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Assessing lumbar sagittal motion using videography in an *in vivo* pilot study

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Abstract

There are currently limited data regarding the number of cycles the spine undergoes during a given time period. The purpose of this study was to develop a technique for assessment of lumbar spine motion in an uninhibited ergonomic environment. An *in vivo* motion analysis of the lumbar spine was conducted which estimated an average of 1,029,600 extreme bends occur during working hours over a 10-year period.

Relevance to industry

This information will assist lumbar disc replacement manufacturers with device production and possible device longevity.

Keywords: Lumbar spine; Motion

1. Introduction

There are currently limited data regarding the number of cycles the spine undergoes during a given time period. This lack of normative data is unlike other joint replacements, such as the knee and the hip. Biomechanical studies have attempted to quantify the gross lumbar range of motion (Hsieh and Pringle, 1994; Lee and Wong, 2002; Lund et al., 2002; Menezes et al., 1995), and lumbar segmental angles (Feipel et al., 2001; Lee et al., 2002; McGregor et al., 2001; Miyasaka et al., 2001; Steffen et al., 1997), while other researchers are addressing the load variable of lumbar motion (Murdock et al., 2000; Rohlmann et al., 2001; Van Dieen et al., 2001). The combination of segmental lumbar motion, lumbar load production and the estimates of bends during work or leisure, combined with new innovations in biomaterials will provide lumbar disc replacement manufacturers with much needed information for device production and possible device longevity (Hallab et al., 2003).

There have been approximately 2000 spinal arthroplasty surgeries since the October 2004 FDA approval of the Charite (Depuy Spine, Inc., Rayham, MA) in the United States, not counting clinical trials of other devices. This new technology including spinal disc replacements and other motion preservation devices has extreme economic potential. These devices offer an alternative to the 450,000 lumbar and cervical fusion procedures performed by spine surgeons in the United States annually (Singh et al., 2004). The estimated direct expense related to spinal arthroplasty devices is $2.18 billion (Singh et al., 2004). This type of market will spur many entrepreneurs to develop additional spinal arthroplasty devices, similar to that available for knee and hip arthrosis. The optimum way for manufacturers to generate reliable, robust devices is by utilizing basic scientific research.

Scientific research for lumbar motion is composed of numerous design types. Assessing spinal motion is difficult when utilizing external markers and devices that are

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adhered to the skin due to the lack of reliability in measurements. This variability may be related to the error that exists when measuring joint movement based on skin reflective marker location. Devices such as the CA6000 Spine Motion Analyzer (Orthopedic Systems Inc., Union City, CA) and the Polhemus Fastrak system (Polhemus, Colchester, VT) have demonstrated different measures in extension and axial rotation, which raise question to the reliability of angular measurements of vertebral motion (Mannion and Troke, 1999). Although internal markers used in lumbar spine research increase the reliability of motion assessment, it also increases the risk to the volunteering participants. Cadaveric studies have inherent error related to tissue differences, and finally the availability of biomechanical laboratories is limited and tends to have high cost related to training personnel and purchasing equipment. Therefore, most research is expensive, laboratory induced, and uses highly sophisticated software and research devices, unlike the current study.

The purpose of this *in vivo* pilot study was to develop a technique for assessment of lumbar spine sagittal motion in an uninhibited ergonomic environment.

2. Material and methods

The two-dimensional motion of the lumbar spine was measured in five healthy volunteers (mean age: 30 years, range: 22–39 years) using a digital video recorder (X-2 Canon, Canon Electronics Inc., Tokyo, Japan) and a video camcorder (CC176 RCA, Thomson Inc., Indianapolis, IN). The use of two recorders allowed investigators to monitor motions from different angles. Table 1 provides summary data on the participants. These participants had varied occupational assignments and therefore exhibited different types and extent of lumbar motions. Participants' occupations included courier, secretary, medical records personnel, magnetic resonance imaging technician, and physical therapist. Exclusion criteria included current low back pain or significant history of back pathology. Ethical approval was obtained from the Western Institutional Review Board (Olympia, WA). All participants completed informed consents prior to data collection.

Each participant was video recorded for 4 h during a typical workday. Video recording occurred in 30 min, 1 and 2 h increments. Two video recorders followed participants throughout their workstations with one video recorder attached to a tripod, when appropriate. Not all work environments were conducive to a tripod or two people following the participants.

Table 1
Summary data on study participants

Variable	Mean	S.D.
Height (cm)	175.3	9.33
Weight (kg)	93.9	42.3
Age (years)	30.4	6.39
Male	2	
Female	3	

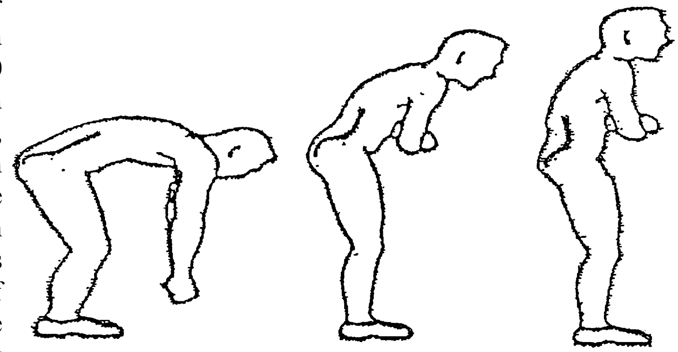

Fig. 1. Description of defined motions identified based on degree of forward bend.

Lumbar flexion was defined by three motion parameters: Lumbar neutral to a one-third bend (0°–20° flexion), beyond a one-third bend to a two-third bend (20°–50° flexion), and all motion beyond a two-third bend to a full bend (>50° flexion) as shown in Fig. 1. Measurements were estimated by video visualization; no exact angular measurements were collected. It was believed that categorizing motions allowed for improved reliability of data collection.

Author-developed grind sheets were utilized to record data for each participant on a time line. Three data collectors independently viewed the video recordings for each participant's 4 h of motion. Results were recorded while viewing, and the extent of rewinding during viewing was left to the discretion of the viewer. An inter-reviewer reliability was assessed by a group viewing of two participants for 15 min to ensure data recording consistencies. Lateral and rotational bending was not assessed and viewer group discussion clarified these movements. If there was a discrepancy in categorization of a specific bend, the videos were reviewed by the group and discussed until a consensus was reached.

3. Results

3.1. Number of bends

A two-way repeated measures ANOVA with an alpha of .05 was used to determine whether type of bend (one-third, two-thirds, full) and viewer (1, 2, 3) were related to the total number of bends performed in a 4-h workday. Type of bend was a significant predictor of total number of bends, $F(1.6, 6.4) = 21.41$, MSE = 6398.94, G–G $p < .01$. Viewers did not differ significantly on number of bends, $F(1.91, 7.65) = 8.96$, G–G $p > .05$. There was not a significant interaction between viewers and type of bend $F(1.35, 5.38) = 4.59$, G–G $p > .05$. The pair-wise t-test comparison indicated that subjects performed less full bends ($M = 120$, S.D. $= 82.85$) than one-third bends

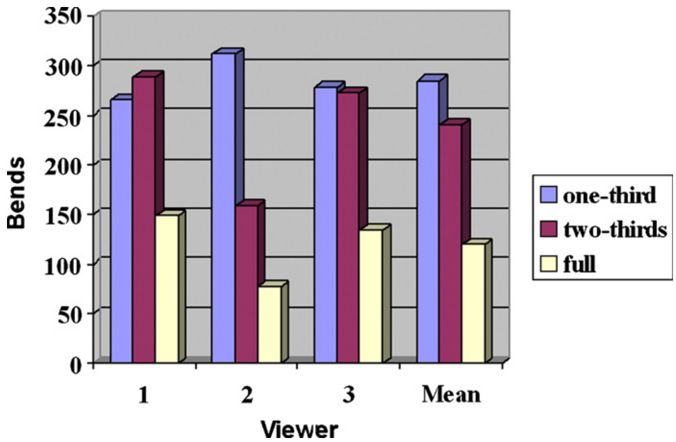

Fig. 2. Number of each type of bend calculated by each viewer during 4-h period and mean values.

($M = 285.20$, S.D. $= 118.15$). No significant difference existed between two-thirds bend ($M = 240.33$, S.D. $= 134.03$) and full bends, or one-third bends and two-thirds bends (Fig. 2).

Since there was one participant per occupation type, only the descriptive data are provided for the type of bends and the total number of bends by each viewer (Fig. 3). Differences in occupations (physical therapist, medical records person, MRI technician, courier, receptionist) varied considerably. The relationship between occupation type and extent of bending needs further analysis, which may need to control for personality type, time of day and varied workloads across different days.

3.2. Reliability of measures

An intra-class coefficient was significant, indicating the inter-rater reliability among viewers was similar ($r = .91$). Pearson's correlations revealed viewers could consistently watch video recordings of different occupations and establish similar numbers of one-third, two-third and full bends ($r = .82$–$.99$) as shown in Table 2.

Extrapolation of the raw data predicted an average range of 420–1980 full bends during a 40-h workweek, and 218,400–1,029,600 extreme bends during working hours over a 10-year period if the number of bends observed during the study period remained constant. After each of the viewers counted the number of bends individually for all of the videos, there was a consensus meeting of the three viewers. At this time, they reviewed a 4-h segment of the physical therapist, which allowed the viewers to agree (within two bends) on the number of full bends. The results of this meeting demonstrated that although some bends were visually missed the majority of bends were changed from a two-third bend to a full bend upon group discussion. However, for the data collector with an overall low number of bends, it was speculated that bends were simply not counted when they should have been. Therefore, the authors concluded it would be reasonable to use the highest range recorded within each occupation. The intra-class coefficient was calculated based on the original data prior to the consensus meeting. The consensus meeting was done after data analysis to discuss any disagreement among viewers.

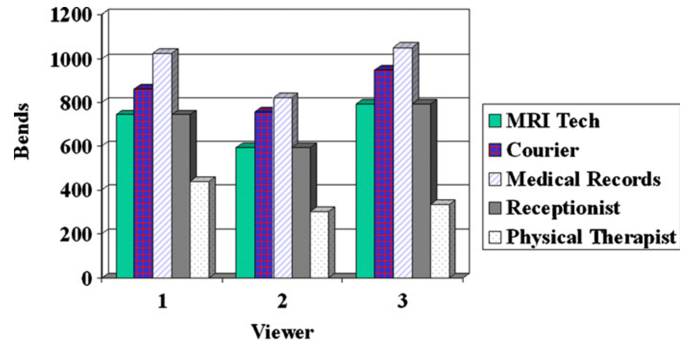

Fig. 3. Total number of bends calculated by each viewer for each participant type during a 4-h period.

Table 2
Pearson's correlations comparing the number of calculated bend among the three viewers

Bend	Viewer 1–Viewer 2	Viewer 1–Viewer 3	Viewer 2–Viewer 3
One-third	.92	.99	.96
Two-third	.82	.96	.94
Full	.87	.83	.94

4. Discussion

The extent of bending among occupations appeared to be different; however, results were not reflective of general assumptions about activity levels in each occupation. Occupations perceived as sedentary such as receptionist and medical records personnel produced greater numbers of bends than the physical therapy technician, although, the number of participants in this study was limited. The secondary finding was that an inexpensive research design for quantifying sagittal motion with two-dimensional video analysis appears to be a reliable method.

A limitation of the current study was only including a portion of the workday. In future studies all activities of daily living will need to be accounted for to provide an accurate projection of spinal movement. Many activities of daily living affect the lumbar spine with predominant motions including housework, caregiving (either for young children or the physically disabled), land and animal cultivation (yard work, gardening, farming), and recreational activities. Women report spending 3.9 h a day doing household chores and family activities as reported by the Michigan Time Use Study in 1988, which is similar to a 1998 Ransdell and Wells College Alumni Questionnaire that reported 20–30% of daily energy expended was related to home and family care while less than 1% of daily time is devoted to leisure physical activities (Ainsworth, 2000).

Data from National surveys (BRFSS, NHANES, NHIS) predict that only 25% of the American populations are exercising regularly per week, with 30% of the population being completely inactive. Americans spend their leisure time reading (35%), watching television (21%) spending time with family (20%) and going to movies (10%) as reported in the Harris Poll in 2004 (Harris Interactive, 2004). Recreational sports, gardening, housework, and lifting small children or elderly as part of time spent with family are probably the most common and important out of work demands on lumbar motion. Each of theses areas will need further study to assess what normal spinal motion is for a typical person with age and occupation as confounding variables. Development of a lumbar activity index that can account for lumbar motion during all activities of daily living may help physicians better care for their patients in the future.

Exhaustive normative data may help physicians better understand lumbar cyclic motion based on work-related tasks and leisure/home-related activities. Life expectancy of patients who receive spinal arthroplasty is around 50 years if they need these devices at age 35 (which is a common age for disc pathology). Our results projected a high end of 1,029,600 extreme bends during a 40-h workweek over a 10-year period. Other researchers predicted 2 million strides per year and 125,000 significant bends would result in over 100 million cycles (Hallab et al., 2003). Device manufacturers may determine "one-style or one-size" should not fit all individuals, and the estimated life of the spinal arthosis may need to be based on personal activity level.

There are various different categories of artificial disc. One major design factor is whether the disc is constrained or unconstrained. In a constrained disc each of the individual component of the disc replacement are secured to each other and do not allow any translation motion to occur. In the unconstrained designs, the components are allowed to translate on each other in an attempt to more accurately reproduce normal spinal kinematics. Huang et al. (2003) stated that unconstrained designs appear to add advantages to the kinematic functions of the low back, but constrained devices increase protection of the posterior elements from shear loading. The affects of different styles of total disc replacement devices on patient success as it relates to activities of daily living are unknown. The authors surmise that the extent of individuals' activities of daily living, which includes home and work, may need to be a variable in choosing device design.

Categorizing flexion motion in full bends, one-third and two-thirds bends were done to allow for better reliability in measurements during the study. Greater bending motions are expected to place more strain across the spinal segments than partial bending. In the current study, it was not possible to accurately measure specific angular motions.

Reliably estimating spinal motion cycles will be necessary for the development of biomechanical studies of wear and fatigue testing in the emerging technology of spinal arthroplasty. It is hoped that this pilot data will allow for future studies to better define the cyclic motion patterns of the lumbar spine.

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