictor of future LBP in countless studies (Waddell and Burton, 2001, and there is also evidence that advancing age (Loney and Stratford, 1999), and exposure to occupational demands (for new workers) can increase the risk of LBP (Adams et al, 2002). The role of gender is less certain, but was deemed an important consideration.

Clinical and occupational psychosocial factors were also included in the multivariable model, even though these are best known for their ability to predict the consequences of LBP (Bigos et al, 1991; Croft et al, 1996). The reason for their inclusion is that there is evidence that psychological distress (Mannion et al, 1996; Adams, 1999; Feyer et al, 2000) and certain psychosocial aspects of work (social support, job satisfaction) (Bongers et al, 1993; Papageorgiou et al, 1997; Hoogendoorn et al, 2000) can play a role in the development of LBP. Furthermore, a number of clinical psychosocial factors have been shown to be related to persistent LBP, including psychological distress and fear avoidance beliefs (Pincus et al, 2006), function and disability (Waddell et al, 2003). Occupational psychosocial factors have equally been shown to be important predictors of chronic (persistent) LBP (Waddell et al, 2003). Therefore, the inclusion of psychosocial factors was justified, particularly given the results of studies that have found psychosocial and biomechanical factors to be associated (*see section 5.6).*

Finally, symptoms and symptom modifying factors were included in the analysis. Most of these were work-relevant, and there is a lack of research measuring such factors. Does the severity of current back discomfort at work help to explain future symptoms? Are workers who report their symptoms to be aggravated by work more likely to experience recurrent or persistence symptoms? These are unanswered questions, and answers would help to improve our understanding of the relationship between work-relevant symptoms and future LBP. The presence of musculoskeletal symptoms in >2 regions (in addition to LBP) was also measured, largely to control for the possibility of a sub-group of workers with widespread symptoms; such co-morbidity might dominate other variables in the prediction of future LBP.

The first multivariable model was constructed to predict 'future LBP', and although perhaps less precise than predicting specific outcomes (incidence, recurrence, persistence), such a model maximised all available outcome data and related to *a priori* hypothesis. In order to allow for interrelationships, all independent variables were considered in the analysis. Starting with the lumbar movement characteristics in Table 58 (also including exposure to prolonged sitting ≥60 mins: yes/no), demographic, psychosocial and then symptom data were sequentially added to the model, stepwise analysis taking place with the addition of each set of data. The results show that variation in lumbar movement dominated other lumbar movement characteristics (OR 0.84, 95% CI 0.73-0.97, $P<0.01$), explaining 8% of the variance in future LBP. The addition of demographic factors (age ≥38yrs: yes/no, male gender: yes/no, job tenure ≥2 yrs: yes/no, previous LBP: yes/no, current LBP: yes/no) resulted in current LBP being retained (OR 4.1, 95% CI 1.6-10.4, $P<0.01$) alongside variation in lumbar movement (OR 0.85, 95% CI 0.73-0.99, $P<0.05$), improving the explanatory power of the model (17%).

The inclusion of clinical and occupational psychosocial factors (see Table 58) resulted in variation in lumbar movement being retained as the sole significant predictor, and the amount of variance in future LBP that was explained reduced (16%). Finally, the symptom variables and symptom modifying factors were included in the model, but further reduced the amount of future LBP explained (14%), with no change in the dominant predictor (variation in lumbar movement). No further combinations of different types of variables were able to improve the explanatory power of the model; current LBP and variety of lumbar movement were the best predictors of future LBP.

Whilst there was insufficient data to allow incident and recurrent LBP to be predicted, multivariable (stepwise) prediction of persistent LBP was undertaken. Using variables with univariate significance as the covariates (n=6), one variable was retained that explained 11% of the variance in persistent LBP: variation in lumbar movement (OR 0.81, 95% CI 0.66-0.99, $P<0.05$). It is important to consider that there are number of practical and statistical limitations to the aforementioned analyses, and these are considered prior to the conclusions (*see main limitations*).

RESULTS 6

Prediction of future sickness absence using lumbar movement characteristics, demographic, psychosocial and symptom data

19.1) Introduction

In the 6-month follow-up survey, data on the occurrence and duration (>7 days) of sickness absence due to LBP were collected from respondents. This section considers the relative predictive influence of lumbar movement characteristics, demographics, psychosocial and symptom data on these outcomes of interest. Results section six therefore tests the prospective component of sub-hypotheses 1, 3, and 5, and aspects of the main hypothesis.

19.2) Prediction of future sickness absence due to LBP

From the 367 workers that returned the 6-month follow-up booklet, 8.7% (n=32) had taken at least one period of absence due to LBP, resulting in 220 total working days lost. The mean and median durations of absence were 7 and 3 days respectively, and 31% (n=10) of the workers who took absence did so for >7 days. From the workers that reported taking absence, at baseline: 5 reported no previous LBP, 2 reported 1 previous episode, and 25 reported recurrent LBP. Most absentees (72% n=23) also reported current LBP at baseline.

The following logistic regression analyses (to predict the occurrence and extent of absence) will aim to identify: (1) univariate predictors; (2) predictors within different groups of factors; and (3) predictors between different groups of factors. Exploration of predictors within groups is intended to give some idea of the relative importance of variables (which may be missed in between group analysis), some of which may be amenable to intervention. Between groups analyses will control for a wider range of confounding variables, and this approach might also help to identify obstacles to effective intervention for variables found to be influential within, but not between groups.

19.2.1) Occurrence of absence

In univariate analysis of the following demographic variables: gender (male/female), age (<38 years/≥38 years), job tenure (2 years/≥2 years), previous LBP (yes/no), current LBP (yes/no) and absence due to LBP in the past 12-months (yes/no), only the LBP variables were found to significantly predict the occurrence of absence ($P<0.05$). The ORs were highest for absence due to LBP in the past 12-months (OR 5.15, 95% CI 2.35-11.35), with previous LBP (OR 3.32, 95% CI 1.25-8.86) and current LBP (OR 3.84, 95% CI 1.72-8.56) having similar predictive properties. Table 59 shows univariate associations between other types of baseline data and absence due to LBP. Whilst most baseline data were obtained from the workforce survey, lumbar movement characteristics were collected from a smaller experimental sample (n=140), hence the smaller number of absentees for this set of data. Using crude ORs with 95% confidence intervals, no lumbar movement characteristic measured during prolonged periods of sitting significantly predicted absence (column 4). However, absentees generally spent a higher proportion of sitting time with a kyphotic lumbar posture, changed posture (per second) more, but used less variety of lumbar movement compared to non-absentees. For variation in lumbar movement, the independent *t*-test showed unequal variances between these groups ($P<0.05$), and a statistically significant difference between mean scores was found ($P<0.05$). Therefore, the lack of significance in logistic regression analysis might be explained by the small sample size or unequal variances between absentee and non-absentee groups.

In terms of symptoms and symptom modifying factors (SMFs), reported high levels of low back discomfort whilst sitting at work and physical-aggravating factors were each significant predictors (column 4), explaining more of the variance in absence than any other variable, 18% and 22% respectively. Symptom bothersomness (13%) and pain in >2 body regions also significantly increased the risk of absence (8%). For the clinical psychosocial factors, fear avoidance beliefs, reduced function (indicated by a higher score), and increased disability were each weak predictors of absence (column 5). Occupational psychosocial factors explained up to 7% of the variance in absence (column 5); strong beliefs about the causes of discomfort (work: organisation, environment), job dissatisfaction and high psychological demand significantly increased risk.

Table 60 (column 3) shows which variables were retained following separate stepwise analysis of all the variables within each group. Lumbar movement characteristics are not included, since no predictors in regression analysis at group level were found. Controlling for symptoms and SMFs, discomfort whilst sitting at work and physical-aggravating factors dominated other variables, explaining more of the variance in absence than any other group of factors (22%). For the clinical psychosocial factors, function was retained as the sole significant predictor, accounting for a similar amount of the variance in absence (11%) as the retained occupational psychosocial factors (10%) (causal beliefs about work organisation, and psychological demands at work). For the demographic factors, current LBP and absence due to LBP in the past 12-months were significant predictors, explaining 13% of the variance in absence.

Table 59: Univariate associations with future sickness absence occurrence due to LBP

Baseline variables (range)	Absence occurrence due to LBP		Crude OR 95% (CI)	R^2%
	Yes	No		
Lumbar movement characteristics: [a]	*n=10*	*n=130*		
% of sitting time lordotic (0-100)	17.1% (75.5)[m]	24.2 % (60.5)[m]	0.96 (0.97-1.01)	3%
% of sitting time ≥ 80% ROM (0-99)	18.7% (41.2)[m]	22.6% (46.8)[m]	0.99 (0.97-1.02)	1%
% of sitting time ≤ 40% ROM (0-58)	0.83% (0.64)[m]	1.37% (1.82)[m]	0.94 (0.74-1.20)	0.1%
Angular velocity °sec^{-1} (1-12)	5.0 (3.63)	3.81 (2.11)	1.2 (0.93-1.58)	5%
Variation – SD° (2-25)	6.26 (1.31)[b]	8.92 (4.69)	0.80 (0.61-1.05)	8%
Symptoms and SMFs:	*n= 32*	*n=335*		
Discomfort whilst sitting 'today' (0-100) [†]	37.5 (30.7)	12.4 (18.7)	1.03 (1.02-1.05)**	18%
Physical-aggravating (6-30) [†]	22.5 (4.14)	17.5 (4.44)	1.33 (1.19-1.47)**	22%
Movement-relieving (3-15) [†]	11.1 (3.24)	10.1 (2.57)	1.15 (0.99-1.34)	2%
Posture-relieving (2-10) [†]	7.8 (1.59)	7.5 (1.73)	1.09 (0.87-1.37)	0.4%
Bothersomness (1-5)	3.1 (1.26)	2.2 (1.72)	1.77 (1.38-2.26)*	13%
MSK symptoms: [c] **>2 regions**	62.5% (20)	28.9% (97)	4.05 (1.90-8.61)**	8%
Clinical psychosocial factors:	*n=32*	*n=335*		
Psychological distress (0-36)	12.9 (5.45)	11.5 (4.83)	0.96 (0.83-1.19)	0%
Fear avoidance beliefs- phys (4-25)	12.9 (5.22)	11.2 (4.05)	1.10 (1.01-1.22)*	3%
Disability (1-5)	2.84 (4.20)	0.69 (2.94)	1.12 (1.04-1.21)**	5%
Function (0-25)	1.96 (1.49)	0.82 (1.21)	1.86 (1.12-1.07)**	14%
Occupational psychosocial factors:	*n=32*	*n=335*		
Work organisation (3-15)	7.7 (2.42)	6.1 (2.67)	1.23 (1.08-1.41)**	6%
Work environment (5-25)	16.9 (3.41)	14.3 (4.29)	1.17 (1.06-1.29)**	7%
Physical demands at work (4-20)	15.4 (3.91)	15.0 (3.33)	1.03 (0.92-1.16)	1%
Job satisfaction (1-5)	2.9 (0.77)	3.4 (1.02)	0.69 (0.48-0.97)*	3%
Psychological demand (12-48)	37.7 (4.58)	35.2 (4.93)	1.11 (1.02-1.20)**	5%
Social support (5-20)	16.5 (2.44)	16.1 (3.09)	1.04 (0.91-1.19)	0.3%

[Unless stated variables expressed as mean scores, with standard deviations (SD) for 'yes' and 'no' groups]
[[m] = median and interquartile range (IR)] [[†] work-relevant factor] [R^2 = proportion of variance in absence explained]
[[a] measured during the 3 longest periods of sitting]
[[b] statistically significant difference between 'yes' and 'no' group using the independent *t*-test (5% level)]
[[c] not including LBP, reported in the past 7-days] [* ORs statistically significant at the 5% level, ** at the 1% level]

Table 60: Multivariable prediction of future sickness absence occurrence due to LBP (yes/no), within and between different groups of factors

Baseline variables (range)	***P<0.05*** [‡]	**Adjusted OR 95% (CI):** [a] **within group**	R^2 **(%)**	**Adjusted OR 95% (CI):** [b] **final model**	R^2 **(%)**
Symptoms and SMFs:					
Discomfort whilst sitting 'today' (0-100)	Yes	1.01 (1.01-1.04)*		1.02 (1.01-1.04)*	
Physical-aggravating (6-30) [†]	Yes	1.24 (1.11-1.39)**		1.15 (1.01-1.32)*	
Movement-relieving (3-15) [†]	No				
Posture-relieving (2-10) [†]	No				
MSK symptoms:[c] **>2 regions**	Yes				
Bothersomness	Yes		**22%**		
Clinical psychosocial factors:					
Psychological distress (0-36)	No				
Fear avoidance beliefs- phys (4-25)	Yes				
Disability (1-5)	Yes				
Function (0-25)	Yes	1.72 (1.27-2.33)**	**11%**		
Occupational psychosocial factors:					
Work organisation (3-15)	Yes	1.24 (1.08-1.43)**			
Work environment (5-25)	Yes				
Physical demands at work (4-20)	No				
Job satisfaction (1-5)	Yes				
Psychological demand (12-48)	Yes	1.09 (1.01-1.18)**		1.12 (1.01-1.25)*	
Social support (5-20)	No		**10%**		
Demographic factors					
Age (<38 yrs/≥38 yrs)	No				
Gender (male/ female)	No				
Job tenure (<2 yrs/≥2 yrs)	No				
Previous LBP (yes/no)	Yes				
Current LBP (yes/no)	Yes	3.02 (1.25-7.31)**			
LBP absence: past 12-month (yes/no)	Yes	3.52 (1.51-8.22)**	**13%**		**24%**

[Absentees n=32, non-absentees n=335] [‡ for crude ORs at univariate level]
[a after controlling for group variables]
[b after controlling for all variables in the Table using a stepwise procedure]
[c not including LBP, reported in the past 7-days]
[† work-relevant factor]
[* ORs statistically significant at the 5% level, ** at the 1% level]
[R^2 = proportion of variance in absence explained by each model]

To address *a priori* hypothesis, the combined influence of clinical and occupational psychosocial factors was explored by including both sets of factors in a multivariable (stepwise) model. Psychological demand at work (OR 1.14, 95% CI 1.02-1.26), beliefs about work organisation as a cause of back discomfort (OR 1.19, 95% CI 1.02-1.40) and function (OR 1.67, 95% CI 1.20-2.33) were retained, explaining 21% of the variance in absence. When the influence of the variables in Table 60 were explored in a multivariable (stepwise) model, three predictors were retained: back discomfort whilst sitting at work 'today' (OR 1.02, 95% CI 1.01-1.04), physical-aggravating factors (OR 1.15, 95% CI 1.01-1.32), and psychological demand at work (OR 1.12, 95% CI 1.0-1.25), explaining a small amount of the variance in absence (24%).

19.2.2) Extent of absence

Variables associated with the extent of future absence due to LBP (defined as total absence >7 days during the follow-up period), were investigated in order to identify obstacles to return-to-work. However, since only 3 workers that took part in the experimental investigation took absence >7 days, no lumbar movement characteristics were explored.

At univariate level: gender (male/female), age (<38 years/≥38 years), job tenure (<2 year/≥2 years), previous LBP (yes/no) and current LBP (yes/no) failed to significantly predict the extent of absence due to LBP, although a history of absence due to LBP in the past 12-months was a strong predictor (OR 10.1, 95% CI 2.75, 37.3, *P<0.01*). Table 61 shows univariate associations for other types of data, indicating that low back discomfort whilst sitting at work, physical-aggravating factors and function were each significant predictors (column 4). However, these variables were more strongly associated with absence occurrence than absence extent. One exception was for psychological distress, which significantly predicted 6% of the variance in absence >7 days. Within group multivariable (stepwise) analysis showed that for symptoms and SMFs, low back discomfort whilst sitting at work 'today' dominated other variables, accounting for 17% of the variance in absence >7 days (Table 62: column 4). Psychological distress also remained the only significantly predictive clinical psychosocial factor. No occupational psychosocial factors were predictors, and absence due to LBP in the past 12-months remained the only significant demographic factor, explaining 12% of the variance in absence >7 days. In the final multivariable model, including all variables, discomfort whilst sitting at work and absence due to LBP in the past 12-months were retained as predictors (column 5), explaining 26% of the variance in absence >7 days.

Baseline variables (range)	**>7 days absence**		**Crude OR 95% (CI)**	**R^2 %**
	Yes n= 10	***No n=357***		
<u>Symptoms and SMFs:</u>				
Discomfort whilst sitting 'today' (0-00) [†]	44.6 (32.5)*	32.5 (20.4)	1.04 (1.01-1.06)*	16%
Physical-aggravating (6-30) [†]	21.3 (4.30)*	17.9 (4.66)	1.17 (1.01-1.37)*	6%
Movement-relieving (3-15) [†]	12.0 (2.78)	10.2 (2.64)	1.32 (0.99-1.75)	5%
Posture-relieving (2-10) [†]	7.33 (1.65)	7.60 (1.73)	0.91 (0.63-1.32)	0.3%
Bothersomness (1-5)	3.0 (0.57)	2.3 (1.03)	1.44 (0.97-2.15)	4%
MSK symptoms: [a] **>2 regions**	50% (5)	31.4% (112)	2.18 (0.62-7.70)	2%
<u>Clinical psychosocial factors:</u>				
Psychological distress (0-36)	15.2 (6.05)	11.6 (4.82)	1.12 (1.01-1.24)*	6%
Fear avoidance beliefs- phys (4-25)	12.0 (5.95)	11.4 (4.16)	1.03 (0.87-1.22)	0.2%
Disability (1-5)	4.0 (4.04)	2.0 (4.58)	1.09 (0.99-1.21)	3%
Function (0-25)	2.0 (1.63)	0.89 (1.25)	1.67 (1.12-2.50)**	7%
<u>Occupational psychosocial factors</u>:				
Work organisation (3-15)	7.6 (2.91)	6.2 (2.67)	1.19 (0.95-1.50)	3.1%
Work environment (5-25)	15.4 (4.33)	14.5 (4.31)	1.05 (0.89-1.23)	0.6%
Physical demands at work (4-20)	14.4 (3.43)	15.1 (3.84)	0.94 (0.79-1.14)	4%
Job satisfaction (1-5)	2.7 (0.54)	3.3 (1.01)	0.58 (0.32-1.02)	4%
Psychological demand (12-48)	36.3 (5.41)	35.4 (4.93)	1.03 (0.91-1.17)	0.4%
Social support (5-20)	15.7 (2.45)	16.2 (3.05)	0.94 (0.78-1.14)	0.4%

Table 62: Multivariable prediction of future sickness absence >7 days due to LBP (yes/no), within and between different groups of factors

Baseline variables (range)	***P<0.05*** [‡]	**Adjusted OR 95% (CI):** [a] **within group**	**R^2 (%)**	**Adjusted OR 95% (CI):** [b] **final model**	**R^2 (%)**

Symptoms and SMFs:					
Discomfort whilst sitting 'today' (0-100) †	Yes	1.04 (1.01-1.06)**		1.04 (1.01-1.07)*	
Physical-aggravating (6-30) †	Yes				
Movement-relieving (3-15) †	No				
Posture-relieving (2-10) †	No				
MSK symptoms: [c] **>2 regions**	No				
Bothersomness	No		**17%**		
Clinical psychosocial factors:					
Psychological distress (0-36)¥	Yes	1.14 (1.02-1.27)*			
Fear avoidance beliefs- phys (4-25)	No				
Disability (1-5)	No				
Function (0-25)	Yes		**7%**		
Occupational psychosocial factors:					
Work organisation (3-15)	No				
Work environment (5-25)	No				
Physical demands at work (4-20)	No				
Job satisfaction (1-5)	No				
Psychological demand (12-48)	No				
Social support (5-20)	No		**0%**		
Demographic factors					
Age (<38 yrs/≥38 yrs)	No				
Gender (male/ female)	No				
Job tenure (<2 yrs/>2yrs)	No				
Previous LBP (yes/no)	No				
Current LBP (yes/no)	No				
LBP absence: past 12-months (yes/ no)	Yes	4.28 (1.01-18.9)**	**12%**	6.10 (1.01-36.9)**	**26%**

[Absentees n=10, non-absentees n=357]
[R^2 = proportion of variance in absence explained by each model]
[* ORs statistically significant at the 5% level, ** at the 1% level]
[‡ for crude ORs at univariate level]
[[a] after controlling for group variables using a stepwise procedure]
[[b] after controlling for all variables in the Table using a stepwise procedure]
[[c] not including LBP, reported in the past 7-days]
[† work-relevant factor]
[¥ In the final model (excluding LBP absence: past 12-months) this variable was dominated by discomfort)

19.3) Theoretical framework of the multivariable models

The purpose of this section is to reflect on the theoretical framework of the predictive models that were used to predict sickness absence (occurrence and extent). It is anticipated that this will help to justify selection of the models independent variables. Overall, the multivariable models incorporated a range of different types of factors that been shown to be influential in previous studies. Including a wide range of factors was deemed justifiable in order to help avoid missing potentially important predictors. This ‘biopsychosocial’ approach is also concordant with the current LBP literature (*see sections 5.3 and 5.5*).

It was envisaged that the same lumbar movement characteristics that were used to predict ‘future LBP’ would also be incorporated in the prediction of ‘future sickness absence’. The justification for the inclusion of biomechanical factors is that previous research has failed to include such data alongside demographic and psychosocial factors (Davis and Heaney, 2000). However, it transpired that biomechanical date could not be included, which is a limitation of the theoretical models; the relative importance of self-reported data may be confounded to some extent, by not accounting for potential associations with biomechanical factors.

A range of demographic variables were included in the predictive models (*see Tables 60 and 62*) because the importance of these variables has been shown to vary between different studies (Dionne, 1999; Burton et al, 2005). This is due to the influence of different job types, and justified the use of a logical ‘battery’ of measures in order to determine the most relevant influences on sedentary (call centre) workers. The only demographic factor for which there is strong and consistent evidence of an association with disability is age; workers >50 years have shown to be more likely to develop long term incapacity (Waddell, 2003). Thus, this may be an important predictor of the ‘extent’ of absence.

It was considered fundamental to include symptoms variables (alongside other variables) in the predictive models, since numerous previous studies have highlighted their role as risk factors for sickness absence (Elders and Burdorf, 2001; Gheldof et al, 2005; Kuijer et al, 2006). Whilst clinically orientated measures (e.g. symptom bothersomness, co-existing symptoms in >2 regions) have previously been used, measures of back discomfort at work and symptom modifying (aggravating/relieving) factors were new. These were developed and included in response to anecdotal reports from workers and patients that suggest such factors are important in sedentary jobs, and analysis would enable their relevance to be evaluated alongside more established (generic) clinical measures. However, it should be acknowledged that the results would need to be replicated on additional (independent) data sets, since the validity of the 'new' measures has not yet been broadly established.

Although clinical psychosocial factors are implicated in the development of disability, most notably psychological distress (Pincus et al, 2006), and function (Waddell et al, 2003), very little is known about their ability to predict the occurrence and extent of sickness absent prior to clinical presentation. There is also considerable debate about whether or not certain factors (notably fear avoidance beliefs) contain any unique predictive qualities independent of other measure (Pincus et al, 2002; Pincus et al, 2006). The occupational psychosocial factors that were included in the analysis were selected due to their known significant influence on work loss (job satisfaction, social support, causal beliefs about work) (Waddell and Burton, 2001). Psychological demand was also measured, since this variable has received comparatively less attention. Overall there were strong theoretical arguments for including the aforementioned psychosocial factors; few authors have measured clinical and occupational psychosocial predictors of sickness absence together (Burton et al, 2005; Shaw et al, 2007).

19.4) Reliability of the self-reported absence data

Company recorded absence data was made available by WYP and three of the JCP sites. Therefore, the self-reported occurrence and extent (>7 days) of absence due to LBP could be compared to the company data for 83% (n=305) of the follow-up respondents. Using the company-records as the reference standard, the sensitivity and specificity of self-reports for the occurrence and extent of absence due to LBP were calculated. In total, ten respondents reported taking sickness absence due to LBP, three for longer than 7 days. The sensitivity of the self-reported data was 75% for both the occurrence and extent of absence (Appendix 13a and 13b). The specificity values for the occurrence and extent of absence were higher, 99.6% and 100% respectively. Since neither set of data was assumed to be superior, agreement between the data sets was determined using Cohen's Kappa. Close agreement was demonstrated for the occurrence (0.81) and extent (0.78) of absence. Therefore, the self-reported and company recorded absence data from WYP and some of the JCP sites were similar, suggesting that either could be used to measure sickness absence. This issue of reliability is further discussed in section 20.2.3.

SUMMARY POINTS: PROSPECTIVE RESULTS:

Prediction of future LBP

- Accepting that prediction of future self-reported LBP was limited due to small worker numbers, lack of variation in lumbar movement whilst sitting at work predicted symptom persistence.
- Adopting a kyphotic lumbar sitting posture at work was not associated with future LBP.
- The clinical and occupational psychosocial factors studied were largely unrelated to future LBP, although low levels of function and job dissatisfaction each explained a small amount of symptom persistence.
- Low back discomfort whilst sitting at work was significantly predictive of LBP recurrence and persistence, yet the effect sizes were small.
- The optimal explanatory model comprised biomechanical (variation in lumbar movement whilst sitting) and demographic (current LBP) data, yet was weak in effect.

Prediction of future sickness absence due to LBP

- Seated lumbar movement characteristics measured during work had limited ability to explain the occurrence of absence.
- Apart from psychological demand (for absence occurrence), the psychosocial factors studied were not significantly predictive of the occurrence or extent of absence (in final multivariable models).
- Physical-aggravating factors at work were a strong predictor of future absence, dominating most psychosocial and all demographic factors.
- Self-reported previous absence due to LBP was a more notable predictor of absence >7 days than for shorter periods, and the influence of this variable was augmented by low back discomfort whilst sitting at work.
- Controlling for a range of different variables, low back discomfort whilst sitting at work, physical aggravating factors and psychological demand were significant predictors of the occurrence of absence due to LBP.
- Considering the influence of a broad mix of variables, low back discomfort whilst sitting at work and previous absence due to LBP in the past 12-

months were significant predictors of the extent (>7 days) of absence due to LBP.

DISCUSSION

20.1) Summary of the study

LBP is highly prevalent amongst the general population (Department of Health, 1999), and occupational (biomechanical) risk factors are known to contribute to its development. Whether sitting at work is associated with LBP remains controversial, with conflicting studies found in systematic reviews of the epidemiological literature (Hartvigsen et al, 2000; Lis et al, 2007). However, biomechanical factors in sedentary jobs have not been objectively quantified, so their association with LBP is unclear. Some workers who develop LBP will also take sickness absence, perhaps for prolonged periods as a function of obstacles to return-to-work (Main and Burton, 2000). Currently, little is known about the biopsychosocial determinants of sickness absence amongst sedentary workers. Therefore, seated lumbar movement characteristics needs to be considered, alongside other factors, in the context of an investigation among sedentary workers.

The present study was designed to fill gaps in knowledge about sedentary (call centre) work by: (1) investigating cross-sectional relationships between a range of data (demographics, clinical and occupational psychosocial factors, activities and lumbar movement characteristics, symptoms); and (2) exploring predictors of LBP, and sickness absence due to LBP. The main hypothesis investigated was that: lumbar movement characteristics measured during work are predictive of future LBP, yet psychosocial factors are stronger predictors of sickness absence due to LBP. A range of sub-hypotheses were also tested to explore areas that require better understanding (see p59)

20.2) Discussion of the methodology

In order to test the hypotheses, various problems had to be overcome. This section will discuss how experimental methods were developed and validated to meet the needs of this study. Six main areas will be discussed: (1) the ability of the FOG system to reliably measure activities and lumbar movement characteristics; (2) the ability of the psychosocial instruments to reliably measure clinical and occupational psychosocial factors; (3) the reliability of the self-reported sickness absence data; (4) the reliability of the self-reported symptom data; and (5) the suitability of the samples obtained (response rates and representativeness).

20.2.1) Reliability and validity of the FOG system

For the purposes of this study, it was necessary to simultaneously measure workers' activities (sitting, standing, walking), and lumbar movement characteristics. No tool meeting these specifications could be found in the literature. However, the fibre optic goniometer (FOG) developed by Stigant (2000) to continuously measure lumbar sagittal curves had the potential to be developed. This tool is reported to be intrinsically accurate and robust, with minimal angular drift (in response to temperature changes) and hysteresis (in response to repeated oscillations) (Stigant, 2000).

To develop the FOG system to detect activities, a second FOG sensor was developed that could be used to monitor hip movement. Through a series of experiments (see Methods 1), both lumbar and hip sensors were shown to be: (1) accurately calibrated (maximum difference from calibration jigs: 2.1°); and (2) attached repeatable (maximum mean reapplication difference for all test positions: 1.41°). The lumbar FOG was also shown to be comparable to other dynamic systems such as the Lumbar Motion Monitor (in terms of repeatability on a calibration jig).

The 2-element FOG system was subsequently used to develop customised Interrogator (activity and posture detection) software. This complete system was shown to be valid through observational experiments on students (University setting) and sedentary workers (call centre setting). Overall, the system detected activities with a high degree of sensitivity (97%) and predictive value (97%). Many of the postural algorithms used to characterise workers had previously been validated by Stigant (2000), and new algorithms were confirmed to be accurate through manual calculations.

A number of checks were also undertaken to ensure that the main results could be confidently accepted: (1) because there would be natural drift in the lumbar sensors (outputs) over time these were re-calibrated after 24 days (minimal drift was found: mean difference from calibration jig: +1.37°); (2) all datatrains and activity logs were visually screened to check that the sensors and activity detection algorithms were working properly; and (3) a 5% random sample of activity logs were compared to the authors own activity classifications, and the agreement was high (>93%). Therefore, the FOG system was shown to be reliable and valid for this study.

20.2.2) Reliability and validity of the psychosocial instruments

Clinical and occupational psychosocial data were collected primarily to identify cross-sectional associations with low back discomfort whilst sitting at work, and future sickness absence due to LBP. Seven instruments were chosen due to their conceptual importance, short-length, widespread validation and acceptance within the literature (see Methods 2). Thus, there was no reason to suspect that these instruments would not be reliable or valid if used on a cohort of sedentary workers.

No instruments could be found in the literature to measure sedentary workers' beliefs about the work-related causes of back discomfort. Understanding more about these beliefs was deemed relevant to due to the paucity of research in this area. Therefore, an existing instrument, the Work-Related Causal Attributions Questionnaire, previously validated by Bartys (2003) was modified. This new instrument, the 'Sedentary Work Causal Attributions Questionnaire' was validated using a sample of call centre workers. Principal components analysis (PCA) identified three sub-scales measuring causal beliefs about: (1) work organisation; (2) the work environment; and (3) physical demands at work. These were shown to have a sufficiently high level of internal consistency and test-retest reliability to be used in the main study (see Methods 3).

The questionnaires construct validity and internal consistency was largely confirmed using the main study data, although an item from the physical demands sub-scale (prolonged sitting) unexpectedly loaded more strongly onto the work environment sub-scale. However, since the questionnaire was found to have adequate psychometric properties prior to the main study, it was used in its original form to analyse the main results. Nonetheless, further work is required to fully interpret the complex nature of individual's beliefs about the work-related causes of back discomfort.

20.2.3) Reliability of the self-reported sickness absence data

The issue of whether self-reports of sickness absence reflects actual sickness absence is clearly fundamental, since self-reports were used as a predictive outcome in this study. In order to explore the reliability of the self-reported absence data company-recorded absence data were requested from all companies, but were only made available by WYP and three of the JCP sites. Reasons for non-compliance were due to concerns over ‘data protection’ or a lack of sufficiently detailed company absence records.

Using company records as the reference standard, the sensitivity and specificity of the follow-up questionnaire to detect the occurrence of absence was high. This concurs with previous studies that have found self-reported questionnaires to have a similarly high level of sensitivity and specificity for detecting the occurrence of absence (Agius et al, 1994; Burdorf et al, 1996; Fredriksson et al, 1998; Voss et al, 2008). Substantial differences between self-reported and company-recorded absence are evident in the literature, although tend to occur when the number of episodes of sick leave are considered. This present study also found that absence >7 days was detected (by questionnaire) with a similar degree of sensitivity and specificity to absence occurrence. Although this analysis was limited due to small worker numbers, the results appear to differ from previous research that has found absence >7 days to be detected less reliably than absence occurrence (Van Poppel et al, 2002).

Importantly, the reliability of company procedures used to record absence tend not to be scrutinised in the literature, and in this present study it also cannot be assumed that company-records were more accurate than self-reports. However, there was close agreement between the company and self-reported absence data. Previous research also suggests that if self-reported data is to be used, the optimal recall period is between 2 and 6-months (Severens et al, 2000; Van Poppel et al, 2002). These facts suggest that the self-reported absence data were reasonably accurate. However, although doubtful it should be recognised that both types of data might be inaccurate.

20.2.4) Reliability of the self-reported symptom data

In the workforce survey, previously validated instruments were used to collect data about LBP history and symptom bothersomness. However, no instruments could be found in the literature to measure low back discomfort whilst sitting at work and work-relevant symptom modifying factors. These factors were of interest to in order to determine associations with other data, notably lumbar sitting postures and sickness absence due to LBP. Therefore, through experiments on a sample of sedentary workers two new instruments were validated: (1) the low back discomfort scale; and (2) Sitting and Symptom Modifying Factors Questionnaire (SSMQ).

The low back discomfort scale comprised a 0-100mm VAS, and although difficult with instruments that measure symptoms, test-retest reliability over a two week period was established (see Methods 3). The SSMQ was validated using PCA, and was shown to measure three sub-scales (physical-aggravating, posture relieving, and movement-relieving factors). These were found to be internally consistent and reliable to test-retest measures (see Methods 3). The validity of this questionnaire was also confirmed using the main study data. Thus, these new instruments were considered to have an acceptable level of reliability and validity, and were used in the main study.

The extent to which respondents accurately reported a history of LBP was impossible to ascertain, although research has shown that the ability to recall LBP diminishes over time (Svensson and Andersson, 1982). However, problems ensuring the reliability of anamnestic data are inherent to most self-reported data, so any inaccuracies in this present study may be consistent with similar surveys of LBP in the literature. Although difficult with self-reported data, attempts were made to identify sub-groups of workers who experienced: (1) incident LBP; (2) recurrent LBP; and (3) persistent LBP during the 6-month follow-up period. Logical rules were used to divide the workers into sub-groups (see p173, 175). Whilst these appeared to make conceptual sense, some misclassification between sub-groups may have taken place. Workers who experienced ‘persistence’ were the sub-group for whom associations in the data were most prevalent, and this was considered the most valid classification (being less dependant on anamnestic ability).

20.2.5) Response rates and representativeness

This section discusses two areas in relation to the workforce survey and experimental investigation samples obtained: (1) the response rates, including the problem of non-response bias, and (where appropriate) non-compliance; and (2) the representativeness of the samples (compared to the company's workforces and the call centre sector).

Workforce survey

The individual company response rates (following one reminder) varied: 29.5% (FD), 30.2% (WYP), and 58.9 (JCP), and might be explained by differences in self-reported job length (JCP had significantly more new workers than FD or WYP). Discussion with management at each company suggested that workers at FD and WYP had previously completed similar types of survey (related to work health), whereas JCP workers had not. This might explain the differences in response rates. Alternatively, these differences could relate to the fact that workers at JCP were approached by a fellow employee (not the researcher), and only asked to complete the questionnaire surveys (not to wear the FOG system), unlike at FD or WYP.

Two workers commented (on their incomplete questionnaires) that they failed to respond because of concerns that management would see their results, presumably due to the sensitive nature of some of the questions. These concerns might also have existed amongst other non-responders, and arose despite information on the introductory page of the questionnaire booklet and the consent form highlighting that responses were strictly confidential and would not be seen by management (Appendix 5). The prospective nature of this study meant that an employee ID number was necessary in order to track respondent absence over the follow-up period. Insisting on total anonymity might have helped to promote compliance, but this was not possible in a prospective study. Although tempting, further steps to enhance compliance (e.g. by contacting non-responders), were avoided on ethical grounds.

From the combined company workforces, 1537 respondents were invited to take part in the study, and the overall response rate to the survey was 39% (n=600). The literature suggests that a response rate of 70% is typical for a questionnaire distributed at work (Linton and Warg, 1993). However, lower response rates have been reported by researchers that have used five or more questionnaires: 26% (Symonds, 1995); 59% (Burton et al (2005); 39% (Sprigg et al, 2003). Therefore, the response rate in this present study was typical given the large number of questionnaires respondents were asked to complete.

In terms of demographics (age, gender, job tenure), the respondents to the workforce survey were largely representative of their respective company's workforce. The demographic characteristics of survey respondents in this present study were also similar to the one previous published report of the demographics of UK call centre workers (Sprigg et al, 2003); most workers were female, aged 30-39 years, and many had been in post for >3 years. The study by Sprigg et al (2003) included 1141 workers across 36 call centres. These findings suggest that the present study sample were representative (demographically) of call handlers in the wider call centre sector.

After 6-months, 61% (n=367) of respondents to the baseline survey completed and returned the follow-up survey. A significantly greater proportion of males and workers who had been employed for >3 years responded. The reason for this is unclear, although the size of these differences was not substantial, and the follow-up respondents were broadly representative of baseline respondents.

Experimental investigation sample

Two companies (WYP and FD) were targeted to take part in the experimental investigation because of their close geographical location. A cohort of 240 workers (120 from each company) initially agreed to participate, although some workers failed to attend their appointment or changed their mind. Workers from both companies (WYP n=89, FD n=92) finally wore the FOG system (n=181, 75%), and the number of workers recruited was restricted due to the limited number of available FOG systems and time. FOG data from only 143 (79%) of the workers could be used due to sensors either being broken by workers, or removed soon after attachment. The 2-element FOG system had not previously been extensively tested in the field, and made predicting this rate of non-compliance difficult.

Each worker was invited to wear the FOG system during work and 'ideally' in leisure time (Appendix 8a), but to remove the system if it became uncomfortable. Only 6% (n=8) of the sample wore the system beyond work, and informal discussions suggested that this was because some workers found the hip sensor uncomfortable, whilst others didn't perceive it to be important to wear the system at home because their concerns about LBP related to work. Therefore, only work data were analysed.

Workers who wore the FOG system generally had similar demographic characteristics to the workforce survey respondents. However, a significantly greater proportion of workers with previous LBP took part in the experimental investigation, suggesting that it was attractive to this group of workers.

In conclusion, a large workforce survey was undertaken using validated tools (to minimise bias), there was a typical response rate, and respondents were demographically similar to the combined company's workforce and the wider call centre sector. An experimental investigation was also conducted using a largely representative sub-sample of respondents to the workforce survey. At a pragmatic level, the extent and representativeness of the survey and experimental data collected enabled most of the studies hypotheses to be tested. However, the study sample was small in comparison to the call centre sector, meaning that the results from the work environments studied may not be generalisable to the wider population.

20.3) Discussion of the cross-sectional results

The cross-sectional results will be discussed in four main sections: (1) the prevalence of self-reported LBP and low back discomfort; (2) the biomechanical and psychosocial characteristics of call centre workers; (3) multivariable associations with LBP; and (4) factors associated with low back discomfort. The results will be interpreted in light of the current literature, with new knowledge contributed by this present study being identified.

20.3.1) Prevalence of self-reported LBP and low back discomfort

The lifetime prevalence of self-reported LBP in this study was 63%, and similar to the high prevalence rates reported by Papageorgiou et al (1995) and Hillman et al (1996) for the general population (58% and 59%). The 12-month

LBP prevalence rate found in this present study (54%) was higher than that reported by the Department of Health (1999) (40%). However, the 7-day prevalence rate in this present study (43%), was similar to the upper range (point prevalence) limit (42%) reported by De Beeck and Hermans (2000) for different study populations. Therefore, on balance, it is difficult to conclude that the prevalence of LBP amongst call centre workers is higher than that of the adult general population.

Worker's experiences of low back discomfort whilst sitting at work were measured in order to better understand associations with LBP, and biomechanical data. Personal clinical experience suggested that back discomfort is commonplace, and becomes more pronounced during an episode of LBP (symptoms >24hrs). The data supported this view, and the proportion of respondents who reported low back discomfort whilst sitting at work 'today' was high (54%), and became more prevalent for respondents reporting LBP in the past 12-months (62%) and 7-days (75%). Whilst the mean intensity of discomfort 'today' was generally low (15pts), and remained stable for workers reporting LBP in the past 12-months (13pts), it increased for workers reporting current LBP (26pts).

20.3.2) Biomechanical and psychosocial characteristics of call centre workers

This section discusses the occupational biomechanical (activities and seated lumbar movement characteristics) and psychosocial characteristics of the sample of call centre workers (including univariate associations with LBP). It is anticipated that this will enable the results to be interpreted in a wider context relating to: (1) the current health and safety and ergonomic literature; and (2) the nature of the psychosocial work environment in call centres.

Biomechanical characteristics

The health and safety literature widely advocates the importance of taking regular breaks from sitting (Flaspoler et al, 2005; HSE, 2006; HELA, 2006). These recommendations appear to be based on early biomechanical and epidemiological studies that suggest prolonged sitting is a risk factor for the development of LBP (Nachemson and Elstrom, 1970; Magora, 1975; Kelsey and White, 1980; Videman et al, 1990). The literature also contains an abundance of experimental studies and narrative reviews that advocate the adoption of a lordotic lumbar sitting posture to prevent LBP (Hedman and Fernie, 1997; Harrison, 1999; Pynt et al, 2001, 2008). Thus, there is a general perception that kyphotic lumbar postures are hazardous.

Based on employer's reports, all workers included in this present study received standard Health and Safety Executive training as part of their induction (HELA, 2006; HSE, 2006), with annual refresher courses. This included training on: (1) how to set up their chair/workstation; (2) sit supported with a lumbar lordosis; and (3) the importance of taking regular breaks from sitting. All workers had adjustable office chairs. To date, the extent to which these recommendations are adopted within sedentary jobs has received little attention. This present study helps to shed light on this question by continuously measuring exposure to uninterrupted sitting during call centre work.

On average, most workers were not exposed to prolonged (uninterrupted) sitting periods in excess of one hour. Therefore, in the call centres studied, workers generally changed position from sitting by standing up regularly, either deliberately or because of work organisation. This suggests some conformity with health and safety recommendations. With regards to LBP, no cross-sectional association with prolonged sitting was identified. However, workers who sat (on average) for longer than one hour were significantly more likely to report future LBP (*this is further discussed in section 20.4.1*). Thus, this study provides evidence that advice to avoid prolonged periods of sitting is justified. However, it was not possible to provide a robust measure of 'work-breaks' from sitting, and the duration of breaks might be more influential than the frequency of changes in position from sitting.

To the authors' knowledge, this is the first study to have measured dynamic lumbar sitting postures at work. The results show that workers were not very compliant with postural recommendations from their employer; the majority of sitting time (74%) was spent adopting a kyphotic lumbar posture. This might be due to a combination of ineffective delivery (during training) and/or lack of enforcement. Research by Sprigg et al (2003) supports the view that the uptake of current HSE advice is less than optimal. In their survey of 36 call centres, 49% of workers reported that they had not received HSE training (even though they had). One alternative possibility why lordotic sitting postures were not adopted for long is that they were simply not comfortable. There is an apparent lack of evidence regarding the comfort afforded by lordotic sitting postures, although there is research to suggest that moderately flexed postured are perceived to be comfortable (Mclean et al, 2001).

The data also revealed a weak cross-sectional association between sitting with a kyphotic lumbar posture and LBP, although failing to maintain a lordotic lumbar posture whilst sitting did not increase the risk of future LBP. Sitting with a static lumbar posture is also thought to be associated with LBP, and has prompted the development of numerous ergonomic interventions designed to encourage lumbar movement (Reinecke et al, 1994; van Deursen et al, 2000; Aota et al, 2007; Lengsfeld et al, 2001, 2007). The findings from this present study suggest that a relative lack of lumbar movement is in fact a normal feature of natural sitting. Workers spent 66% of the time sitting relatively static (accumulating 5° of lumbar motion), and no association between movement variables and current LBP was found. However, future LBP (notably symptom persistence) was associated with not changing posture regularly (*see section 20.4.1 for further discussion*).

This studies contribution to knowledge tentatively raises questions about the utility of some of the advice offered to workers by their employees, as recommended by statutory bodies. For instance, kyphotic sitting postures may not pose a risk to sedentary workers; workers spent most of their time with such postures, yet the prevalence of LBP was similar to that found in the general population. Furthermore, sitting with a lumbar kyphosis did not increase the risk of reporting future LBP. Therefore, current health and safety recommendations may require re-evaluation in light of the results from this and other studies (Althoff et al, 1992; Mclean et al, 2001; Vegara and Page, 2002). Perhaps a more evidence based view would advocate the adoption of comfortable lumbar sitting postures, which might well be reclined and moderately flexed, along with regular breaks and changes in sitting posture (Mc Gill, 2006).

Psychosocial characteristics

Many of the same instruments used to measure psychosocial factors (social support, psychological distress, psychological demand) in this present study have also been used amongst different occupational groups, enabling the results to be compared. The call centre workers reported higher levels of social support at work than cohorts of industrial workers (Symonds, 1995; Bartys, 2003), and greater psychological distress than industrial workers, police officers or supermarket cashiers (Burton et al, 1996; Mackay et al, 1998; Bartys, 2003). This latter finding concurs with the survey of psychosocial factors amongst call centre workers undertaken by Sprigg et al (2003), who found a higher risk of mental health problems compared to professional, manual and administrative workers. The level of psychological demand amongst the workers measured in this present study was also notably higher than that reported amongst 9 different occupational groups (n=34,972) across Europe (Smet et al, 2005). Therefore, the notion that call centre workers are exposed to high levels of psychosocial risk factors (Flaspoler et al, 2005) (at least for psychological demand and distress), was confirmed.

Most psychosocial scores were similar between respondents, regardless of self-reported LBP history. The exception was for the clinical psychosocial factors (psychological distress and fear avoidance beliefs). All respondents with a history of LBP were significantly more distressed than respondents with no history of LBP, and the size/significance of this difference (1.2 points) was largest for respondents who had experienced LBP in the past week. This finding supports previous epidemiological data that has found psychological distress to be associated with LBP (Nahit et al, 2001), and acute symptoms (Grotle et al, 2004). As has previously been shown in the literature, fear avoidance beliefs were associated with LBP (Vlayen et al, 1996); scores were highest for workers reporting LBP in the past 7-days, and then the past 12-months.

The lack of association between occupational psychosocial factors (job satisfaction, social support, psychological demand) and LBP was surprising given the numerous previous reports in systematic reviews of the literature (Burdorf and Sorock, 1997; Davis and Heaney, 2000; Linton, 2001). Causal beliefs about work were also not associated with LBP. These findings suggest that amongst the call centre workers studied, occupational psychosocial factors: (1) did not directly influence the development of LBP; and (2) were not influenced by the perception of LBP. However, the pattern of psychosocial scores was one of detriment (more negative influence) for workers with LBP, and a larger sample size might have found weak associations.

No previous studies that have focused specifically on the relationship between LBP and psychosocial factors amongst call centre workers could be found. Two studies were found that grouped together call centre workers with musculoskeletal symptoms (including LBP); both demonstrated an association between high psychological demand and musculoskeletal symptoms (Halford and Cohen, 2003; Norman et al, 2004). However, the high levels of psychological demand reported in this present study were not related to self-reported LBP or other musculoskeletal symptoms, rather these were a general feature of call centre work.

20.3.3) Multivariable associations with low back pain

This section discusses the cross-sectional (multivariable) relationships between the different types of data collected in this study and LBP. Whilst such analysis is unable to establish cause and effect, it may be useful in identifying associations that can later be more rigorously studied. To date, few studies of factors associated with LBP have been conducted in sedentary work environments. The studies that do exist have used imprecise methods to measure biomechanical factors, and failed to control for a wide range of potential confounding variables (Riihimaki et al, 1989; Burdorf et al, 1993). This present study sought to address this niche.

Whilst a variety of seated lumbar movement characteristics were associated with LBP, it was the extent of sitting time spent with a lordotic posture that explained most of the variance in current LBP. In contrast, no occupational psychosocial factors were associated with current LBP. This might be partly explained by the high levels of social support (at work) in the call centres; job dissatisfaction and causal beliefs (work: organisation, physical demands) were negatively associated with this variable. This ‘buffering’ effect supports the view of Linton et al (2001), and is a potentially important finding. Unlike other psychosocial factors, at a conceptual level social support may be amenable to change, leading to the hypothesis: can improving social support have a statistically significant effect on other occupational psychosocial factors?

Previous researchers that have investigated occupational psychosocial factors among sedentary workers have found a weak association with LBP (for job satisfaction), but did not measure social support (Spyropoulos et al, 2007). The results of this present study suggest that such an association might be due to poor social support at work. The clinical psychosocial factors measured in this present study were associated with LBP, and fear avoidance beliefs dominated psychological distress. This finding amongst an occupational group fits with the balance of previous clinical research; whilst both factors are known to be associated with LBP (Waddell et al, 1993; Croft et al, 1996), psychological distress is better known for its association with poor functional outcomes (Pincus et al, 2002), rather than pain (Simmonds et al, 1996).
Together, low back discomfort whilst sitting at work 'today' and physical aggravating factors explained more of the variance in current LBP (having a dual influence: R^2 0.32), than any other group of factors. This demonstrates a modest strength association between new factors measured in this study and LBP. Thus, it would appear that back discomfort at work and physical aggravating factors are of concern to sedentary workers with LBP, suggesting that their management is important (*see section 20.4.2: these factors predicted future sickness absence due to LBP*).

Multivariable (stepwise) analysis between groups of variables found that the proportion of time spent sitting with a lumbar posture ≥80% ROM, and low back discomfort whilst sitting at work explained a modest amount of the variance in current LBP (R^2 0.40). Thus, these factors warrant more rigorous future study in order to fully determine their relationship to LBP, since both might be modifiable. The fact that psychosocial data were not retained in multivariable analysis adds to the evidence base. Previously, similar findings have only been reported for biomechanical factors in physical jobs, which dominated psychosocial aspects of work (Davis and Heaney, 2000). The fact that psychosocial factors were not retained alongside biomechanical factors, in this present study, also contradicts the perception held by the European

Agency for Safety and Health at Work about the risks for LBP present in call centres.

The finding that biomechanical factors dominated psychosocial factors appears to conflict with the results from a recent study of sedentary (office) workers (Spyropoulos et al, 2007). Multivariable methods were also used, although biomechanical risk factors (related to sitting) were measured subjectively as self-reports. The validity of such measures has not been examined extensively (Daniels et al, 2005), and the retention of psychosocial factors (job satisfaction, anger in the past 30-days) in the multivariable model may have been due to workers inaccurate reports of biomechanical exposure (body position in sitting: forward, bent >2hrs, non-bent). Alternatively, differences in the results might also be explained by the heterogeneity of the samples, or the risk factors measured.

20.3.4) Factors associated with low back discomfort

This section of the results will discuss the relevance of different types of data associated with low back discomfort whilst sitting at work, notably: (1) activities during work; (2) seated lumbar movement characteristics; and (3) clinical and occupational psychosocial factors. These data will then be considered in a multivariable model, in order to provide a more robust explanation of back discomfort.

Activities during work

On average, workers reporting low back discomfort whilst sitting (65% of whom reported an episode of LBP in the past 12-months) sat for significantly longer (56mins) than discomfort free workers (47mins), although there was no association between prolonged (uninterrupted) sitting and discomfort intensity. Workers reporting more intense discomfort did, however, spend significantly less time walking than discomfort free workers, and spent more time sitting. These findings suggest that workers experienced more discomfort because they spent longer adopting static activities (and so should be encouraged to walk around more at work). An alternative explanation is that since these workers had stronger fear avoidance beliefs about physical activity than workers with no discomfort, sitting may represent a form of activity avoidance.

However, the small mean difference in fear avoidance beliefs (2.5 pts) between these groups suggests that the reduced activity during work may be attributable to other factors.

Seated lumbar movement characteristics

To date, the evidence base related to lumbar movement-in-sitting and back discomfort largely comprises experiments conducted in controlled laboratory settings, and is equivocal. Some studies have found that movement-in-sitting is positively associated with discomfort (Vegara and Page, 2002), whilst others have found a negative association with back symptoms (Damkot et al, 1984; Majeske and Buchanan, 1984; Reinecke et al, 1994; Aota et al, 2007). This present study, the first to have investigated these associations in an occupational setting, found that workers who reported discomfort whilst sitting at work changed their lumbar posture significantly less than workers without discomfort.

Although tempting, based on this study the mechanism for this weak association cannot be explained. Two possible explanations are that: (1) workers experienced discomfort because of a lack of movement-in-sitting; or (2) because movement was perceived to exacerbate discomfort workers chose not to move (static sitting representing a form of avoidance behaviour). Interestingly, the amount of movement-in-sitting was negatively associated with discomfort intensity; workers who changed posture less frequently reported significantly more discomfort. The direction of this relationship tentatively suggests that interventions that encourage lumber movement in-sitting have a role in reducing back discomfort.

Early research by Williams et al (1990) found that patients with LBP who used a lumbar roll in sitting achieved a 21% reduction in back pain intensity. This has prompted many to advocate lumbar rolls (and the maintenance of a lumbar lordosis) to manage LBP symptoms related to sitting. However, the extent to which adopting a lumbar lordosis can reduce symptoms is unknown. This present study explored if maintaining a lumbar lordosis was associated with reduced levels of back discomfort. Using the median amount of time spent maintaining a lumbar lordosis as the cut-off point, workers were split into two groups: (1) high lordosis (median ≥26%); and (2) low lordosis (median

<26%). The high lordosis group reported less discomfort (mean difference: 4pts) (*P>0.05*). This reduction in symptoms is less sizable than that found by William et al (1990), and could be explained by: (1) the different tools used to measure symptoms; (2) the fact that patients in a clinical setting may have had more intense symptoms at baseline (and thus responded better to the intervention); or (3) the fact that workers in this present study (in the high lordosis group) did not all spend long maintaining a lordosis. Since it is also unknown how long the patients in the Williams et al (1990) study maintained a lumbar lordosis, the reported reduction in pain intensity may also be attributable to other factors.

Overall, the results of this present study show that whilst postural variables were not associated with back discomfort, movement variables were. These findings support earlier suggestions that perhaps there should be a shift towards encouraging lumbar movement whilst sitting, instead of maintaining a particular posture. Indeed, over emphasise of 'correct' lumbar posture may actually discourage workers from moving in sitting or getting up.

Clinical and occupational psychosocial factors

To the authors' knowledge, this is the first study to have reported associations between clinical and occupational psychosocial factors and low back discomfort whilst sitting at work. Compared to the few associations with LBP, a much wider range of similarly weak associations were found for discomfort, although the size of these differences was generally larger. It would thus appear that the discomfort scale was more sensitive at detecting associations with psychosocial factors than a traditional episodic definition of LBP. The relevance of this finding is that due to its widespread association with clinical and occupational psychosocial factors, discomfort might represent a useful 'composite' measure. This may be particularly useful in future studies that construct multivariable models to explain occupational outcomes, where the aim is to find a small number of factors that explain a large amount of the variance in outcome.

Multivariable explanation of discomfort

Whilst univariate analysis established that limited variety of lumbar movement whilst sitting at work was associated with back discomfort, this variable was dominated by other variables in a multivariable model. In this model, fear avoidance beliefs and physical-aggravating factors were most influential. Since the amount of variance in discomfort explained was modest (R^2 0.30), this suggests that targeted interventions to reduce fear avoidance beliefs and physical aggravating factors might have some effect on back discomfort. However, fear avoidance beliefs and physical aggravating factors might also be associated with an unmeasured factor that exerts an influence on discomfort. Therefore, it cannot be assumed that modifying these variables will improve workers levels of back discomfort.

20.4) Discussion of the prospective results

The prospective results will discuss associations between baseline data and: (1) future LBP; (2) future sickness absence due to LBP (both reported during the 6-month follow-up period). Interpretation of the results will focus on the relative predictive ability of variables, and their potential to be modified through intervention.

20.4.1) Prediction of future LBP

The literature contains a myriad of references to prolonged sitting at work being a risk factor for LBP (Lengsfeld et al, 2000; Beach et al, 2005; Flaspoler et al, 2005; Aota et al, 2007). Lack of knowledge in this area is exemplified by the fact that the level at which exposure to prolonged sitting at work may become hazardous has not been defined. The present study investigated this niche, and prolonged (uninterrupted) sitting (average duration >1h: yes/no) was found to increase the risk of future LBP. This finding appears to be the first established using an objective method to determine 'exposure'. Whilst the effect size was weak (R^2 0.13), this evidence supports advice to avoid prolonged periods of sitting.

To date, most descriptive reviews of the literature (that consider the biomechanical evidence), emphasise the clinical view that kyphotic lumbar postures are an important risk factor for LBP (Harrison et al, 1999; Pynt et al, 2001, 2008). However, despite using a range of variables to measure the degree and amount of time spent sitting with a lumbar kyphosis, none were significant predictors. Thus, this present study of natural sitting postures amongst sedentary workers challenges the general perception that sitting with a kyphotic lumbar posture is hazardous. Instead, perhaps attention should be shifted towards encouraging regular changes in sitting posture, since limited variety of lumbar movement predicted a larger amount of the variance in future LBP than any other variable.

Whilst a variety of symptom variables were associated with future LBP they generally had limited predictive ability (apart from LBP symptom bothersomness). Certain psychosocial factors (job dissatisfaction, function) were also weakly linked to future LBP, a finding strongly supported by the literature (Bongers et al, 1993; Burdorf and Sorock, 1997; Davis and Heaney, 2000; Linton, 2001).

In order to control for potential confounding influences, independent variables were considered together in a multivariable (stepwise) model. The only two factors retained were: (1) current LBP; and (2) limited variety of lumbar movement. Current LBP was retained by the model because most workers who reported 'future' LBP were experiencing persistence, and were thus symptomatic at baseline. The fact that lumbar movement-in-sitting dominated prolonged (uninterrupted) sitting shows that these variables were correlated. Thus, during prolonged periods of sitting workers become more static (changed lumbar posture less). Appreciating that these variables are inter-related can be useful in understanding more about LBP; biomechanical data about workers in future studies may not include all of the risk factors measured in this study. The interpretation from this finding is that lumbar movement (by either a break from prolonged sitting or regular movement-in-sitting) can reduce the risk of future LBP. Overall, the amount of future LBP explained by the multivariable model was weak (R^2 0.17), suggesting that factors unmeasured in this study have a more powerful influence.

Through controlling for objectively measured occupational biomechanical factors, the prospective results of this study are somewhat unique; previous studies have generally failed to include these factors, or have used crude forms of measurement (Davis and Heaney, 2000; Marras, 2000). Indeed, the authors of several systematic reviews have questioned whether or not the association between occupational psychosocial factors and LBP is confounded by the absence of control for biomechanical covariates (Davis and Heaney, 2000; Linton, 2001). The results of this present study concur with this hypothesis, and tentatively lend support to the view that psychosocial work characteristics may not have a causal effect (Davis and Heaney, 2000), at least amongst sedentary workers.

Based on studies available in the literature, this appears to be the first study to have quantified a link between biomechanical risk factors in sedentary jobs and future LBP. On balance, the results support findings reported in the literature from different jobs that have measured self-reports of biomechanical exposure; physical risk factors are much stronger predictors of future LBP than psychosocial factors (Skov et al, 1996; Gheldof et al, 2005)

Although some future LBP was predicted, this outcome incorporated symptom persistence and recurrence, and might also be influenced (to a lesser degree) by incident episodes of LBP. Therefore, sub-groups were analysed to determine if risk factors for different outcomes varied. None of the variables measured in this study were predictive of LBP incidence (this may relate to the small sample size and short follow-up period). The sole significant predictor for 'recurrence' was low back discomfort whilst sitting at work. From an occupational perspective, intuitively this suggests that workers reporting discomfort should be taken seriously, since they may be at increased risk of a future episode of LBP. However, attention to this potentially modifiable factor may have only a weak influence on recurrence (R^2 0.09), and could be confounded by other variables in a multivariable model.

A larger data set was available to predict persistent LBP, enabling multivariable analysis to take place. The same univariate predictors to 'future LBP' were found, with the exception of prolonged (uninterrupted) sitting (*P=0.09*). The effect sizes were similar, and in a multivariable model limited variety of lumbar movement whilst sitting was the only retained variable. Therefore, in the call centre workers studied, the persistence of LBP was influenced most strongly by lumbar biomechanics in sitting (R^2 0.11).

20.4.2) Prediction of future sickness absence due to LBP

This section of the results will consider the ability of baseline data to predict the occurrence and extent (>7 days) of future sickness absence due to LBP.

The discussion will focus on how the predictors identified in this study add to the existing literature, and the implications of these findings.

Occurrence of sickness absence

Whilst the costs of prolonged absence are often identified, the costs of short-term absence might represent a 'hidden' cost (Main et al, 2008), and so merited specific consideration. This study confirmed the multi-factorial nature of predictors of sickness absence; demographics, biomechanical factors, clinical and occupational psychosocial factors, and symptoms all exerted a significant (univariate) influence. Different types of risk factors were also retained in the final multivariable model that included all data.

Considering the demographic data first; previous LBP, current LBP, and sickness absence due to LBP in the past 12-months were each significant predictors. Age, sex, and job tenure were not significant predictors of sickness absence due to LBP amongst the call centre workers studied. A more sizable study of industrial workers did, however, find that males and older workers were significantly more likely to take absence (Burton et al, 2005). Therefore, the influence of demographic variables appears to vary between occupational groups and/or work environments.

With regards to the biomechanical data, the results show that workers who used a limited variety of lumbar movement whilst sitting at work were at increased risk of future sickness absence. However, the effect of this biomechanical variable was weak (R^2 0.08), and so its targeting for intervention may have limited effect in reducing absence. Furthermore, due to the limited amount of biomechanical data collected, this finding requires further validation. The lack of similar data reported in the literature prevents comparison with other studies.

Based on reports in the literature, it is clearly fundamental to consider the influence of symptoms on the risk of sickness absence (Elders et al, 2003; Gheldolf et al, 2005). This present study used new instruments to measure: (1) low back discomfort whilst sitting at work; and (2) and work-relevant symptom modifying factors. Alongside more established tools used to measure symptoms (NMQ, symptom bothersomness), the 'work-based' measures were dominant and explained more of the variance in absence (R^2 0.22) than any other group of factors. Therefore, this study provides insight into how workers experiences of back discomfort and aggravating factors at work (both of which appear to be potentially modifiable) drive absence behaviour. A strategy to enhance work retention might, therefore, focus on their reduction.

Relatively little is known about the influence of clinical psychosocial factors on sickness absence. In the present study, strong fear avoidance beliefs (about physical activity) were predictive of the occurrence of sickness absence. Previously, amongst different occupational groups, fear avoidance beliefs (relating to work, not physical activity) have only been linked to more prolonged absence (Fritz et al, 2001; Gheldolf et al, 2005). In this present study, fear avoidance beliefs were not predictive of absence when controlling for function. This supports the results of a systematic review (which focused on the wider outcome of poor prognosis: typically measured using the RMDQ and delayed return to work) which questioned whether or not fear avoidance beliefs contain unique predictive qualities independent of other measures (Pincus et al, 2006).

Occupational psychosocial factors are better known for their significant influence on sickness absence. In particular, job satisfaction has strong support in the literature as a weak predictor (Bigos et al, 1991; Waddell and Burton, 2000). Therefore, the fact that job dissatisfaction increased the risk of absence is unsurprising. More original was the finding that psychological demand at work and work-related causal beliefs were predictive of absence; whilst there are strong theoretical arguments for their importance, these factors have received little previous attention (Kuijer et al, 2006). The focus of previous studies that have measured beliefs about the causes of LBP at work was not to investigate their predictive ability alongside other variables (Symonds, 1995; Bartys, 2003). Thus, this present study has added to the literature by showing that beliefs about work organisation as a cause of back discomfort at work can dominate other occupational psychosocial factors (job satisfaction, social support). This raises the question: is job dissatisfaction a consequence of causal beliefs about work and high psychological demand? Previously, job dissatisfaction has been shown to loose its predictive ability when controlling for pain intensity, suggesting that job dissatisfaction may be due to pain. (Gheldof et al, 2005). This present study supports the view that job dissatisfaction can also relate to other occupational psychosocial factors (Van den Heuvel et al, 2004; Shaw et al, 2005).

Comparing the predictive ability of different groups of factors several patterns are relevant; clinical and occupational psychosocial risk factors had similarly weak predictive ability. Previous research by Burton et al (2005) found that in retrospective analysis, the effect of psychological distress (on the likelihood of absence) was comparable to the effect of any occupational psychosocial factors. Whilst including some different psychosocial factors in a prospective investigation, this present study found that a similar proportion of clinical and occupational psychosocial factors were predictive. Also, the ability of clinical and occupational psychosocial factors (as groups of factors) to predict absence was also similar. This suggests that psychosocial factors (whether based on clinical or occupational concepts) are similarly prevalent and weak in their effect on absence. Therefore, although certain clinical and occupational psychosocial factors were predictive of future LBP, based on the results of this study their inclusion would add little to a screening tool.

In the final multivariable model (including all variables), work-relevant low back discomfort, physical aggravating factors and psychological demand were the retained predictors. Thus, these are more compelling markers of risk than other factors, suggesting that attention should be directed towards their management, which requires more than just a psychosocial approach. Although there is a mandate for employers to eliminate sources of back discomfort at work, this is frequently not possible given the uncertainty of its origin. This study suggests that attempts to reduce workers levels of back discomfort (and physical-aggravating factors) should be encouraged, and might have a weak to moderate effect on sickness absence (R^2 0.24). These factors might be easier to modify than psychological demand.

Extent of sickness absence

Little is known about the factors predictive of return-to-work amongst sedentary workers. This is surprising given that reducing the duration of sickness absence due to LBP is arguably the most appropriate target for intervention. Understanding more about the influence of work-relevant biomechanical factors on the extent (>7 days) of sickness absence due to LBP was of particular interest given the lack of reports in the literature. However, due to the small number of workers who took part in the experimental investigation and took absence >7 days (n=3), lumbar movement characteristics were not included in multivariable analysis. A limited number of respondents to the workforce survey also took absence >7 days (n=10). Thus, interpretation of the results should take place with these limitations in mind.

The results of this present study appear to confirm previous reports in the literature obtained from different occupational groups; psychosocial factors have limited ability to predict prolonged sickness absence (Hannson and Jensen, 2004; Burton et al, 2005). No occupational psychosocial factors were significant predictors, although certain clinical psychosocial factors (psychological distress, function) were weakly predictive of the extent (>7 days) of sickness absence. These findings are supported by the literature; low levels of function are known to be associated with more prolonged absence (Crook et al, 2002), and psychological distress is an established predictor of work-time lost (Crook et al, 2002; Pincus et al, 2002). When the clinical psychosocial factors were considered together in a multivariable model, psychological distress dominated function.

In contrast with a recent review (Pincus, 2006); psychological distress did not contribute to impaired work status after controlling for back symptoms (measured as discomfort whilst sitting at work in this present study). Shaw et al (2007) also found that after controlling for pain, emotional distress did not contribute to work status (albeit amongst military personnel, using different tools to measure symptoms and distress). If depressive mood/symptoms precede back pain this may complicate rehabilitation efforts due to negative expectations for recovery. After pain onset, distress may also merge from an inability to cope, or a perception that symptoms will worsen or persist.

Whilst psychological distress is regarded as being important early in the development of disability (Pincus et al, 2006), this present study found that when measured at work this factor had limited ability to predict sickness absence >7 days. In the literature, psychological distress has generally been measured several weeks after absence has commenced (Pincus et al, 2006). This suggests that workers become more distressed over time whilst absent from work. The findings from this present study therefore fit with the notion that psychosocial obstacles to recovery evolve over time (Waddell et al, 2003; Kovacs et al, 2004), and questions the value of measuring psychosocial factors prior to the onset of absence.

When all available data were included in a multivariable model to predict absence >7 days, back discomfort and sickness absence in the previous 12-months dominated all other variables. The amount of variance in absence that was explained approached moderate (R^2 0.26), and is similar to models reported for different occupational groups (Steenstra et al 2005; Shaw, 2007). The finding that preventing absence >7 days is partly a function of preventing absence due to LBP in the preceding 12-months has previously been reported in the literature, albeit in manual jobs (Andersson and Deyo, 1997; Dionne, 1999). More novel is the finding that low back discomfort whilst sitting at work can predict more prolonged absence, since this has not previously been reported in the literature. However, the dominant role of pain in predicting prolonged absence is recognised (Hansson and Jensen, 2004). Eccleston and Crombez (1999) have argued that high intensity pain is not easily ignored, due to the fact that it is perceived as a threat which places a load on our attentional and cognitive systems. This present study tentatively suggests that high intensity back discomfort measured whilst sitting at work may have a similar effect, and can act as an obstacle to return-to work. This is perhaps not surprising given that workers are known to believe that they should be symptom free before returning to work (Waddell and Burton, 2000).

Interpreting the results of this study, the use of psychosocial screening at work to predict the extent (>7 days) of sickness absence due to LBP does not seem justified. However, back discomfort whilst sitting at work and sickness absence due to LBP in the preceding 12-months might be useful factors to consider in a screening tool. This study identifies a clear link to the need for effective occupational management of workers with LBP; interventions to reduce the initial risk of sickness absence, and improve workers' levels of back discomfort whilst sitting at work might have a weak to moderate effect in reducing absence >7 days. In theory, many of the risk factors identified in this present study are potentially modifiable, although considerable work is required to determine the effectiveness of targeted interventions.

DISCUSSION OF THE HYPOTHESES

This section relates back to the hypotheses that the study was designed to test, and determines whether they are supported by the results obtained.

Main hypothesis

Dynamic lumbar sagittal movement characteristics measured during sedentary work are statistically significant predictors of future self-reported LBP, yet clinical and occupational psychosocial factors are stronger predictors of future sickness absence due to LBP.

This hypothesis was supported. In a multivariable (stepwise) model including seated lumbar movement characteristics measured during work, workers who used less variety of lumbar movement were significantly more likely to report future LBP. To predict the occurrence of future sickness absence a range of clinical and occupational psychosocial factors were included in a multivariable (stepwise) model; workers reporting high psychological demand and strong beliefs about work organisation (as a cause of back discomfort) were significantly more likely to report absence. The psychosocial factors explained more of the variance in sickness absence (21%) than the lumbar movement characteristics did for LBP (8%). Whilst demonstrating that biomechanical and psychosocial factors in sedentary jobs significantly impact on future LBP and sickness absence due to LBP, this contribution to knowledge suggests that these outcomes are largely explained by factors unmeasured in this study.

Sub-hypotheses 1

Psychosocial factors (psychological distress, work-related causal beliefs, job satisfaction, psychological demand and social support) are not significantly associated with self-reported low back discomfort at work, but do predict the occurrence and extent (>7 days duration) of subsequent sickness absence due to LBP.

This hypothesis was partly supported. Psychological distress, beliefs about the work-related causes of low back discomfort (work organisation: work environment) and job satisfaction were each significantly associated with low back discomfort whilst sitting at work. Beliefs about the organisational and environmental work-related causes of low back discomfort also independently predicted the occurrence of future sickness absence due to LBP. Thus, this study established that beliefs about aspects of sedentary work being a cause of back discomfort are of potential importance in understanding how workers perceive work and cope during an episode of LBP The only psychosocial factor to predict the extent of sickness absence was psychological distress, although this was dominated by other variables in a multivariable model.

Sub-hypotheses 2
Workers who maintain a lordotic lumbar sitting posture will report significantly less low back discomfort at work and future LBP than workers who adopt a kyphotic lumbar sitting posture.

This hypothesis was not supported. Workers who maintained a lordotic lumbar sitting posture at work did not report significantly less discomfort or future LBP than workers who adopted a predominantly kyphotic posture.

Sub-hypotheses 3
High levels of fear avoidance beliefs are significantly associated with reduced walking outside of work, and are statistically significant predictors of future sickness absence occurrence due to LBP.

This hypothesis was partly supported. Due to the lack of leisure-time activity data (see sub-hypothesis 7) this hypothesis could not be tested. However, fear avoidance beliefs about physical activity significantly predicted the occurrence of future absence due to LBP. Fear avoidance beliefs are widely implicated in the transition from acute to chronic disabling LBP, although the literature contains a lack of prospective studies. This study found that fear avoidance beliefs related to activity (not work) are involved in the decision to take absence, but do not contain any unique predictive qualities independent of other psychosocial factors.

Sub-hypotheses 4
Workers who sit with a static lumbar posture will report significantly more low back discomfort at work than workers who adopt more dynamic sitting postures.

This hypothesis was supported. Low back discomfort intensity whilst sitting at work was significantly greater amongst workers who used less variety of lumbar movement in sitting. The size of this difference was small, suggesting that ergonomic interventions may have limited impact on back discomfort. Workers who were measured to change lumbar posture less frequently (mean angular velocity) also had higher discomfort scores than workers who sat more dynamically, although these differences were not significant.

Sub-hypotheses 5
Physical aspects of sitting reported to aggravate low back discomfort at work are statistically significant predictors of future sickness absence occurrence due to LBP.

This hypothesis was supported. Using a sub-scale of the Sitting and Symptom Modifying Factors Questionnaire (developed during the course of this study), physical-aggravating aspects of sedentary work significantly predicted the occurrence and extent (>7 days) of future sickness absence due to LBP. The influence of work-relevant symptom modifying factors in sedentary jobs does not appear to have received attention in the literature. This study suggests that symptom aggravating aspects of sedentary work are important, playing a significant role (alongside a range of other factors) in the occurrence of sickness absence.

Sub-hypotheses 6
Higher levels of physical activity (walking) outside of work will significantly reduce the probability of recurrent LBP and future sickness absence (occurrence and extent) due to LBP.

Only 6% of the sample (n=8) wore the FOG system during leisure-time, with the vast majority of workers choosing to remove it at the end of their working shift. Therefore, due to the lack of leisure-time data, it was not possible to test this hypothesis.

Sub-hypotheses 7
Future self-reported LBP can be significantly predicted from dynamic lumbar sagittal movement characteristics at work, although the addition of demographic and psychosocial data will enhance predictive ability.

This hypothesis was partly supported. In a multivariable model, future self-reported LBP was significantly predicted by lumbar movement characteristics measured at work. Whilst sitting, using less variety of lumbar movement increased the risk of reporting future LBP, and the inclusion of demographic data (current LBP) enhanced the models predictive ability, although the addition of psychosocial data did not. The lumbar movement characteristics of sedentary workers have not previously been investigated, and so their measurement alongside other variables is novel.

MAIN LIMITATIONS

This study was ambitious in nature, and the extent to which the findings can be confidently accepted will now be considered in light of the main limitations:

- Selection threats to external validity appear to have been controlled; the call handlers recruited were from two companies across 4 call centres, and were demographically representative of workers in the call centre sector.

- Convenience samples were accessed during the course of this study, and due to organisational policy approaches to worker recruitment varied. However, a standardised information sheet and consent form was used, and there were minimal demographic and psychosocial differences between the company samples.

- Instrumentation effects were minimised by using: (1) standardised validated questionnaires with appropriate psychometric properties; and (2) a validated FOG system that was re-calibrated during the course of study.

- Workers could have altered their lumbar postures in response to wearing the FOG system (reactivity). Previous research and pilot work suggests that such an effect may be negligible; wearers report being unaware of the system several minutes after attachment.

- Since repeated measures using the FOG were not undertaken it was not possible to determine the extent to which activity and posture measurements were repeatable (intra-worker variability). However, because measures were taken from a large group and not confined to a particular day, 'variability' effects might be consistent within the data.

- Potentially important biomechanical factors were not measured in this study; lumbar spine loading whilst sitting at work was not considered, yet could account for some back discomfort at work. This may confound the results, although at present no method is available to continuously measure dynamic loading conditions at work.

- Low back discomfort whilst sitting at work was measured once, near the start of work. Since a weak association with lumbar movement-in-sitting was found, it is feasible that discomfort measured towards the end of work might demonstrate a stronger association.

- Call handlers have been found to deal with 1,000 phone calls during a day (Westin, 1992), and levels of task attentiveness and objective workload might be associated with lumbar movement characteristics, symptoms or psychosocial measures (thus confounding the results).

- Workers' activity levels and lumbar movement characteristics outside of work were not measured, although leisure-time activity might have a profound influence on the risk of LBP and sickness absence.

- This study failed to consider personal psychosocial or socio-economic factors. Due to the lengthy nature of the questionnaire booklet used in this study, these factors were purposefully excluded.

- A wide range of variables were deliberately collected during this study, and could lead to 'overfitting'. To minimise this effect a stepwise procedure was used, although some researchers have suggested that overfitting can still take place when using such an approach. However, the results suggest that overfitting was not a problem; R^2 values were generally low and often reduced when more variables when added to a model; no factors that failed to show univariate significance became significant in the presence of other variables; and efforts were taken to avoid multicollinearity.

- Whilst models of varying explanatory ability were reported, these were not empirically validated, and the extent to which similar results would be obtained using a different set of data is unknown.

- A sample size calculation was not undertaken prior to this study; some of the variables measured were new, and a convenience sample was accessed. As it transpired, the sample size was too small for robust analysis of some prospective outcomes.

CONCLUSIONS

- Prevalence rates for low back pain were high amongst the population studied, yet no higher than might be expected from any occupational group. The experience of back discomfort whilst sitting at work was reported by most workers, and was most pronounced for workers reporting current LBP (symptoms >24hrs).

- There was a clear cross-sectional relationship between clinical psychosocial factors (psychological distress, fear avoidance beliefs) and LBP, although no association with occupational psychosocial factors was evident. Overall, levels of work-related social support were high, and had a weak 'buffering' effect against job dissatisfaction and causal beliefs about the work environment, amongst workers with LBP.

- Call centre workers spent most of the working shift sitting with a kyphotic lumbar posture, and got up from sitting regularly. Whilst sitting with a lumbar kyphosis did not increase the risk of future LBP, exposure to prolonged (uninterrupted) sitting did. Thus, advice to avoid prolonged periods of sitting seems justified.

- Kyphotic lumbar sitting postures were weakly associated with current LBP and became more pronounced over time, but were not associated with back discomfort whilst sitting at work.

- Measured whilst sitting at work, lumbar kinematic variables and low back discomfort were weakly associated; workers that maintained a relatively static posture were more likely to report discomfort, and of a greater intensity. Therefore, targeted ergonomic interventions to reduce back discomfort might have some effect.

- Predictors of future LBP and sickness absence due to LBP (in multivariable models) were not the same, and the greatest proportion of variance explained was for sickness absence.

- Lumbar biomechanics (limited variety of lumbar movement-in-sitting) dominated clinical and occupational psychosocial factors in their prediction of future (persistent) LBP. Within the confines of this study, only a small amount of the variance in future LBP was explained.

- Regarding prediction of future sickness absence, in a multivariable model work-relevant low back discomfort, physical-aggravating factors and psychological demand explained a small to moderate amount of the variance in outcome. Thus, clinical and occupational psychosocial factors (also controlling for demographics) had limited ability to predict absence.

- Several obstacles to return to work (sickness absence >7 days) were identified; discomfort whilst sitting at work and a history of absence due to LBP in the past 12-months were the most influential, having a weak to moderate effect in a multivariable model.

FUTURE RESEARCH

Partly due to a lack of technology, biomechanical factors in sedentary jobs have not been precisely measured. Validation of the FOG system has opened up this area for investigation. Thus, this study incorporated biomechanical data within multivariable models that included a range of other types of data, to predict future LBP and sickness absence. Future research should address the limitations of this study, again within an overarching conceptual framework (to control for potential confounding variables). This is necessary to determine if the results from this present study can be replicated amongst a different (call centre) sample, and to develop and validate more powerful predictive models. The results might enable modifiable risk factors to be targeted for intervention.

One of the main limitations to this study was its sample size and short follow-up, which limited prediction of prospective outcomes. Therefore, a larger-scale study of sedentary work environments should take now place, incorporating an 18-month follow-up period. Since many of the variables measured in this present study were not associated with LBP or sickness absence (after controlling for other factors), perhaps future research should consider only incorporating factors that were shown to be significant, or have a wider theoretical importance to justify their inclusion. This should create space for a range of socio-economic factors to be measured.

Considerable work is required to better understand the influence of leisure-time activities and lumbar movement characteristics on LBP and sickness absence. This is important to ensure that models of occupational risk (for LBP and absence) are not confounded. Ideally, the FOG system should be further developed to make detection of lying down more sensitive, perhaps by the inclusion of a mercury gyroscope.

Researchers have identified many obstacles to return-to-work, and there is a growing body of literature about which factors are most influential. However, the literature might be considered imprecise, in that obstacles (and their relative influences) might vary between different jobs. In particular, sedentary workers remain an under researched occupational group. Future research should measure a battery of different types of factors at repeated intervals over time, in order to: (1) identify modifiable obstacles to return-to-work; (2) determine when focused interventions may be most effective. There is also a need to determine if interventions can achieve risk factor reduction, and whether or not these can reduce return-to-work times.

Whilst large scale investigations are worthwhile, more focused randomised controlled trials might help to answer specific questions about work: (1) Can maintaining a lordotic sitting posture reduce discomfort whilst sitting? (2) To what extent can lumbar movement reduce discomfort whilst sitting? The small size of the FOG sensor makes it an ideal tool to objectively investigate such questions. This could help to establish if ergonomic interventions have a role to play in managing back symptoms at work.

At present, biomechanical models are perhaps quite distanced from real life sitting conditions. Using the lumbar movement characteristics of sedentary workers, more realistic biomechanical models could be developed. This might help to elucidate the mechanisms by which sitting may contribute to the development of LBP.

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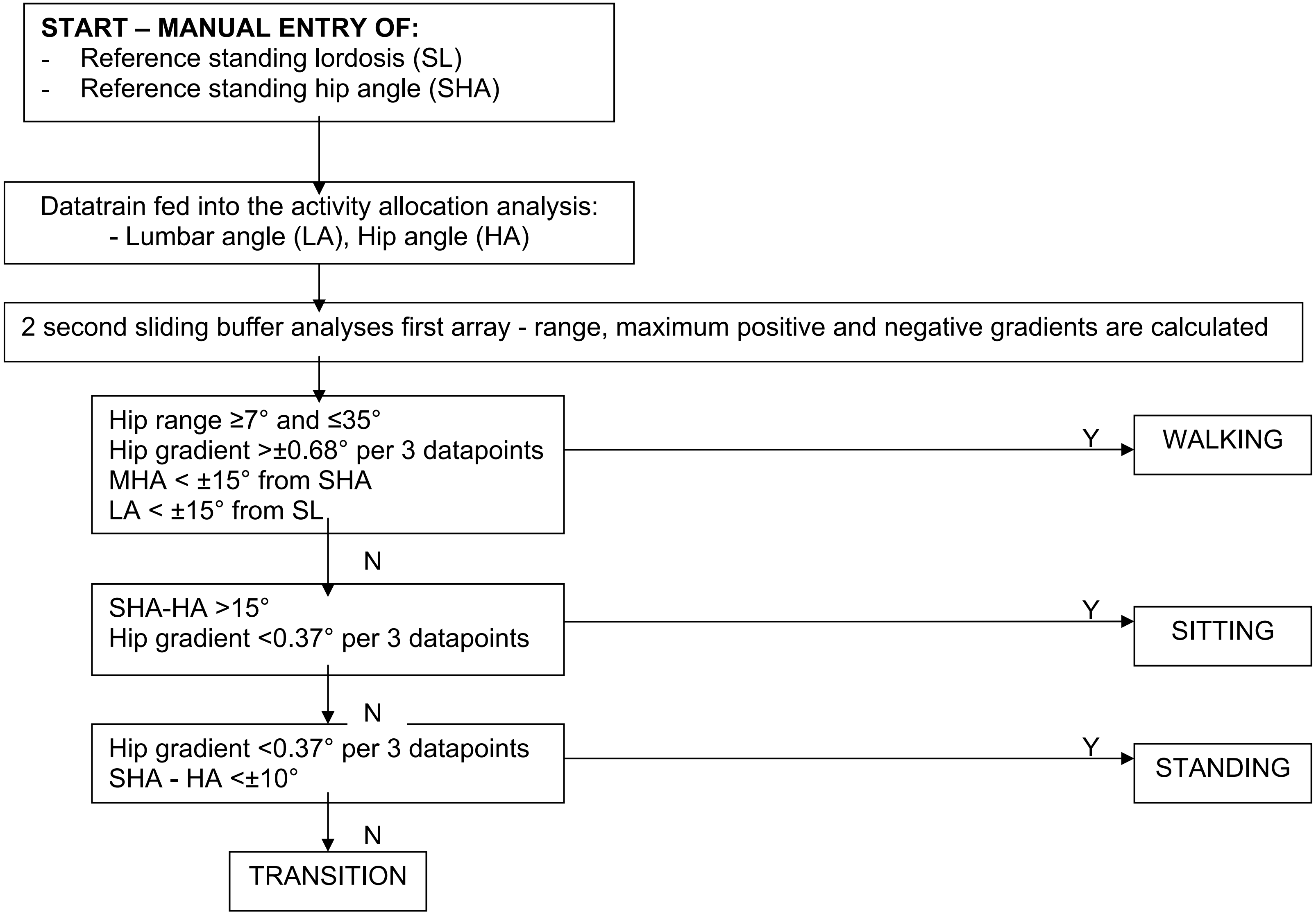
APPENDICES

APPENDIX 1:

Prototype analytical algorithm for activity detection


START – MANUAL ENTRY OF:
- Reference standing lordosis (SL)
- Reference standing hip angle (SHA)
Datatrain fed into the activity allocation analysis:
- Lumbar angle (LA), Hip angle (HA)
2 second sliding buffer analyses first array - range, maximum positive and negative gradients are calculated
Hip range ≥7° and ≤35°
Hip gradient >±0.68° per 3 datapoints
MHA < ±15° from SHA
LA < ±15° from SL
Y
WALKING
N
SHA-HA >15°
Hip gradient <0.37° per 3 datapoints
Y
SITTING
N
Hip gradient <0.37° per 3 datapoints
SHA - HA <±10°
Y
STANDING
N
TRANSITION

APPENDIX 2:

Calculations used to establish the validity of the Interrogator software

The following values and notations were used to determine validity (class 'c' relates to standing, sitting or walking):

$A_c(s)$:	Total time that the Observer and Interrogator agree about class 'c' at the same second.
$Tv_c(s)$:	Total time that class 'c' occurred according to the Observer.
$Ti_c(s)$:	Total time that class 'c' occurred according to the Interrogator.
$Tvo_c(s)$:	Total time that all classes occurred according to the Observer.
$Tio_c(s)$:	Total time that all classes occurred according to the Interrogator.
$Ao_c(s)$:	Total time that the Observer and Interrogator software agree about all classes at the same second.

Class sensitivity (based on the Observer record):

$$\text{S min (minimum sensitivity)} = \frac{A_c(s)}{Tv_c(s)} \qquad (1)$$

Class predictive value (based on the Interrogator record):

$$\text{P min (minimum predictive value)} = \frac{A_c(s)}{Ti_c(s)} \qquad (3)$$

Overall sensitivity (Based on the Observer record):

$$\text{S min}_o \text{ (minimum sensitivity overall)} = \frac{Ao_c(s)}{Tvo_c(s)} \qquad (4)$$

Overall predictive value (Based on the Interrogator record):

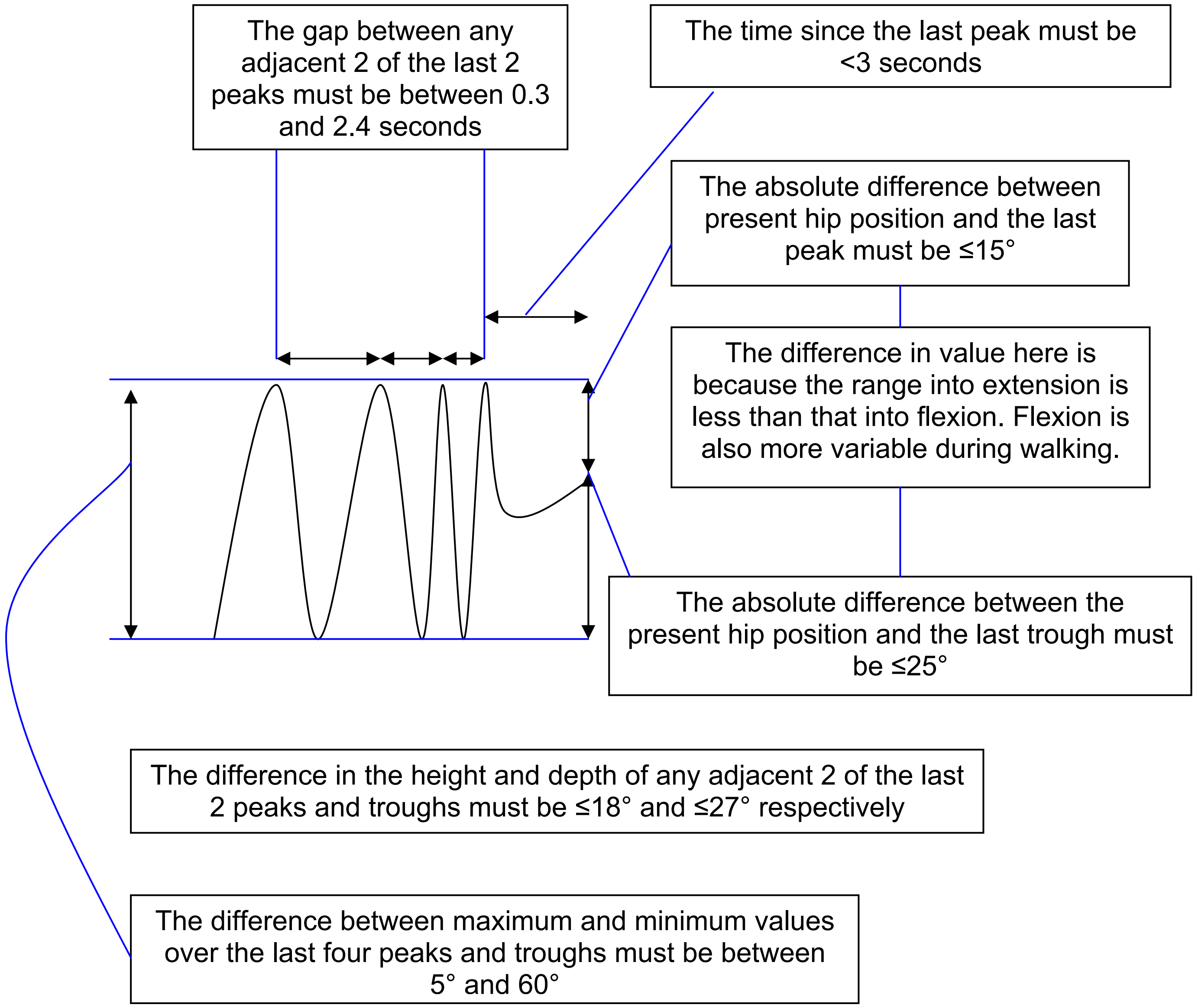
$$\text{P min}_o \text{ (minimum predictive value overall)} = \frac{Ao_c(s)}{Tio_c(s):} \qquad (5)$$

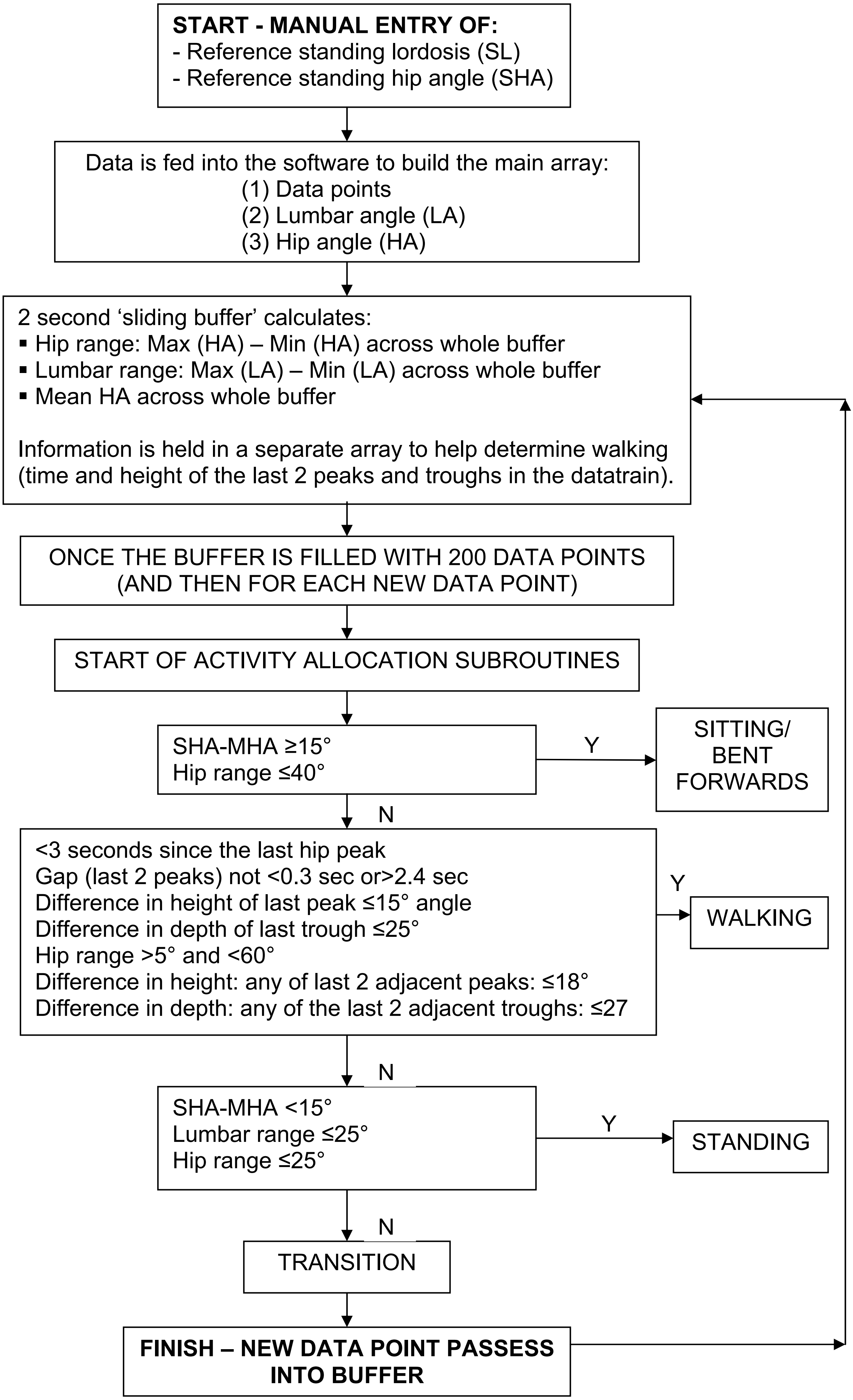
APPENDIX 3:

a. Diagrammatic representation of walking

b. *Improved algorithm for activity detection*

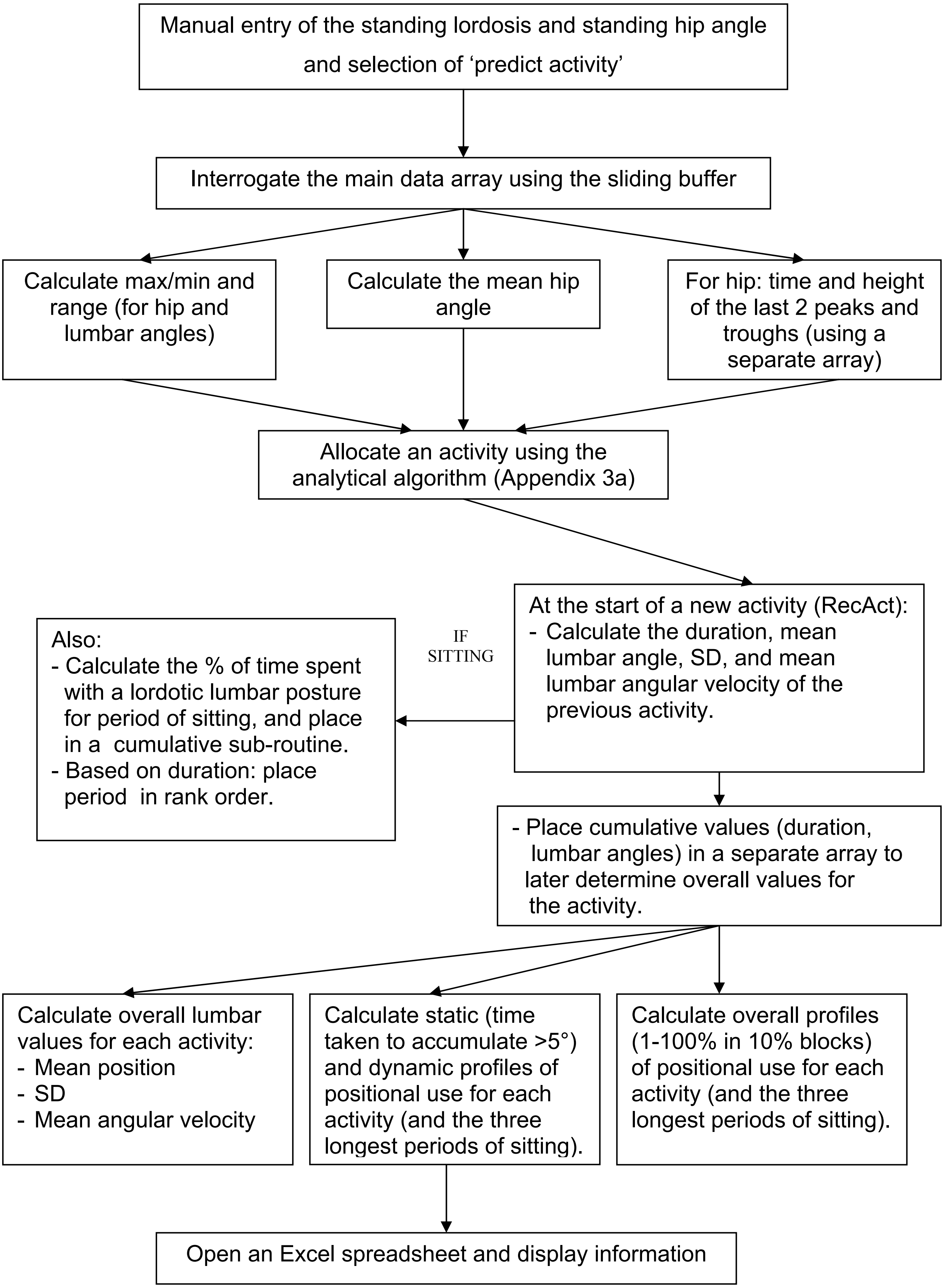
Diagrammatic representation of walking




START - MANUAL ENTRY OF:
- Reference standing lordosis (SL)
- Reference standing hip angle (SHA)
Data is fed into the software to build the main array:
(1) Data points
(2) Lumbar angle (LA)
(3) Hip angle (HA)
2 second ‘sliding buffer’ calculates:
▪ Hip range: Max (HA) – Min (HA) across whole buffer
▪ Lumbar range: Max (LA) – Min (LA) across whole buffer
▪ Mean HA across whole buffer
Information is held in a separate array to help determine walking (time and height of the last 2 peaks and troughs in the datatrain).
ONCE THE BUFFER IS FILLED WITH 200 DATA POINTS (AND THEN FOR EACH NEW DATA POINT)
START OF ACTIVITY ALLOCATION SUBROUTINES
SHA-MHA ≥15°
Hip range ≤40°
Y
SITTING/ BENT FORWARDS
N
<3 seconds since the last hip peak
Gap (last 2 peaks) not <0.3 sec or>2.4 sec
Difference in height of last peak ≤15° angle
Difference in depth of last trough ≤25°
Hip range >5° and <60°
Difference in height: any of last 2 adjacent peaks: ≤18°
Difference in depth: any of the last 2 adjacent troughs: ≤27
Y
WALKING
N
SHA-MHA <15°
Lumbar range ≤25°
Hip range ≤25°
Y
STANDING
N
TRANSITION
FINISH – NEW DATA POINT PASSESS INTO BUFFER

APPENDIX 4:

Schematic flowchart of the data analysis procedures



Manual entry of the standing lordosis and standing hip angle and selection of 'predict activity'
Interrogate the main data array using the sliding buffer
Calculate max/min and range (for hip and lumbar angles)
Calculate the mean hip angle
For hip: time and height of the last 2 peaks and troughs (using a separate array)
Allocate an activity using the analytical algorithm (Appendix 3a)
At the start of a new activity (RecAct):
- Calculate the duration, mean lumbar angle, SD, and mean lumbar angular velocity of the previous activity.
IF SITTING
Also:
- Calculate the % of time spent with a lordotic lumbar posture for period of sitting, and place in a cumulative sub-routine.
- Based on duration: place period in rank order.
- Place cumulative values (duration, lumbar angles) in a separate array to later determine overall values for the activity.
Calculate overall lumbar values for each activity:
- Mean position
- SD
- Mean angular velocity
Calculate static (time taken to accumulate >5°) and dynamic profiles of positional use for each activity (and the three longest periods of sitting).
Calculate overall profiles (1-100% in 10% blocks) of positional use for each activity (and the three longest periods of sitting).
Open an Excel spreadsheet and display information

APPENDIX 5:

a. Baseline questionnaire booklet

b. Questionnaire scoring

SPINAL RESEARCH UNIT

University of *HUDDERSFIELD*

UNDERSTANDING BACK TROUBLE

Your Chance to Help

School of Human and Health Sciences,
Queensgate, Huddersfield, HD1 3DH, UK
Telephone: 01484 472984

Research Associate: Jamie Bell, MSc
E-Mail: j.bell@hud.ac.uk

INTRODUCTION

Thank you for agreeing to help with this project. With your help we can find out why some people develop back trouble, which should lead to better treatments. Please complete this booklet of questionnaires.

Of course, your identity will **not** be put on a computer, all information is **strictly confidential** and will **only** be available to the researcher**. Your employer/manager will not see your answers.**

Some of the questions we ask may appear to be unrelated to low back pain, indeed some are not related, but these questions are needed to take a wider look at the problem of back pain.

It is very important that we know what happens to you over the next six months, so we hope you will complete further forms when they are sent to you.

Thank you once again for your kind offer of help.

Jamie Bell MSc
Research Associate
Spinal Research Unit
The University of Huddersfield
01484 472460

ID:

GENERAL INFORMATION

Please could you provide the following details, you may have to tick a box if appropriate.

1. Are you male or female? ……………

2. What is your age? ……………**years.**

3. What is your Job?

Support Staff (Civilian)	Police Staff	Civilian Supervisor	Police Supervisor
☐	☐	☐	☐

4. How long have you worked in your current job? …… **years** …… **months**

5. Did your previous job involve any manual work or heavy lifting?

Yes	No
☐	☐

6. In your previous job did you spend a lot of time sitting?

Never	Occasionally	Quite a lot	All the time
☐	☐	☐	☐

7. In a typical week, how many days do you participate in sport, exercise in a gym, or go for a walk? …………… **total days**

8. On a typical weekday how many hours do you spend sitting outside of work (watching TV, reading etc) ?

1- 2	3-4hrs	5hrs+
☐	☐	☐

YOUR EXPERIENCE OF LOW BACK DISCOMFORT

We are trying to find out about your low back discomfort at work. This may be anything from an ache, strain, unpleasant sensation or a pain.

9. Please mark on the line below the intensity of any low back discomfort you have felt while sitting at work in the PAST WEEK.

NO DISCOMFORT ____ SEVERE DISCOMFORT

10. Please tick the box that best describes how many times you have experienced low **back discomfort while sitting at work in the** PAST WEEK.

Never	Occasionally	Quite a lot	All the time
☐	☐	☐	☐

11. Thinking about TODAY please mark on the line below the intensity of any low back discomfort you have felt while sitting at work .

NO DISCOMFORT ____ SEVERE DISCOMFORT

We would now like to know to what you think about the causes of low back discomfort at work.

Please answer ALL questions and rate how important you feel each item is in causing discomfort by circling the appropriate number on the scale ranging from 1=NEVER A CAUSE to 5=ALWAYS A CAUSE.

NEVER A CAUSE ***ALWAYS A CAUSE***

1 2 3 4 5

		NEVER A CAUSE				ALWAYS A CAUSE
12	*Monotonous work*	1	2	3	4	5

13	*Rapid work pace*	1	2	3	4	5
14	Poor work posture	1	2	3	4	5
15	Poor chair	1	2	3	4	5
16	*Lack of interest from unions*	1	2	3	4	5
17	*Long working hours*	1	2	3	4	5
18	Too few breaks	1	2	3	4	5
19	*Workplace's physical environment*	1	2	3	4	5
20	Lack of work organisation	1	2	3	4	5
21	Lack of interest from company's management	1	2	3	4	5
22	Prolonged sitting	1	2	3	4	5
23	Hotdesking (e.g. sharing your chair with other people)	1	2	3	4	5

We are also interested in knowing how your low back feels, particularly when you are sat at work.

Please answer <u>ALL</u> statements and indicate whether you <u>agree</u> or <u>disagree</u> with each statement by circling the appropriate number on the scale ranging from 1=STRONGLY DISAGREE to 5=STRONGLY AGREE.

Please indicate your views <u>even if you have never had any discomfort.</u>

STRONGLY DISAGREE				STRONGLY AGREE
1	**2**	**3**	**4**	**5**

		STRONGLY DISAGREE				STRONGLY AGREE
24	Prolonged sitting makes my back feel worse	1	2	3	4	5
25	Sitting in a slumped position aggravates my back	1	2	3	4	5
26	Having to 'hotdesk' and share my chair aggravates my back	1	2	3	4	5
27	After sitting for a while standing up makes my back feel worse	1	2	3	4	5
28	Sitting at break times makes my back feel worse	1	2	3	4	5
29	Being at work aggravates my back	1	2	3	4	5
30	Sitting upright or leaning backwards when I am sat eases my back	1	2	3	4	5
31	Adjusting the position of my chair makes my back feel better	1	2	3	4	5

32	Moving around in my seat relieves my back ache	1	2	3	4	5
33	Having a break from sitting always makes my back feel better	1	2	3	4	5
34	Exercising at break times eases my back	1	2	3	4	5

WORK SITUATION

Next, this section asks questions about your general work situation.

First of all we would like to know more about how your chair is used at WORK. Please indicate how your chair is used by putting a tick in the appropriate box.

35. Do you have your own chair that only you use every day? Yes ☐ No ☐

36. Please list any postural aids that you use to ease your back pain (e.g. cushion, lumbar roll) …..………...……………………………

37. How often do you check that your chair Is adjusted for your posture? Never ☐ Occasionally ☐ Quite a lot ☐ All the time ☐

Now we would like to know what you think about your job.

Please answer ALL statements and indicate whether you agree or disagree with each statement by circling the appropriate number on the scale ranging from 1=STRONGLY DISAGREE to 5=STRONGLY AGREE.

Remember, nobody connected with work will see your answers.

STRONGLY DISAGREE ***STRONGLY AGREE***

1 2 3 4 5

		STRONGLY DISAGREE			STRONGLY AGREE
38	My job requires working very fast.	1	2	3	4
39	My job requires working very hard.	1	2	3	4
40	I am not asked to do excessive amounts of work.	1	2	3	4
41	I have enough time to get the job done.	1	2	3	4
42	I am free from conflicting demands that others make.	1	2	3	4

		STRONGLY DISAGREE				STRONGLY AGREE
43	I can turn to a fellow worker for my help when I have problems.	1	2	3	4	5

44	I like most of my fellow workers.	1 2 3 4 5
45	My fellow workers talk over things with me.	1 2 3 4 5
46	My fellow workers accept and support my new ideas.	1 2 3 4 5

Please answer the following question to indicate how satisfied you are with your job by circling the appropriate number on the scale ranging from 1=NOT AT ALL SATISFIED to 5=COMPLETELY SATISFIED.

		NOT AT ALL SATISFIED				COMPLETLEY SATISFIED
47	If you take into consideration your work routines, management, salary, promotion possibilities, and work mates, how satisfied are you with your job?'	1	2	3	4	5

PLEASE CONTINUE TO COMPLETE ALL THE QUESTIONS, WE DO APPRECIATE YOUR HELP

LIFE IN GENERAL

We should now like to know if you have had any medical complaints and how your health has been in general, over the past few weeks.

Please answer ALL the questions by underlining the answer which you think most nearly applies to you.

Remember that we want to know about your present and recent complaints, not those that you have had in the past. It is important that you try to answer ALL the questions.

HAVE YOU RECENTLY:

48-been able to concentrate on whatever you're doing?	Better than usual	Same as usual	Less than usual	Much less than usual
49-lost much sleep over worry?	Not at all	No more than usual	Rather more than usual	Much more than usual
50-felt that you are playing a	More so	Same as	Less useful	Much less

useful part in things?	than usual	usual	than usual	useful
51-felt capable of making decisions about things?	More so than usual	Same as usual	Less so than usual	Much less capable
52-felt constantly under	Not at all	No more than usual	Rather more than usual	Much more strain? than usual
53-felt you couldn't overcome difficulties?	Not at all	No more than usual	Rather more than usual	Much more your than usual
54-been able to enjoy your normal day to day activities?	More so than usual	Same as usual	Less so than usual	Much less than usual
55-been able to face up to your problems?	More so than usual	Same as usual	Less able than usual	Much less able
56-been feeling unhappy and depressed?	Not at all	No more than usual	Rather more than usual	Much more than usual
57-been losing confidence in yourself?	Not at all	No more than usual	Rather more than usual	Much more than usual
58-been thinking of yourself as a worthless person?	Not at all	No more than usual	Rather more than usual	Much more than usual
59-been feeling reasonably happy, all things considered? than usual	More so than usual	About same as usual	Less so	Much less than usual

YOUR EXPERIENCES OF MUSCULOSKELETAL DISORDERS

Musculoskeletal disorders are problems that affect muscles, ligaments and joints (e.g. sprains, strains, trapped nerves, etc) and are experienced at work and away from work; we are interested in both.

Please answer ALL these questions, even if you have never had any trouble in any parts of your body, by ticking either the 'Yes' or 'No' box.

Have you at any time during the past 12 months had trouble (ache, pain, discomfort, numbness) in:			Have you had trouble during the last 7 days:		
60. Neck	No ☐1	Yes ☐2	61. Neck	No ☐1	Yes ☐2
62. Shoulders	No ☐1	Yes ☐2 right shoulder ☐3 left shoulder ☐4 both shoulders	63. Shoulders	No ☐1	Yes ☐2 right shoulder ☐3 left shoulder ☐4 both shoulders
64. Elbows	No ☐1	Yes ☐2 right elbow ☐3 left elbow ☐4 both elbows	65. Elbows	No ☐1	Yes ☐2 right elbow ☐3 left elbow ☐4 both elbows
66. Wrist/hands	No ☐1	Yes ☐2 right wrist ☐3 left wrist ☐4 both wrists	67. Wrist/hands	No ☐1	Yes ☐2 right wrist ☐3 left wrist ☐4 both wrists
68. Upper back	No ☐1	Yes ☐2	69. Upper back	No ☐1	Yes ☐2
70. One or both hips/thighs/	No ☐1	Yes ☐2	71. Hips/thighs/	No ☐1	Yes ☐2
72. One or both knees	No ☐1	Yes ☐2	73. Knees	No ☐1	Yes ☐2
74. One or both ankles/feet	No ☐1	Yes ☐2	75. Ankles/feet	No ☐1	Yes ☐2

76	What is your most dominant hand?	Left hand ☐1	Right hand ☐2	Both (ambidextrous) ☐3

THIS NEXT SECTION IS ABOUT LOW BACK PAIN.

If you HAVE experienced low back pain lasting more than 24 hours **please complete the rest of this booklet.**

Importantly, it will help us to understand more about your back pain.

If you have NEVER experienced low back pain please GO TO THE LAST PAGE (page 13).

HISTORY OF BACK PAIN

Firstly we are interested in how back pain has affected you.

Please answer the questions and put a tick in the appropriate box.

77. Have you ever had low back pain? **Yes** ☐ **No** ☐

78. In which year did you first experience low back pain? ……………………..

79. How long did your first episode of low back pain last?

a few days	a few weeks	a few months	it never really got better
☐	☐	☐	☐

80. How many episodes of low back pain have you had?

one	a few (2-4 times)	many (more than 4 times)
☐	☐	☐

81. Have you had any low back pain in the past 12 months? **Yes** ☐ **No** ☐ → IF NO, PLEASE GO TO THE NEXT PAGE (P11)

	Yes	No
82. Have you had any sick leave in the 12 months for any reason?	☐	☐

a. If Yes: How many days were you sick …………..……… days.

b. How many days have you been sick due to low back pain? …………………… days.

83. In the last 12 months, have you consulted any of the following due to low back pain?

	Yes	No
G.P.	☐	☐
Occupational Health Practitioner	☐	☐
Osteopath/Physiotherapist/Chiropractor	☐	☐
Hospital Specialist	☐	☐

Now we are interested in the effect work activity had or still has on your back pain.

Please answer <u>ALL</u> statements and indicate whether you <u>agree</u> or <u>disagree</u> with each statement by circling the appropriate number on the scale ranging from 1=STRONGLY DISAGREE to 5=STRONGLY AGREE.

STRONGLY DISAGREE				*STRONGLY AGREE*
1	***2***	***3***	***4***	***5***

Activity and Back Pain		STRONGLY DISAGREE 1	2	3	4	STRONGLY AGREE 5
84	My pain was caused by physical activity:	1	2	3	4	5
85	Physical activity makes my pain worse:	1	2	3	4	5
86	Physical activity might harm my back:	1	2	3	4	5
87	I should not do physical activities which (might) make my back worse:	1	2	3	4	5
88	I cannot do physical activities which (might) make make my pain worse:	1	2	3	4	5

If you have NOT **had any low back pain in the** past week**, please go to the last page (page 13).**

Otherwise, please continue.

This section is to determine how much your low back has troubled you recently.

89. During the past week, how bothersome have your LBP symptoms been?

Not at all Bothersome	Slightly Bothersome	Moderately Bothersome	Very Bothersome	Extremely Bothersome

1	2	3	4	5

90. During the past week, how much did pain interfere with your normal work (including both work outside the home and housework)?

Not at All	A Little Bit	Moderately	Quite a Bit	Extremely
☐	☐	☐	☐	☐

91. During the past 4 weeks, about how many days did you cut down on the things you usually do because of low back pain?

……………..…. Number of days

Many thanks for completing the questionnaires, your help is really appreciated and will go some way to helping others.

As I said at the beginning, we need you to fill in some more (shorter) questionnaires in six months time. I hope that is okay. Thank you once again.

If you have any general comments about your low back pain, or these questionnaires, please write them here:

Jamie Bell
Research Associate

Appendix 5b: Questionnaire scoring

Low Back Discomfort Scale

Questions 9, 11. Scored as single items with a score anywhere from 0-100 each (score measured in mm).

Sedentary Work Causal Attributions Questionnaire (SWATTRIB)

WENV - Questions 12, 13, 17, 18, 19.

PDEM – Questions 14, 15, 22, 23.

WORG – Questions 16, 20, 21.

Each item consists of a 5 point Likert scale and scores are summed to give a total score for that sub scale.

Sitting and Symptom Modifying Factors Questionnaire (SSMQ)

PHYAGG – Questions 24, 25, 26, 27, 28, 29.

POSREL – Questions 30, 31.

MOVREL – Questions 32, 33, 34.

Each item consists of a 5 point Likert scale and scores are summed to give a total score for that sub scale.

Psychological Demands Questionnaire (PDQ)

Questions 38-42. Scale score is established by [(Q38+Q39)x3 + 2x(Q40+Q41+Q42)].

Social Support Questionnaire (SSQ)

Questions 43-46.

Each item consists of a 5 point Likert scale and scores are summed to give a total score for the scale.

Job Satisfaction Questionnaire (JSQ)

Question 47. Scored as a single item anywhere from 1-5.

General Health Questionnaire (GHQ)

Questions 48-59. Each item consists of a 4 point Likert scale ranging from 0-3. Scores are then summed to give an overall score.

The Nordic Musculoskeletal Questionnaire (NMQ)

Questions 60-75 comprised yes/no responses.

Fear Avoidance Beliefs Questionnaire – Physical Activity (FAB-phys)

Questions 85-88. Each item consists of a 5 point Likert scale and scores are summed to give a total score for the scale.

Any remaining questions were used for descriptive purposes only.

APPENDIX 6:

Follow-up questionnaire booklet

INTRODUCTION

Thank you for continuing to help with this project. As you know we are trying to find out why some people develop back trouble, which should lead to better treatments. Please complete this booklet of questionnaires.

Your identity will **not** be put on a computer, all information is **strictly confidential** and will **only** be available to the researcher**.**

Your employer will not see your answers.

Some of the questions we ask may appear to be similar to those you answered 6 months ago, indeed some are, but these questions are needed to improve our understanding of the course of back pain.

Thank you once again for your support and help.

Jamie Bell MSc
Research Associate
Spinal Research Unit
The University of Huddersfield
01484 472460

GENERAL INFORMATION

Please could you provide the following details, you may have to tick a box if appropriate.

	No (Unaltered)	Yes (Increased)	Yes (Decreased)
1. In the past 6 months have the total number of hours you work in a typical week changed?	☐	☐	☐

a. If Yes: How many hours do you now work in a typical week? …………… **total hours**

2. In a typical week, how many days do you participate in sport, exercise in a gym, or go for a walk? …………… **total days**

	1-2hrs	3-4hrs	5hrs+
3. On a typical weekday how many hours do you spend sitting outside of work (watching TV, reading etc)?	☐	☐	☐

YOUR EXPERIENCE OF LOW BACK DISCOMFORT

We are trying to find out about your low back discomfort at work. This may be anything from an ache, strain, unpleasant sensation or a pain.

4. Please mark on the line below the intensity of any low back discomfort you have felt while sitting at work in the PAST WEEK.

NO DISCOMFORT ____ SEVERE DISCOMFORT

5. Please tick the box that best describes how many times you have experienced back discomfort while sat at work in the PAST week.

Never	Occasionally	Quite a lot	All the time
☐	☐	☐	☐

6. Thinking about <u>TODAY</u> please mark on the line below the intensity of any low back discomfort you have felt while sitting at work.

NO DISCOMFORT ____ SEVERE DISCOMFORT

THIS NEXT SECTION IS ABOUT LOW BACK PAIN LASTING MORE THAN 24 HOURS.

If you HAVE **experienced low back pain lasting** more than 24 hours **in the past 6 MONTHS (i.e. since completing the last booklet of questionnaires) please complete the rest of this booklet.**

If this is not you, please GO TO PAGE 6

HISTORY OF LOW BACK PAIN

Firstly we are interested in how low back pain has affected you.

Please answer the questions and put a tick in the appropriate box.

	Yes	No
7. Have you had any low back pain? n the past 6 months?	☐	☐

8. When did that low back pain start? …………………… **month.**

	a few days	a few weeks	a few months	it never really got better
9. How long did that episode of low back pain last?	☐	☐	☐	☐

	At work	At home	Made no difference
10. When was your back pain worse?	☐	☐	☐

	Yes	No
11. Have you had any sick leave in the past 6 months for any reason?	☐	☐

a. If Yes: How many days were you sick ……………..……… days.

b. How many days have you been sick due to low back pain in the past 6 months? …………………… **days.**

12. Have you seen you doctor or any other

health professional for low back pain
in the past 6 months? **Yes** ☐ **No** ☐

PLEASE CONTINUE

Now we are interested in the effect of activity on your low back pain.

Please answer <u>ALL</u> statements and indicate whether you <u>agree</u> or <u>disagree</u> with each statement by circling the appropriate number on the scale ranging from 1=STRONGLY DISAGRE to 5=STRONGLY AGREE.

STRONGLY DISAGREE				***STRONGLY AGREE***
1	***2***	***3***	***4***	***5***

Activity and Back Pain

		STRONGLY DISAGREE				STRONGLY AGREE
13	My pain was caused by physical activity:	1	2	3	4	5
14	Physical activity makes my pain worse:	1	2	3	4	5
15	Physical activity might harm my back:	1	2	3	4	5
16	I should not do physical activities which (might) make my back worse:	1	2	3	4	5
17	I cannot do physical activities which (might) make make my pain worse:	1	2	3	4	5

Many thanks for completing the questionnaires, your help is really appreciated and will go some way to helping others.

If you have any general comments about your low back pain, or these questionnaires, please write them here:

Jamie Bell
Research Associate

APPENDIX 7:

a. Study invitation letter

b. Details of the proposed investigation

Jamie Bell
Research Associate
Spinal Research Unit
The University of Huddersfield
Queensgate, Huddersfield
HD1 3DH
Tel: 01484 472984
E-Mail: j.bell@hud.ac.uk

Dear Sir/Madam,

Re: Research project investigating low back pain and related sickness absence

Following our telephone conversation please find enclosed two documents. The first provides a brief outline of the proposed investigation and the benefits to your employee's, company and the wider community. The second document provides information on the insurance cover provided by the University of Huddersfield .

The research forms part of my PhD and is fully funded by the University of Huddersfield, who have also provided ethical approval for the project to take place. I am sure that the project would not disrupt normal working patterns to any significant degree, and could benefit all those involved.

Thank you for your interest to date. Please do not hesitate to contact me should you wish to discuss any aspect of the research project in further detail. I would also be pleased to attend any meetings necessary, at your convenience, in order to establish the project and get the research underway.

I look forward to hearing from you.

Yours Sincerely,

Jamie Bell MSc
Research Associate

The Proposed Investigation

Title

Low back pain and absence in sedentary workers: The influence of lumbar sagittal movement characteristics and psychosocial factors

Background to The Spinal Research Unit

The Spinal Research Unit at the University of Huddersfield has an excellent international reputation for research into work-related musculoskeletal disorders. The Unit's work is supported by a number of bodies including the Health and Safety Executive and the NHS, and results are regularly published in scientific journals, reports, and books. Recently, work has been conducted with the Association of British Motor Insurers to reduce cost following whiplash injury.

Aim

To conduct a large-scale investigation of spinal posture, individual factors and low back pain in call handlers.

Rationale for the Investigation

Traditionally, some organisations are known to suffer a high turnover of staff plus a high rate of sickness and non-attendance. This has been attributed to stress, but may not be strictly due to work related factors. In their advice to call handlers The Health & Safety Executive have highlighted that stress can also lead to ill health and physical problems such as back pain, as it does in other industries. Conversely, back pain is known to be multifactorial in origin, and may lead to feelings of stress. The interactions and combined effect of these factors needs to be established.

It is also yet to be determined whether absence attributed to back pain is related to poor posture or other factors. The consequences of this may not only relate to increased absence, but reduced staff morale and performance, and increased turnover.

The Research

The research team has carefully developed the study design to provide answers to scientific questions about absence, stress and posture, and also to provide useful information to the employer. The proposed project will comprise 3 phases: **(1)** a questionnaire based survey, **(2)** measurement of posture, and **(3)** a follow-up questionnaire survey.

The survey will initially entail workers completing some questionnaires, perhaps during their break. The measurement of posture will require the researcher to spend no more than a few minutes with each worker. A miniaturised movement-recording device will be stuck in place on the lower back and hip; the instrument is not uncomfortable, is unobstrusive, and will not affect the normal pattern of work. The follow-up questionnaire will be administered after 6 months. Ideally, several hundred call centre workers are required.

Members of Staff Involved In The Work

Main Researcher: Jamie Bell MSc.
Professor Kim Burton PhD (Director, Spinal Research Unit).
Dr. Mark Stigant PhD (Senior Physiotherapy Lecturer)

Expected Benefits

This research project is innovative and ambitious, but with the help of the industry is perfectly feasible. The results will answer scientific and medical questions of interest to employers, employees and HSE.

Traditionally some organisations have received criticism for their working practices, and may have problems retaining staff, with high absence rates, stress and back pain often being cited as the cause. However, call handlers are known to have the same level of stress as other industries. The HSE has offered some guidance on posture, but recognises the need for more information. By collaborating in this research and becoming an active partner, you would be contributing to the evidence-base for future guidance on worker training and work organisation.

We anticipate that our industrial partners will gain more immediate benefit from an understanding of how posture, and musculoskeletal symptoms are related; simple workplace attention to these factors may help improve productivity and staff retention. Potentially, this could lead to a significant cost saving. However, the project may simply justify current health and safety practice and demonstrate that factors outside of the workplace are perhaps the major cause of absence.

The research team presents itself as ‘politically neutral’ when conducting this sort of project. This enables workers and their Union representatives to appreciate that the employer is concerned, and is actively contributing to improving the health and welfare of employees. On completion, if agreed, publication of the results in a scientific journal will provide collaborators with the opportunity to associate themselves with the research, although anonymity could be provided if necessary. The wishes of management would be respected at all times.

APPENDIX 8:

a. Study information sheet

b. Subject consent form

Low Back Pain and Absence in Sedentary Workers: The Influence of Lumbar Sagittal Movement Characteristics and Psychosocial Factors

Jamie Bell, Research Associate (Spinal Research Unit) at The University of Huddersfield, will be the Principal Investigator on this project.
University of Huddersfield – Jamie Bell 01484 472984 (direct line),
E-mail: J.Bell@hud.ac.uk

INFORMATION SHEET

You are being invited to take part in a research study. Before you decide if you would like to be included it is important that you understand why the research is being done and what it will involve. Please take time to read the following information carefully to decide whether or not you wish to take part. If anything is not clear to you or you would like more information please contact Jamie Bell.

The research is investigating how sitting posture and psychosocial factors influence low back pain and sickness absence. As part of the study we would like to measure how you sit by attaching a small posture measuring device to your low back and hip while you are at work, and ideally we would also like you to wear this for a twenty-four hour period at home. Attaching this device would not require you to undress, but would require the researcher to gain access to the side of your hip and low back. The device is comfortable to wear and sticks onto the skin, connecting to a small box that can be fitted to your belt or placed in a pocket. You will also be asked to fill in some questionnaires at the start of the study, and then again after 6 months. This information is strictly confidential, and will only be seen by the researcher.

If you agree to take part, the important information you provide may help people with back pain. Taking part will initially involve spending no more than 25 minutes at a meeting with the researcher at your place of work, where you will be asked to sign a consent form, have the device attached, and be given some questionnaires to complete. If you decide to take part you are still free to withdraw at any time without giving a reason. Please tick one of the boxes below to indicate if you would like to participate, please also write your name.

No, I do not want to participate ☐

Yes, I would like to participate ☐

Name (BLOCK CAPITALS) …………….……………….

NB: The information sheet was modified for distribution to JCP (details of the measuring device, i.e. FOG were excluded)

Low Back Pain and Sickness Absence in Sedentary Workers: The Influence of Lumbar Sagittal Movement Characteristics and Psychosocial Factors

Jamie Bell, Research Associate (Spinal Research Unit) at The University of Huddersfield will be the Principal Investigator on this study.
University of Huddersfield – Jamie Bell 01484 472984 (direct line)
E-mail: J.Bell@hud.ac.uk

CONSENT FORM

Please Tick

1. I confirm that I have read the information sheet, understand what the study is about and how I will be involved. ❑

2. I confirm that I have had the opportunity to ask questions and discuss the study. ❑

3. I understand that all the information collected in the study will be kept secure in a locked filing cabinet at The University of Huddersfield, will only be seen by the researcher, and that all my personal details will remain confidential. ❑

4. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason, without my legal rights being affected. ❑

5. I agree that the researcher can gain access to my sickness records for the purposes of this study. ❑

6. I am aware that I should inform the researcher if I have sensitive skin (or any skin complaint), before any posture measuring device is attached, and that occasionally the skin may remain dry for 48 hours after wearing the device. ❑

7. I understand that I can remove the posture measuring device if it becomes uncomfortable, and that removing the device will feel similar to removing a plaster from the skin. ❑
8. I agree to take part in the study. ❑

___________________________	__________________	____________
Name of Participant	Date	Signature
___________________________	__________________	____________
Name of Researcher taking consent	Date	Signature

1 for participant; 1 for researcher;

Appendix 9:

Confirmatory principal components analysis (a) and internal consistency (b) of the Sedentary Work Causal Attributions Questionnaire

9a: Results of confirmatory principal components analysis of the Sedentary Work Causal Attributions Questionnaire (n=367)

Variance explained by principal components

	Initial Eigenvalues		Extraction: Squared Loadings	
	% of Variance	Cumulative %	% of Variance	Cumulative %
1	39.3	39.3	39.3	39.3
2	11.9	51.3	11.9	51.3
3	8.7	60.1	8.7	60.1

Rotated (varimax) principal components analysis

Item	**Component**		
	1	**2**	**3**
Monotonous Work	.833		
Rapid Work	.726		
Long Hours	.726		
Too Few Breaks	.600		
Workplace Environment	.433	.423	
Poor Posture		.843	
Poor Chair		.752	
Hotdesking		.706	
Prolonged Sitting	.810		
Lack of Organisation			.637
Lack of Interest from Management			.567
Lack of Union Interest			.468

[Work environment sub-scale] [Physical demands sub-scale] [[Work organisation sub-scale]

9b: Internal consistency of each sub-scale

Sub-scale	**No. of items**	**Cronbach's Alpha**
Work environment (WENV)	5	.772
Physical demands at work (PDEM)	4	.710
Work organisation (WORG)	3	.755

Appendix 10:

Confirmatory principal components analysis (a) and internal consistency (b) of the Sitting and Symptom Modifying Factors Questionnaire

10a: Results of confirmatory principal components analysis of the Sitting and Symptom Modifying Factors Questionnaire (n=367)

Variance explained by principal components

	Initial Eigenvalues		Extraction Sums of Squared Loadings	
	% of Variance	Cumulative %	% of Variance	Cumulative %
1	33.8	33.8	33.8	33.8
2	13.9	47.7	13.9	47.7
3	9.5	57.3	9.5	57.3

Rotated (varimax) principal components analysis

	Component		
	1	2	3
Prolonged sitting makes my back feel worse	.704		
Slumped in a slumped position aggravates my back	.679		
Having to hotdesk and share my chair aggravates my back	.677		
After sitting for a while standing up makes my back feel worse	.674		
Sitting at break times makes my back feel worse	.628		
Being at work aggravates my back	.516		
Sitting upright when I am sat eases my back		.785	
Adjusting the position of my chair makes my back feel better		.760	
Moving around in my seat relieves my back ache		.657	.336
Having a break from sitting makes my back feel better			.816
Exercising at break times eases my back			.760

[Physical-aggravating sub-scale] [Posture-relieving sub-scale] [Movement-relieving sub-scale]

10b: Internal consistency of each sub-scale

Sub-scale	No. of items	Cronbach's Alpha
Physical-aggravating (PHYAGG)	5	.704
Posture-relieving (POSREL)	4	.660
Movement-relieving (MOVREL)	3	.680

Appendix 11:

Results from the main study

a. Mean symptom modifying scores and LBP

b. Association between demographics and discomfort prevalence

c. Association between psychosocial factors and discomfort scores

d. Association between mean symptom modifying factor scores and discomfort

e. Association between symptom modifying factors and discomfort frequency

11a: Mean symptom modifying scores and standard deviations (SD) for self-reported LBP histories

SSMQ sub-scale	No history n=230	LBP (but not in the past 12-months) n=43	LBP (in past 12-months, but not the past week) n=94	LBP (in the past week) n=233
Physical-aggravating factors (6-30)	16.6 (4.90)	15.8 (4.62)	18.5* (4.45)	19.6* (4.22)
Posture-relieving factors (2-10)	7.44 (1.90)	6.97 (2.30)	7.57 (1.62)	7.48 (1.74)
Movement-relieving factors (3-15)	10.0 (2.80)	9.40 (3.02)	10.40 (2.37)	10.4 (2.38)

[Statistically significant difference from no history and LBP (not in the past 12-months) groups, at the 5% level]*

11b: Associations between demographic factors and discomfort prevalence

Demographic factors		Low back discomfort whilst sitting at work 'today'	
		Yes (n=323)	No (n=261)
Sex	Male	40.6% (131)	39.1% (102)
	Female	59.4% (192)	60.9% (159)
Job tenure	≤2 years	44.9% (145)	41.0% (107)
	>2 years	55.1% (178)	59% (154)
Age	≥38 years	50.5% (143)	49.5% (140)
	<38 years	59.7% (176)*	40.3% (119)

[statistically significant difference from the 'older' group (5% level)]*

11c Bivariate association between psychosocial factors and discomfort scores

	dis	worg	wenv	pdem	support	Jobsat	demscore	ghscore	fabscore	func	disability
dis	1.000	.137**	.186**	.089*	-.045	-.151**	.010	.230**	.173**	.509**	.305**
worg	.137**	1.000	.585**	.381**	-.113**	-.125**	.095*	.099*	.120*	.056	-.006
wenv	.186**	.585**	1.000	.564**	-.016	-.181**	.178**	.134**	.164**	.058	.112
pdem	.089*	.381**	.564**	1.000	-.015	-.050	.039	.032	.116*	-.032	.076
support	-.045	-.113**	-.016	-.015	1.000	.184**	-.166**	-.187**	-.086	-.071	-.084
jobsat	-.151**	-.125**	-.181**	-.050	.184**	1.000	-.076	-.336**	.035	-.071	.016
demscore	.010	.095*	.178**	.039	-.166**	-.076	1.000	.149**	.044	-.045	.020
ghscore	.230**	.099*	.134**	.032	-.187**	-.336**	.149**	1.000	.084	.157**	.212**
fabscore	.173*	.120*	.164**	.116*	-.086	.035	.044	.084	1.000	.202**	.369**
function	.509**	.056	.058	-.032	-.071	-.071	-.045	.157**	.202**	1.000	.546**
disability	.305**	-.006	.112	.076	-.084	.016	.020	.212**	.369**	.546**	1.000

[Correlation coefficient: Spearman's Rho]
[statistically significant association at the 5% level, ** at the 1% level) [Sample N=600]*

11d: Mean symptom modifying factor scores and standard deviations (SD) for workers who did and did not report discomfort in the 'past week' and 'today'

	Low back discomfort whilst sitting (past week):	Mean	SD
Physical-aggravating factors	Yes (n=409)	19.21**	4.15
	No (n=191)	15.34	4.91
Posture-relieving factors	Yes (n=409)	7.56*	1.67
	No (n=191)	7.40	2.12
Movement-relieving factors	Yes (n=409)	10.55**	2.38
	No (n=191)	9.59	2.92

*[** statistically significant difference from the 'no' group, (1% level)]*

	Low back discomfort whilst sitting (today):	Mean	SD
Physical-aggravating factors	Yes (n=323)	19.82**	4.15
	No (n=277)	15.95	4.91
Posture-relieving factors	Yes (n=323)	7.52	1.67
	No (n=277)	7.36	2.12
Movement-relieving factors	Yes (n=323)	10.74**	2.38
	No (n=277)	9.70	2.92

*[** statistically significant difference from the 'no' group, (1% level)]*

11e: ***Association between symptom modifying factors and discomfort frequencies (yes/no), expressed as ORs with 95% confidence intervals (CI)***

SSMQ Sub-scales	Frequency of low back discomfort (past week)			
	never n=229	occasionally n=85	quite a lot n=36	All the time n=170
PHYAGG	0.81* (0.7-0.8)	1.05* (1.01-1.09)	1.18* (1.1-1.2)	1.3* (1.1-1.4)
MOVREL	0.86* (0.8-0.9)	1.1* (1.04-1.2)	1.03* (0.9-1.1)	1.1 (0.9-1.3)
POSREL	0.91 (0.8-1.0)	1.1* (1.02-1.31)	0.97 (0.86-1.1)	1.02 (0.83-1.2)

[ORs statistically significant, (5% level)]*

Appendix 12:

a. Mean (baseline) psychosocial and SMF scores between respondents and non-respondents at follow-up

b. Univariate associations between baseline data and future incident LBP

a. Mean psychosocial and symptom modifying factor scores (SD) between respondents and non-respondents at follow-up

Symptom modifying factors:	***Respondents (n=367)***	***Non-respondents (n=233)***
Discomfort whilst sitting 'today' (0-100) †	14.7 (21.4)	16.8 (23.0)
Physical-aggravating (6-30) †	18.0 (4.68)	18.0 (4.91)
Movement-relieving (3-15) †	10.2 (2.65)	10.1 (2.52)
Posture-relieving (2-10) †	7.6 (1.72)	7.1 (1.97)
Clinical psychosocial factors:		
Psychological distress (0-36)	11.7 (4.88)	13.1 (6.33)*
Fear avoidance beliefs (4-25)	11.4 (4.22)	11.2 (4.43)
Occupational psychosocial factors:		
Work organisation (3-15)	6.2 (2.68)	6.0 (2.48)
Work environment (5-25)	14.5 (4.31)	14.1 (4.39)
Physical demands at work (4-20)	15.1 (3.39)	14.7 (3.88)
Job satisfaction (1-5)	3.30 (1.01)	3.02 (1.04)
Psychological demand (12-48)	35.4 (4.93)	35.0 (5.06)
Social support (5-20)	16.2 (3.04)	16.4 (2.69)

*P<0.05

b. Univariate associations with incident LBP (yes/no)

Baseline variables (range)	Incident LBP [a]		Crude OR 95% (CI)	R^2%
	Yes	No		
Lumbar movement characteristics: [b]	***n=5***	***n=135***		
% of sitting time lordotic (0-100)	10.1 (88.5)	24.7 (26.1)	1.01 (0.97-1.02)	0.1%
% of sitting time ≥ 80% ROM (0-99)	22.2 (32.6) [m]	21.6 (40.5) [m]	0.99 (0.96-1.03)	0.1%
% of sitting time ≤ 40% ROM (0-58)	2.43 (6.49) [m]	1.08 (1.07) [m]	0.99 (0.91-1.08)	0.1%
Angular velocity °sec^{-1} (1-12)	3.23 (1.83) [m]	3.03 (2.07) [m]	0.82 (0.48-1.38)	2%
Variation – SD° (2-25)	10.5 (6.71)	8.31 (4.1)	1.09 (0.93-1.29)	0.3%
Symptoms:	***n=20***	***n=347***		
Discomfort whilst sitting 'today' (0-100) [ǂ]	11.5 (21.3)	14.9 (21.4)	0.99 (0.96-1.01)	0.4%
MSK symptoms:[c] **≥2 regions**	25% (5)	32.2% (112)	0.69 (0.24-1.97)	0.4%
Clinical psychosocial factors:	***n=20***	***n=347***		
Psychological distress (0-36)	10.6 (4.24)	11.7 (4.92)	0.95 (0.85-1.05)	0.8%
Occupational psychosocial factors:	***n=20***	***n=347***		
Work organisation (3-15)	5.7 (2.60)	6.2 (2.69)	0.92 (0.76-1.10)	0.8%
Work environment (5-25)	13.8 (4.01)	14.5 (4.33)	0.96 (0.86-1.06)	0.4%
Physical demands at work (4-20)	15.3 (3.25)	15.1 (3.40)	1.02 (0.89-1.17)	0.1%
Job satisfaction (1-5)	3.05 (0.97)	3.31 (1.01)	0.78 (0.50-1.21)	0.1%
Psychological demand (12-48)	35.9 (5.92)	35.2 (4.97)	1.02 (0.93-1.13)	0.3%
Social support (5-20)	16.6 (3.32)	16.2 (3.02)	1.05 (0.89-1.23)	0.3%
Demographic factors	***n=20***	***n=347***		
Age (<38 yrs, ≥38 yrs)	60% (12)	48.9% (170)	0.57 (0.22-1.50)	1%
Job tenure (<3 years, ≥3 years)	40% (8)	50.4% (175)	0.65 (0.26-1.64)	0.7%

[Unless stated variables expressed as mean scores, with standard deviations (SD) for 'yes' and 'no' groups]
[[m] = median and interquartile range (IR)]
[[a] all workers reported no previous history of LBP]
[[b] measured during the 3 longest periods of sitting]
[[c] not including LBP, reported in the past 7-days]
[ǂ work-relevant factor]
[* ORs statistically significant at the 5% level, ** at the 1% level]
[R^2 = proportion of variance in LBP explained]

Appendix 13:

Reliability analysis of the self-reported absence data

a. Absence occurrence

b. Absence extent

13a: Cross-tabulated self-reported and company recorded absence data, expressed for the occurrence of absence

		Company recorded absence	
		Yes	**No**
Self-reported absence	**Yes**	9	1
	No	3	292

[Cohen's Kappa = 0.81)
[Sensitivity = 75% (9/12x100)]
[Specificity = 99.6% (292/293x100]

13b: Cross-tabulated self-reported and company recorded absence data, expressed for the extent (>7 days) of absence

		Company recorded absence	
		Yes	**No**
Self-reported absence	**Yes**	3	0
	No	1	301

[Cohen's Kappa = 0.78)
[Sensitivity = 75% (3/4x100)]
[Specificity = 100%]

PUBLICATIONS RELATED TO THIS THESIS

The following peer reviewed papers and conference abstracts have resulted from this work:

Papers:

Bell, J., Stigant, M. (2008). Validation of a fibre-optic goniometer system to investigate the relationship between sedentary work and low back pain. *International Journal of Industrial Ergonomics* **38**(1): 934-941

Bell J., Stigant M. (2007). Development of a fibre-optic goniometer system to measure lumbar and hip movement to identify activities and their lumbar postures. *Journal of Medical Engineering and Technology* **31**(5):361-366

Conference abstracts:

Bell J., Burton, A. K., Stigant M. (2008). *Sitting postures at work are associated with current and future LBP*. Britspine: podium presentation, 30th April. Belfast, Northern Ireland.

Bell J., Burton, A. K., Stigant M. (2007). *Prediction of absence among sedentary workers using beliefs and symptom modifying factors*. Society for Back Pain Research: poster presentation, 28th June. Helsinki, Finland.

Bell J., Burton, A. K., Stigant M. (2007). *Are causal beliefs about sedentary work associated with low back pain?* International Society for the Study of the Lumbar Spine: poster presentation, 12th June. Hong Kong, China.

Bell, J., Burton, A. K., Stigant, M. (2006). *Development and validation of the sitting and symptom modifying factors questionnaire*. Society for Back Pain Research: poster presentation, 4th November. Guisborough, UK.

Bell, J., Burton, A. K., Stigant, M. (2006). *Development and validation of the low back discomfort scale for use in sedentary work environments.* Society for Back Pain Research: poster presentation, 4th November. Guisborough, UK

Bell, J., Stigant M. (2005). *Quantification of sedentary activities using 2 fibre-optic goniometers: A validation study.* Society for Back Pain Research: podium presentation, Friday 11th November. Warwick, UK.