Original article

Posterior-anterior (PA) pressure Puffin for measuring and treating spinal stiffness: Mechanism and repeatability

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ABSTRACT

Background: Posterior–anterior (PA) pressure technique is widely used for assessing and treating spinal segments. PA pressure is manually applied and stiffness is subjectively assessed. The method has been deemed unreliable and is associated with occupational strain.

Objectives: To introduce a new ergonomically designed hand-held device measuring spinal stiffness, and to assess its repeatability.

Design: Quasi experimental study.

Method: A convenience sample of 30 university students, 20–30 years old was used. The participants were tested two consecutive days by two physical therapy students using the new device; the PA pressure Puffin. The spinal segments under study were L1, Th12, Th7 and Th6 which all were tested three times with 9 kg force by both testers, both days. Intra-class correlation coefficients (ICCs) were used to assess intra- and inter-tester repeatability and analysis of variance with alpha-level at 0.05 was used to assess differences in joint mobility at the four segments measured. Linear regression analyses were used to assess repeatability.

Results: Inter-tester and intra-tester coefficients (ICCs) ranged from 0.88 to 0.97 and from 0.83 to 0.97, respectively. There was no significant difference in displacement between Th6 and Th7 but all other joints were significantly different from each other. Displacement was always significantly greater the second day compared with day one (p < 0.05).

Conclusions: This close to final prototype of the PA pressure Puffin measures segmental spinal stiffness and its ergonomically designed handle provides a promising tool for physical therapists applying PA pressure. Further research is needed for validation and reliability assessments.

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1. Introduction

Physical complaints are common among physical therapists (PTs) including those who use posterior–anterior (PA) pressure technique. The prevalence of hand/wrist symptoms has been reported 22–30% (Bork et al., 1996; Holder et al., 1999; Cromie et al., 2000), 34% report symptoms in thumbs (Cromie et al., 2000) and 18–21% of PTs identify manual therapy tasks as risk factors for work-related disorders. In cohorts of PTs primarily using spinal manipulative techniques the prevalence of pain in thumbs has been reported 64–83% (Wajon and Ada, 2003; Wajon et al., 2007; Snodgrass et al., 2010). Among identified risk factors associated with thumb pain are alignment of the thumbs (Wajon et al., 2007) and lack of support to joints during PA pressure (Snodgrass et al., 2003). Work related injuries are costly for any professional as well as the society, therefore it is important to implement preventative measures as recent publications indicate (Snodgrass and Rivett, 2002; Walsh et al., 2011). An ergonomically designed instrument for applying PA pressure is an option for preventing strain on hands and thumbs of physical therapists.

The widely used PA pressure test for evaluating displacement and stiffness relies on subjective perception. Strong evidence has been reported for unacceptable levels of reliability between testers.
and within testers using motion palpation tests (Schneider et al., 2008; Walker et al., 2015). For PA pressure technique, two hand-held ergonomically designed devices have been introduced; the Superthumb and the Kneeshaw device. These devices are used as a point of contact with the patient rather than the traditional therapist’s thumbs or hand. When using either one of these devices or the pisiform grip, PTs are equally able to detect small changes in stiffness but compared with the pisiform grip both devices were judged more uncomfortable by PTs and patients (Maher et al., 2002). Another hand-held manual mobilization device has been described, using dynamometer. This device has maximum hand contact area for the user and instantaneous force readout and users show significantly less variability in applied force and greater comfort compared with using the traditional pisiform grip without feedback (Waddington and Adams, 2007). Yet another hand-held device has been introduced using electromagnetic tracking and a force transducer but it is not clear if this device is ergonomically designed (Owens et al., 2007).

These devices designed to decrease the risk of work-related injuries do not solve the problem of subjectivity of the results. Some mechanical devices measuring PA stiffness have been introduced, such as the Therapeutic Spinal Mobilizer (TSM) (Kumar, 2011; Kumar and Stoll, 2011) and Variable Rate Force/Displacement (VRFD) device (Vaillant et al., 2010). The TSM device has been reported reliable and valid when tested on a spinal model (Kumar and Stoll, 2011) used in previous studies (Simmonds et al., 1995; Björnsdóttir and Kumar, 2003), and on humans (Kumar, 2011). The VRFD has also been reported reliable (Vaillant et al., 2010). Some other mechanical devices have been introduced (Snodgrass et al., 2008). None of these instruments seem to be commercially available and mechanically driven instruments are unlikely to be used in the clinical setting.

The main purpose of this report is to introduce and describe a user friendly prototype of a new unique device, the PA pressure Puffin. This device is intended to objectively measure spinal stiffness while its ergonomically designed handle is expected to serve as prevention for repetitive strain for those using PA pressure in the clinical setting. The second aim is to focus on repeatability of the measurements.

2. Methods

2.1. Technical description of the PA pressure Puffin

The PA pressure Puffin (MTT Ltd., Reykjavík, Iceland) is a new hand held computer aided instrument measuring forces applied and the relative displacement that occurs when used, in vivo, to apply PA pressure on a vertebra. The main components of the PA pressure Puffin (Fig. 1) are an ergonomically designed handle, a force sensor connected to a force application pin, and displacement sensors embedded in housing. The housing contains a rechargeable battery, electronics, device computer with data-acquisition software (MMT ltd., Reykjavík, Iceland) and a touchscreen interface. Attached to the housing is an adjustable support system allowing adjustment along the spine to ensure that force can be applied perpendicularly to the spinal process independent from curvature. Results are displayed on a touchscreen user interface mounted on the housing. The screen shows real time graphing, giving a direct feed-back on the force-displacement curve. The housing includes a plug-in for a cord transferring data from the device to a computer with special client software (MMT ltd., Reykjavík, Iceland) installed. The data is transferred to a user friendly PC software giving information on forces applied, the resultant displacement, and calculated stiffness quotient of individual vertebra.

The force application pin is placed directly over the vertebra to be measured, and the displacement sensor covers the upper adjacent vertebra. When the PT applies manual load to the device handle, about 90% of the pressing force is applied to the force application pin. The load is measured with a load cell which gives out voltage proportionally to the applied force with accuracy (non-linearity, hysteresis and repeatability) of ±1% of total span. The load cell has a range up to 50 lbs, or 22.3 Kg force. An Analogue to Digital Converter (ADC), with 10 bits resolution, converts the output voltage of the load cell to digital value at the sampling rate of 62.5 Hz.

The displacement sensor measures the relative displacement between the vertebra under pressure and the upper adjacent vertebra. The displacement sensor has an active range of over 35 mm and gives voltage output that is linearly proportional to the displacement. The producer of the displacement sensor states that the linearity over active displacement range is ±2%. The 10 bits ADC and the data-acquisition software read the sensors position at the same moment that it reads the force value from the load sensor. The device computer software stores the displacement- and load-data. To omit the device’s own weight and the compression of patient’s soft tissues at the start of the measuring, the load measured has to be registered until the pressure has reached 1 Kg force. The force application pin is made out of anatomically shaped silicon which adds to the shape of the patient’s spines process to even out the pressure in order to minimize discomfort and possible pain to the patient. The force application pin deforms slightly when a load is applied. This deformation has to be taken into account because it adds to the displacement sensor readings. Therefore another displacement sensor is placed inside the force application pin to measure the decompression of the silicon padding. This second displacement sensor is identical to the main displacement sensor, except it has shorter travel length. The data-acquisition software reads simultaneously from both displacement sensors and subtracts the decompression of the force application pin from the main displacement sensor readings to give actual displacement between the vertebrae. The device’s sensors were calibrated initially.

2.2. Participants

For this study 30 university students volunteered following an in-school advertisement, approved by university authorities. Inclusion criteria were; age 20–30 years, not pregnant, no history of back pain the past 12 months, and no known active inflammatory or infectious diseases, or other serious symptoms. The study was approved by the Icelandic bioethics committee (nr. 10-066-S1).

2.3. Study settings and procedures

This study was conducted at the Department of physical therapy, University of Iceland and data was collected in January 2012. Participants visited the laboratory two consecutive days for approximately 30 min each time. The participants lay on a plinth in prone, undressed to the waist, arms at the sides, with support under pelvis and feet. Two graduating physical therapy students were specifically trained in using the PA pressure Puffin, prior to the study. To ascertain that the same spinal level was measured, the investigators palpated, agreed on the landmark, and marked the 6th, 7th and 12th thoracic vertebrae and the 1st lumbar vertebra before the measurements started. One after the other they performed the PA pressure test in a non-randomized order, three times on each vertebra at the same time of day, two consecutive days. The investigator not testing stepped aside and was blinded to the measurements of the other investigator. They were unaware of own
and each other test results until the end of data collection. The decision to measure the participants two consecutive days was based on the likelihood that spinal stiffness would generally not vary between two days. Recall bias would be eliminated due to the nature of the measurements which do not rely on memory but on the instrument. The PA pressure Puffin was mounted on the participant’s spine as described above. The investigator stood by the treatment plinth ensuring vertical alignment from shoulders through the handle of the instrument and pushed down during exhalation with an increasing force until the instrument gave a pre-fixed sound at 9 kg force.

2.4. Treatment of data

Data was transferred from the PA pressure Puffin to the client software and then exported to Scilab 5.3.3 (Scilab Enterprises, Versailles, France) software in order to assess the force-displacement graphs. Each measurement procedure started at 1 kg force at which the zero point of displacement was defined. Data was acquired from 1 kg force until the maximum load was reached. For each measurement the displacement and stiffness was extracted at 3–8 kg force by calculating the least square cubic spline fit. A standard deviation (SD) of the distance between the spline and measured data around a given point (3…8 kg force), SD (data-spline) was calculated using data between /0 and /0 kg force around that point. Each measurement was accepted if all the points had SD (data-spline) <0.1 and if the displacement at 3 kg force was >0.05 mm. This requirement caused rejection of 63 measurements from a total of 1804. We used the first accepted measurement for each day in further analysis. To assess reactions to repeated force applications to the vertebra, a line fit was taken through the displacement at 8 kg force versus the repetition number of that vertebra during that day. Consequently, we obtained a distribution of slopes for each vertebra at day 1 and day 2.

2.5. Data analysis

Descriptive statistics were calculated for anthropometric data. To estimate repeatability we used various methods. We estimated intra- and inter-tester coefficients by using analysis of variances (ANOVA) for obtaining intra-class correlation coefficient (ICC) at 8 kg force. We used two-way mixed model with an absolute agreement definition or ICC3,k with 95% confidence intervals (CI) (Shrout and Fleiss, 1979). We decided that an ICC value of ≥0.80 and the CI lower bound ≥0.70 would be acceptable for both intra- and inter-tester estimates. We calculated the standard error of the measurement (SEM) by using the standard deviation of difference scores between the testers or between days. We further computed the coefficient of variation (CVSEM) using the difference scores and assumed ≤20% variation to be acceptable (Portney and Watkins, 2000).

For testing repeatability (Kadaba et al., 1989), that is the difference between days, a linear regression analysis was performed with the model of common slope by Eq. (1),

$$D_{d1,i} = a_0 + a_1 D_{d2,i} + a_2 T + \sum_{j=3}^{\infty} a_j P_j - 2 + e_i$$

(1)

where $D_{d1,i}$ and $D_{d2,i}$ are the displacements or derivatives (displacement on force) on days 1 and 2, respectively, for consecutive forces (3–8 kg force) and at the same order of the three
repetitions each day, T is physical therapist, $P_j$ is participant, and $e_i$ is the error term. For parsimony reasons, the model was reduced to the following Eq. (2),

$$D_{ij} = \alpha_0 + \alpha_1 D_{ij-1} + \alpha_2 T + e_i$$

(2)

The regression coefficients $\alpha_0$ and $\alpha_1$ reflect difference in readings between days, i.e. $\alpha_0$ is equal to zero and $\alpha_1$ is equal to unity if there is not a difference. $\alpha_2$ is used to test if there is a difference between therapists (affecting the intercept, $\alpha_0$). The standard error term for $\alpha_1$ may be looked upon as a measure of the overall repeatability for all forces applied on each vertebra. By this way a detailed description of the difference between days is obtained. Although, both equations show primarily the relationship between days, using either displacement or stiffness, the latter is a simplified version of the former by exclusion of participants since the effect of participants in this study was minimal. Additional term relates to the effect of physical therapist. We estimated differences between vertebrae, assuming there would not be the same motion at all levels. We used one-way ANOVA with least square difference post-hoc comparisons. For treatment of data and statistical analyses we used Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA) and SPSS-20 (PASW statistics 20, SPSS Inc., Chicago, IL). Significance level was set at $p \leq 0.05$.

3. Results

Participants were 18 men and 12 women with mean age of 23.1 years (SD = 2.6) and mean body mass index of 25.5 kg/m$^2$ (SD = 3.1).

The repeatability estimates for displacement at 8 kg force are presented in Table 1. Our results show that intra- and inter-tester coefficient (ICC) estimates vary from 0.83 to 0.97 and 0.88 to 0.97, respectively, when measuring displacement at four different vertebrae. The lowest lower bound CI for the ICCs was 0.63 observed for tester one with repeated measures. All other lower bounds were over 0.70 (data not shown).

We obtained no significant difference ($p > 0.05$) in mean displacement between Th6 and Th7 at any level of forces applied, using point estimates. All other joints and across all levels of forces applied showed significantly different mean displacement (Fig. 2).

Our results show that stiffness (derivatives of displacement on force) gave significant correlations between measurements on day 1 and day 2, Eq. (2), but worse coefficients of determination than displacements. For example, a coefficient of determination of 0.29 was obtained for Th6 using stiffness while displacements gave a coefficient of 0.70. Coefficient of determination for L1 was 0.48 for Th6 while the model excluding the participants, of Eq. (2), gave a coefficient of 0.66. Thus, 14 explanatory variables only explained additional 4% of the variation, and nine of the participants did not differ significantly from each other ($p > 0.05$). For this reason we used Eq. (2) in the regression analysis and results are presented in Table 2 for the four vertebrae studied. The results explain 66, 69, 70 and 81% of the variation in the data for Th6, Th7, Th12 and L1, respectively. The therapist has an effect only when measuring Th6 and Th7 and the displacement on the second day was always significantly greater than on day one.

<table>
<thead>
<tr>
<th>Lumbar vertebra 1</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tester 1</td>
<td>3.76 (1.61)</td>
<td>3.65 (1.65)</td>
</tr>
<tr>
<td>Tester 2</td>
<td>3.52 (1.61)</td>
<td>3.47 (1.47)</td>
</tr>
<tr>
<td>ICC</td>
<td>0.97</td>
<td>0.96</td>
</tr>
<tr>
<td>SEM</td>
<td>0.358</td>
<td>0.430</td>
</tr>
<tr>
<td>CV$_{SEM}$</td>
<td>9.8</td>
<td>12.1</td>
</tr>
<tr>
<td>Thoracic vertebra 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tester 1</td>
<td>3.11 (1.39)</td>
<td>3.11 (1.37)</td>
</tr>
<tr>
<td>Tester 2</td>
<td>3.15 (1.46)</td>
<td>3.10 (1.32)</td>
</tr>
<tr>
<td>ICC</td>
<td>0.97</td>
<td>0.90</td>
</tr>
<tr>
<td>SEM</td>
<td>0.374</td>
<td>0.572</td>
</tr>
<tr>
<td>CV$_{SEM}$</td>
<td>12.0</td>
<td>18.4</td>
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<table>
<thead>
<tr>
<th>Thoracic vertebra 7</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tester 1</td>
<td>2.30 (0.84)</td>
<td>2.32 (0.77)</td>
</tr>
<tr>
<td>Tester 2</td>
<td>2.23 (0.88)</td>
<td>2.24 (0.84)</td>
</tr>
<tr>
<td>ICC</td>
<td>0.95</td>
<td>0.94</td>
</tr>
<tr>
<td>SEM</td>
<td>0.256</td>
<td>0.269</td>
</tr>
<tr>
<td>CV$_{SEM}$</td>
<td>11.3</td>
<td>11.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thoracic vertebra 6</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tester 1</td>
<td>2.28 (0.60)</td>
<td>2.32 (0.66)</td>
</tr>
<tr>
<td>Tester 2</td>
<td>2.34 (0.70)</td>
<td>2.26 (0.82)</td>
</tr>
<tr>
<td>ICC</td>
<td>0.88</td>
<td>0.93</td>
</tr>
<tr>
<td>SEM</td>
<td>0.307</td>
<td>0.267</td>
</tr>
<tr>
<td>CV$_{SEM}$</td>
<td>13.26</td>
<td>11.6</td>
</tr>
</tbody>
</table>

ICC – Intraclass Correlation Coefficient model 3;k; SEM – Standard Error of the Measurement using the SD of the difference scores; CV$_{SEM}$ – Coefficient of Variation using the standard deviation of the difference scores.

4. Discussion

This report introduces a close to final prototype of a new handheld computer aided instrument, the PA pressure Puffin, for objectively testing spinal stiffness and evaluation of treatment results. Briefly, this report demonstrates good intra- and inter-tester repeatability of the PA pressure Puffin when used by graduating PTs. It further differentiates between various mobile segments. The PA pressure Puffin, therefore has the potential to solve two problems; spare the therapist’s hands and give objective and reliable test results.

Loss of sensation is one concern of therapists when discussing possibilities of using devices instead of hand grips when performing manual therapy tests and treatment. Data is scarce for or against this claim but it has been reported that experienced manual therapists are poor and poorer than novice PTs in judging values for displacement and the forces they apply when using PA pressure. However, both groups improve their judgement following feedback training (Björnsdóttir and Kumar, 2003). It has further been reported that therapists are able to discriminate varying stiffness stimuli generated from a mechanical device when performing PA pressure (Maher et al., 2002). Judging physical parameters such as joint play and stiffness requires training whether performed manually or with a device. For a device to be used in the clinical work it needs to have clear advantages equal to or over the hands manually or with a device. For a device to be used in the clinical work it needs to have clear advantages equal to or over the hands manually or with a device. Further research is needed on this matter.

In this study the PA pressure Puffin measured varying magnitude of displacement for the four joints when up to 8 kg forces were applied. This is in line with other studies which show varying regional stiffness with less motion relative to forces applied in the thoracic spine and more in the lumbar spine (Lee et al., 1998; Shirley et al., 2002; Kumar, 2011; Kumar and Stoll, 2011; Kumar, 2012). Further research is needed for expanded validation for diagnostic purposes. This requires research comparing the PA
pressure Puffin with a gold standard such as real-time ultrasound imaging or dynamic radiographs, with sufficient data to determine sensitivity, specificity, positive and negative predictive values. Results from the PA pressure Puffin could also be compared with bending stiffness values (Lee et al., 2005). We observed that the model of Eq. (2) explains 66–81% of the variation in the data for the four joints. Only in the case of Th6 and Th7 does the physical therapist have an effect while their contribution is small albeit significant $(p < 0.05)$. Displacement on the second day is always significantly greater than on day one, i.e. resulting in a slope significantly less than unity $(p < 0.05$, see Table 2), indicating that the treatment/measurements on day one may have resulted in increased mobility of the joints on day two.

There are a number of factors that can influence measurements on a spinal segment. The rate of the loading cycle has been reported as an influential factor with more speed resulting in increased stiffness responses (Kumar and Stoll, 2011). With hand-held devices and manually applied forces the loading speed will always depend on the one using the tool. This factor needs to be considered in future research. The padding on the contact points to the body and the thickness of the skin and other tissues covering the spinal process are of concern when calculating the stiffness quotient. The PA pressure Puffin is designed to neutralize these factors so we are confident that relative displacement of adjacent spinal processes is measured. However, displacement must be considered in terms of underlying tissues and mechanisms involved. Studies using MRI technique to quantify segmental motion during PA pressure show that the angle formed by drawing lines along the endplates of adjacent vertebrae increases with PA pressure and is referred to as angular segmental displacement or sagittal rotation (Powers et al., 2003; Kulig et al., 2007; Landel et al., 2008). Sagittal translational motion appears to increase with PA pressure (Lee and Evans, 1997) and motion occurs in joints cranial and caudal to the vertebra under pressure (Kulig et al., 2004). In previous studies, intersegmental motions including angular and translational motions have been studied and measured by motion radiographs during active flexion and extension of the spine. The magnitude of these intersegmental motions is dissimilar among people with differential levels of disc degeneration (Keorochana et al., 2011) and is increased among women with chronic whiplash-associated disorders (Kristjansson et al., 2003). During PA pressure there will also be compression/distraction of zygapophysial joints (Kulig et al., 2004). Detailed explanations on the underlying mechanisms are beyond the scope of this article. However, the PA pressure Puffin measures the forces applied and the relative difference in translational displacement of two adjacent spinal processes during PA pressure (Fig. 4).

For further development and the final version of the PA pressure Puffin, comments from those involved with data collection are acknowledged and valued. The students suggested improving the contact point and the possibility to include various sizes for measuring and treating along the spinal column given that sizes and shapes of the spinous processes vary. Further research is needed to evaluate if this device fulfills requirements for use in the clinical setting. The user-friendliness and comfort for the one measured as well as the one measuring needs further attention in future research.

There are some concerns that need to be addressed for interpreting the results of this study. Our decision to use two way mixed model for ICC calculations are based on the fact that the testers had no clinical experience in using PA pressure. Inexperienced testers were chosen based on the assumption that experience might bias the results, primarily due to perception and differential clinical reasoning processes (Bjornsdottir and Kumar, 2003). We assumed that experience might influence the tester to perform differently because generally the performer would be judging the magnitude, the quality and tissue reactions to the movement. Due to the nature of the instrument and the purpose of the study to test the instrument it also justifies the decision to use inexperienced testers. Generalizability can only be assumed for testers of no experience. Both testers measured under all conditions and no randomization was applicable.

5. Conclusions

Objective and reliable measurements are essential in manual physical therapy as in all disciplines. The PA pressure Puffin is a valuable adjunct to physical therapy as no other manually driven instrument measures objectively both pressure and displacement and consequently calculates the stiffness quotient for a vertebra. This study shows that the current prototype of the PA pressure...
Fig. 3. a. Displacement of day 1 as a function of displacement at the same force on day 2 for L1. Both physical therapists and all participants included. b. Stiffness (derivative of displacement on force) of day 1 as a function of stiffness at the same force on day 2 for L1. Both physical therapists and all participants included.
Puffin reliably measures the relative displacement of a vertebra at a given force and discriminates between variously mobile segments. The advantage of the PA pressure Puffin is its ergonomically designed handle meant to prevent repetitive strain injuries to the hands of the user. The hand-held cord-free design is convenient for use in clinical setting for assessment and treatment. The PA pressure Puffin has the potential to be used as a measurement tool in the clinic or for research as well as a treatment tool. It is therefore a valuable addition for PTs and their patients.

References

Simmonds MJ, Kumar S, Lechelt E. Use of a spinal model to quantify the forces and motion that occur during therapists’ tests of spinal motion. Phys Ther 1995;75:212–22.

Table 2

Results from the multiple regression analysis for all joints by the model of Eq. (2).

<table>
<thead>
<tr>
<th>Joint</th>
<th>Observations</th>
<th>R²</th>
<th>F</th>
<th>p-value (F)</th>
<th>Slope</th>
<th>Displacement day 2</th>
<th>Therapist</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>s₀ (intercept)</td>
<td>SE</td>
<td>p-value</td>
</tr>
<tr>
<td>Th6</td>
<td>990</td>
<td>0.66</td>
<td>938.2</td>
<td>&lt;0.001</td>
<td>0.17886</td>
<td>0.03793</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Th7</td>
<td>1020</td>
<td>0.69</td>
<td>1150.9</td>
<td>&lt;0.001</td>
<td>0.09595</td>
<td>0.03834</td>
<td>0.010</td>
</tr>
<tr>
<td>Th12</td>
<td>990</td>
<td>0.70</td>
<td>1130.1</td>
<td>&lt;0.001</td>
<td>0.3444</td>
<td>0.04791</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>L1</td>
<td>990</td>
<td>0.81</td>
<td>2113.5</td>
<td>&lt;0.001</td>
<td>0.19872</td>
<td>0.04782</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Fig. 4. Proposed mechanism of the relative displacement of two adjacent vertebrae during PA pressure.


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