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Spinal stiffness in asymptomatic subjects

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ABSTRACT

The objective of the study was to measure postero-anterior stiffness of thoracolumbar spine from normal asymptomatic subjects at T_4, T_9, and L_2 levels using a standardized device and protocol. Sixteen volunteer subjects (eight males and eight females) meeting the inclusion and exclusion criteria were recruited for the study. Their T_4, T_9, and L_2 spinous processes were identified and marked. These spinous processes were cyclically loaded with 22.5 N, 45 N, 90 N, and 135 N fixed forces at 0.1 Hz in postero-anterior direction by a computer controlled and operated Therapeutic Spinal Mobilizer (TSM) for five cycles to the level of subject's acceptance of the load magnitude. The magnitude of the force and displacement experienced at the spinal level were recorded using a load cell and linear variable differential transducer. The stiffness was obtained from the slope of the load/deformation curve. The stiffness values were subjected to analysis of variance to determine the effect of independent variables. The stiffness at different levels was significantly different ($p < 0.0001$) and it was significantly affected by the testing load ($p < 0.0001$). The age, sex, height and weight were not significantly associated with the stiffness, neither were the cycles at the same load. The postero-anterior stiffness of the thoracolumbar spine is different at different spinal levels and varies with testing loads.

1. Introduction

Back pain is a common clinical manifestation with which clinicians have been dealing for a long time. The association of low back pain and spinal stiffness and consequent impact on the spinal motion has rendered its assessment an essential practice in manual therapy. Due to this association it is considered an important indicator of patient's status (Murphy and Craig, 2005). Childs et al. (2004) claimed that the spinal stiffness is one of the five variables that predict which patient may respond favorably to spinal manipulation. Additionally, Latimer et al. (1996) demonstrated that the resolution of low back pain resulted in 8% decline in spinal stiffness among patients of low back pain when in asymptomatic controls it showed no change. Given such a central role of spinal stiffness, both in health and disease, it is disconcerting that the reliability of manual spinal stiffness assessment has been poor (Maher and Adams, 1994; Hawk et al., 1999; Hestback and Leboeuf-Yde, 2000; Seffinger et al., 2004, Stochkendahl et al., 2006).

Studies conducted on spinal stiffness have been diverse in both their methodology and results. The studies can be classified into subjective and objective assessments. Further, the subjective studies have been either indirect, comparing against external references (Maher et al., 1998; Chiradejnant et al., 2003); or theoretical involving modeling (Maher et al., 1998; Nicholson et al., 2001). The objective studies also demonstrate significant diversity. Some studies have used static/quasi static loading protocol (Owens et al., 2007a,b; Ferreira et al., 2008; Maher and Adams, 1995; and others); and others have tested the spinal stiffness using dynamic protocol (Nathan and Keller, 1994; Keller and Colloca, 2007; Herzog et al., 1993; Colloca et al., 2003; Colloca and Keller, 2001; Kawchuk and Fauvel, 2001; and others).

It is worthy to note that there is a frequent mention of lack of agreement between studies and between clinicians (Seffinger et al., 2004; Stochkendahl et al., 2006). All observations by different clinicians may be valid and reliable for the manner and condition under which they were made using the devices they did. It is this diversity of methodology which may lead to variation in findings and hence lack of reliability. Considering these factors Kumar and Stoll (2011) developed a device and standardized methodology which eliminates subjectivity and standardizes the loading and measurement methodology. This could lead to results that can be compared between clinicians, between subjects, and between different sessions. Using the same methodology this paper reports the stiffness at 4th and 9th thoracic and 2nd lumbar vertebral levels from asymptomatic subjects.

2. Methods

2.1. Participants

Sixteen subjects (eight male and eight females between the ages of 22 and 47 years) volunteered for the study. The mean

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age, height and weight of the male sample with their standard deviations were 29.0 (7.6 years), 173.6 cm (20.7 cm), and 83.9 kg (19.9 kg) respectively. The mean age, height and weight of the female sample were 29.0 years (8.9 years), 164.0 cm (7.4 cm), and 64.2 kg (15.2 kg), respectively (Table 1). The inclusion criteria for these subjects were no history of significant back pain within the past 12 months with a visual analog score (VAS) of 2 or more; no generalized neuromusculoskeletal disease; no spinal mobilization within the past 30 days; no current pregnancy; no use of corticosteroids, morphine, street drugs or strong pain killers; no history of spinal or abdominal surgery; no history of significant psychological disorder; and subjects who consider themselves to be generally in good health. Such subjects were informed about the purpose and procedure of the experiment both verbally and in writing and were required to sign an informed consent prior to being enrolled in the study.

The consenting volunteers were asked to come attired in loose clothes. Their backs were palpated to identify the spinous processes of T_4, T_9 and L_2 vertebrae which were marked with ink. Such prepared subjects were laid prone on a treatment plinth ready to be tested.

2.2. Instrumentation

The Therapeutic Spinal Mobilizer (TSM) (Kumar and Stoll, 2011) was used for spinal stiffness testing (Fig. 1). The TSM consisted of a 1/6 horsepower, 16 RPM AC gear motor that drove the loading piston indirectly through a cam and lever system (Fig. 1). The loading piston had a platform on which a known and desired amount of load could be placed to deliver postero-anterior loading stimulus. The cam had a total excursion range of 5 cm to accommodate the maximal spinal deformation. The patient end of the loading piston had a loading block that was circular in shape with rounded edge and 2.0 cm in diameter lined with a human skin-like synthetic high density polymer for comfortable coupling with subject's skin over the spinous process. This loading block was attached to the loading piston which was raised and lowered through the cam. The loading piston was instrumented with a capacitive load cell (iLoad Analog TM, Loadstar Sensors, Fremont, CA) of 450 N measuring range and accuracy of 0.15% full scale in the path of spinal load. The spinal displacement was measured using a Linear Variable Differential Transducer (LVDT) (L.D. 621-100 DC, Omega, Stamford, CT) with a measuring range 0–100 mm full scale and an accuracy of 0.02%. The LVDT was also attached to the loading piston to synchronize the load and displacement traces. The validity and reliability of TSM has been established against a previously developed electromechanical spinal model (Kumar, 1995) and these results have been published.

Table 1
Anthropometric data of the experimental sample.

	Height (cm)	Weight (kg)	Age
Males			
1	174.0	99.4	23.0
2	180.0	89.4	23.0
3	188.0	90.8	25.0
4	183.0	96.3	25.0
5	173.0	62.8	25.0
6	177.8	95.3	31.0
7	188.0	90.8	25.0
8	188.0	79.6	22.0
Mean	181.48	88.2	24.9
St. dev	6.25	11.8	2.8
Females			
1	159.0	50.6	24.0
2	156.5	56.7	23.0
3	159.0	64.1	23.0
4	159.0	44.2	24.0
5	164.0	83.9	22.0
6	170.0	74.8	25.0
7	159.5	55.3	23.0
8	170.2	55	23.0
Mean	162.15	60.6	23.4
St. dev	5.33	13.1	0.9

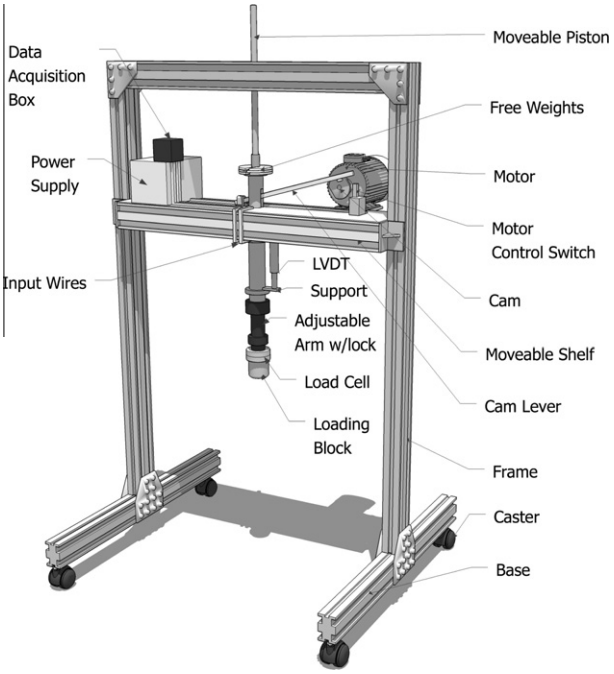

Fig. 1. Therapeutic spinal mobilizer.

2.3. Testing protocol

The volunteers were asked to lay prone on the treatment plinth with a cutout for the face. The TSM was then wheeled over the subject lying prone on the plinth such that the loading block of the piston was just above the appropriate vertebral level. The sequence of vertebral levels to be tested was randomized. Once the experimental set-up was ready the subject was instructed to lie still without contracting any of his muscles or changing posture. Furthermore, subjects were asked to take a breath in and then let it out to a comfortable level where the subject could hold breath or stop breathing for 15 s. This sequence was repeated for five loading and unloading cycles. At this point, the experiment was begun by starting the computer data acquisition program. The latter operated and controlled the motor allowing the chosen load to descend on the selected spinous process for 5 s and then rise cyclically. As the load rose off the spine, the subject was asked to breathe again and stop breathing at the same lung volume as in the previous loading unloading cycle just before the loading piston contacted the spine. This was repeated five times with each of the four loads (22.5 N, 45.0 N, 90.0 N and 135.0 N) in a random order.

2.4. Data collection

The outputs of load cell and LVDT were sampled at 1 kHz using graphical programming with LabView 8.6 on National Instruments PXi computer platform (National Instruments, Austin, TX). The synchronized collected data were stored on the hard drive of the computer to access later for analysis.