Reliability of the Spin-T Cervical Goniometer in Measuring Cervical Range of Motion in an Asymptomatic Indian Population

Shabnam Agarwal, MSc,[a] Garry T. Allison, PhD, PT,[b] and Kevin P. Singer, PhD, PT[c]

Abstract

Objective: To examine the intratester reliability of the Spin-T goniometer, a cervical range of motion device, in a normal Indian population.

Methods: Subjects comprised 30 healthy adults with mean age of 34 years (range, 18-65 years). The subjects were stabilized in the sitting position and the Spin-T goniometer mounted on the head of the subject. The study design was a within-subject repeated intratester reliability trial conducted for cervical range of motion in 6 directions of movement. Three measurements were taken in each direction (flexion, extension lateral flexion, and lateral rotation) per participant. Reliability coefficients, intraclass correlation coefficients, and 95% confidence interval were derived from repeated-measures analysis of variance (ANOVA). Where differences in ANOVA were detected, a paired *t* test was conducted and the typical error values and coefficient of variance were calculated.

Results: All repeated measures showed high intraclass correlation coefficients (all >0.96, $P < .01$). The ANOVA detected no differences between trials for all movements except rotation. The typical error values for the rotation trials did not exceed 2.5° and the coefficient of variance did not exceed 4%, which is clinically acceptable considering the normally variable cervical range of movement.

Conclusion: In this study, the Spin-T goniometer proved to be a reliable measuring instrument for cervical range of movement in an Indian population. The use of a laser pointer fixed to the instrument ensured a consistent neutral start position (J Manipulative Physiol Ther 2005;28:487-492)

Key Indexing Terms: *Reproducibility of Results; Cervical Vertebrae; Range of Motion; Articular*

Clinical measurement of cervical movements is complex because of its normal variability. Neck movements are influenced by pain,[1,2] age,[3] sex,[4-6] trauma,[7] and disease[8] and depend upon whether the movement is measured actively or passively. In spite of this normal variability, the assessment of cervical range of motion (CROM) is often a fundamental component of clinical practice contributing to elements of clinical reasoning, diagnosis, and treatment efficacy. Therefore, an objective measurement technique for CROM that shows both clinical utility and reliability is essential in the context of normal clinical practice.

Although cervical movements within the clinical setting are commonly estimated visually, this method has poor intertester reliability with intraclass correlation coefficient (ICC) values varying between 0.42 and 0.82 for different neck movements.[9] In comparison, the universal goniometer shows slightly improved reliability[9] (intratester ICC values from 0.78 to 0.90 and intertester ICC values from 0.54 to 0.79 for different neck movements). The reliability of measurements varies according to the direction of movement and has been found to be lower for lateral movements separated into left and right components, in comparison with movements restricted to a single plane.[10,11] Other measuring equipment promoted in reliability trials include the rangiometer,[12] radiographs,[13] 3D kinematic method,[14] electrogoniometers (CA 6000 Spine Motion Analyzer; Orthopedic Systems, Inc, Union City, Calif),[15-18] potentiometer-based electrogoniometer,[19] ultrasound-based motion analyzers (CMS 70P; Zebris Medizintechnik GmbH, Isny,

[a] Chief Physiotherapist, Belle Vue Clinic, Kolkata, India.
[b] The Centre of Musculoskeletal Studies, Perth, Western Australia, Australia.
[c] The Centre of Musculoskeletal Studies, Perth, Western Australia, Australia.
Sources of support: No external funds were received for this research.
Submit requests for reprints to: Shabnam Agarwal, MSc, Belle Vue Clinic, 9, Dr. U.N. Brahnachari St., Kolkata 700 017, India (e-mail: *shabnamagarwal@vsnl.net*).
Paper submitted April 19, 2004; in revised form January 17, 2005.
0161-4754/$30.00

doi:10.1016/j.jmpt.2005.07.005

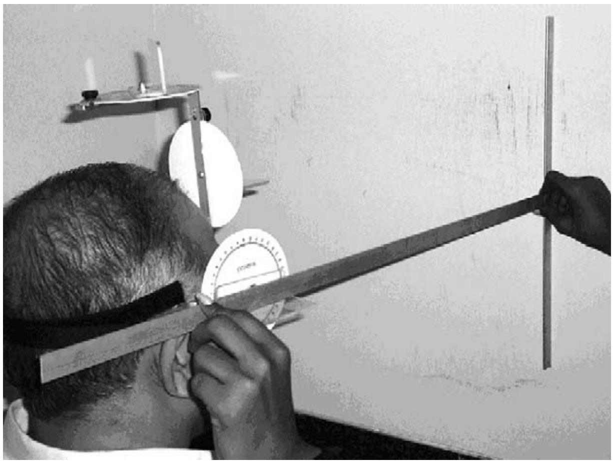

Fig 1. *The Spin-T goniometer strapped on the subject's head. The T square is positioned along the spindle of the flexion-extension dial to provide a perpendicular reference to the wall.*

Table 1. *Summary of ROM (in degrees) in each direction of the cervical spine for 30 subjects*

Movement	Mean range of movement	Range	SD
Flexion	57.1	21-80	12.1
Extension	65.3	25-104	18.2
Lateral flexion (right)	44.4	25-62	8.7
Lateral flexion (left)	45.7	21-62	8.4
Lateral rotation (right)	70.0	44-95	10.7
Lateral rotation (left)	70.9	36-95	11.8

Germany),[20] and FASTRAK (Polhemus, Colchester, Vt), an electromagnetic 3-dimensional tracking system.[11]

The CROM instrument has been repeatedly tested for its reliability and has shown a high intratester (ICC >0.84) and intertester (ICC >0.73) reliability for all neck movements.[9] Garrett et al[21] used the CROM instrument (intratester reliability ICC = 0.93 and intertester reliability ICC = 0.83) for measurement of forward head posture in 40 patients with orthopedic disorders of the cervical spine. However, the CROM instrument does not seem to be designed to measure lateral cervical movements, which are composite in nature.[22] Sophisticated and modern equipment such as the CA 6000 Spine Motion Analyzer,[17] FASTRAK,[11] and ultrasound-based motion analyzers (CMS 70P)[20] are capable of reliably measuring natural combinations of planes of movements. The disadvantage of these tools is that they are expensive and nonportable and are therefore confined to dedicated research laboratories or institutions. The ideal method is a technique that is neither too invasive nor complex to operate and provides data that are clinically accurate and meaningful.

Table 2. *Intraobserver ICC values and their 95% CI for all cervical spine movements*

Movement	ICC	95 % CI Lower	95 % CI Upper	F
Flexion	0.98	0.97	0.99	64.87
Extension	0.98	0.97	0.99	87.04
Lateral flexion (right)	0.96	0.93	0.98	27.72
Lateral flexion (left)	0.97	0.94	0.98	33.75
Lateral rotation (right)	0.98	0.97	0.99	71.89
Lateral rotation (left)	0.98	0.97	0.99	79.56

Table 3. *Repeated-measures ANOVA to measure differences between trials for movement in each direction*

Movement	*df*	F	*P*
Flexion	2	1.79	.17
Extension	2	2.13	.12
Lateral flexion (right)	2	0.43	.65
Lateral flexion (left)	2	0.79	.45
Lateral rotation (right)	2	10.90	<.01
Lateral rotation (left)	2	13.44	<.01

The Spin-T goniometer, designed and developed by Haynes and Edmondston,[22] is capable of measuring composite cervical movements. These include lateral cervical movements that cannot be measured with the CROM device. The reliability of the Spin-T has been established[22] on 23 subjects who showed an intraexaminer reliability (ICC >0.87 and >0.91 for each examiner, respectively) and an interexaminer reliability (ICC >0.75) for different neck movements. A further issue was to identify a method to ensure consistency of the start position between each motion plane assessment.

A review of published literature revealed no study conducted on the Indian population to document the cervical range of movements of a normal or symptomatic population. The purpose of this brief report was to establish the intratester reliability of the Spin-T goniometer on an asymptomatic Indian population.

Methods

The Spin-T consists of a spectacle-type aluminum frame, anchored on the nose and behind the ears with two Velcro straps. A lightweight laser pointer on the left arm of the Spin-T was used to reference the instrument and ensure that a consistent neutral position of the head was achieved between trials. Three 360° dials (marked at 1° interval) attached to the frame lie in orthogonal planes reflecting the cardinal movement planes of the cervical spine. An L-shaped rectangular plastic spindle pivots around the

Table 4. *Results of paired t test as a post hoc test and typical error values with 95% CI for paired rotation trials*

	Change in mean	SD	*t*	*df*	*P*	Typical error	95% CI	
							Lower	Upper
Right								
Trial 1 vs 2	2.10	3.2	3.63	29	.001	2.24	1.78	3.01
Trial 2 vs 3	0.33	2.8	0.656	29	.517	1.97	1.57	2.65
Trial 3 vs 1	2.43	3.3	4.029	29	<.001	2.34	1.86	3.14
Left								
Trial 1 vs 2	1.63	3.3	2.672	29	.012	2.37	1.89	3.18
Trial 2 vs 3	1.43	2.8	2.767	29	.010	2.01	1.60	2.70
Trial 3 vs 1	3.07	3.5	4.795	29	<.001	2.48	1.97	3.33

center of each dial (Fig 1) with the horizontal portion of the L touching the dial (a red line at one end of the spindle coinciding with the degree markings of the dial along its circumference). Measurement of neck movements with the Spin-T requires a corner of a room. The wall in front of the subject serves as a reference for flexion-extension and lateral rotation movements and the wall to the left of the subject serves as a reference for lateral flexion movements. The orientation of each dial is referenced and zeroed to the perpendicular plane of the wall. This is achieved by the use of a lightweight, rigid aluminum T square (Fig 1).

Once the reference position is established, using the T square to reset the spindle on each dial assesses the degrees of relative movement in each plane. From this, excursion in that plane can be documented. In a previous study, the Spin-T goniometer was validated against a high-resolution 3D motion tracking device called the MotionStar (Ascension Technology Corporation, Burlington, Vt). The maximum magnitude of error in this previous study was less than 1.5°.[23]

Thirty asymptomatic healthy subjects (7 women and 23 men; age range, 18-65 years; mean, 34 years [±11.4]; mean height, 164 cm [±7.4]; mean weight, 66 kg [±10.9]; and body mass index, 24.8 [±3.6]) participated in this study. Subjects were recruited from the staff of Belle Vue Clinic, Kolkata, India, which comprised professional, clerical, and manual staff as well as persons accompanying patients. The sample represented people from different states of India and socioeconomic backgrounds, thereby contributing to the applicability of the results to the general population. The purpose and procedure of the study were fully explained to the subjects and a signed consent was obtained.

All subjects were seated upright on a straight back wooden chair with the upper trunk in contact and strapped to the back of the chair. The feet were firmly on the floor or a footstool and the knees close to the wall in front. The participants grasped with each hand the rear leg of the chair they were sitting on. The strap helped in preventing forward movement of the trunk during flexion; the back rest and the strap prevented the trunk from leaning back during extension; and by holding the rear legs of the chair, lateral movement of the trunk during lateral cervical movements was minimized.

Before strapping on the Spin-T goniometer, participants were asked to move their head twice in all directions to their end range, in any order, as a "warm up". For flexion, participants were asked to move the head in the direction of chin to chest and to refrain straining the upper trunk during end-range movements. For lateral flexion, the head and neck moved toward the shoulder without allowing any shoulder elevation, and for rotation, the subjects were asked to rotate the head as if looking over the ipsilateral shoulder.

The Spin-T goniometer was mounted on the head of the seated participant. The laser pointer was used to reference the neutral position of the head at the beginning of each trial. The participants were given instructions to move their head in one direction as far as possible without causing pain or discomfort. Measurements were recorded with the T square aligning the spindle of the relevant protractor at the end point of movement.

Verbal instructions were the same and uniform for all participants. Measurements were taken in the following sequence: flexion, extension, lateral rotation right and left, and lateral flexion right and left. This cycle was repeated 3 times. The T square of the Spin-T was aligned to the wall in front of the subject for sagittal and axial plane measurements. For coronal plane measurements, the wall to the left of the patient was required; measurement of lateral flexion was last.

Statistical Analysis

All descriptive data are reported as mean and SD. Reliability coefficients, ICC (2, 1 a two-way random effects single-measure reliability model),[24] and 95% confidence interval (CI) were derived from repeated-measures analysis of variance (ANOVA). Where differences in ANOVA were detected, a paired *t* test was conducted. The typical error and the coefficient of variance (CV), which expresses the variance as a percentage, were calculated to determine the degree of error. $P < .05$ was considered significant. SPSS for Windows version 11.5 (SPSS, Inc, Chicago, Ill) was used for all analyses.

Results

A summary of the ROM for all 30 subjects is given in Table 1. The ICC for all movements was high (>0.96), showing that the error was a small proportion of the total range of movement recorded and that the repeated measures were highly linearly correlated (Table 2).

The repeated-measures ANOVA (Table 3) showed no significant differences between the 3 trial measurements for flexion (P = .17), extension (P = .12), and lateral flexion (right P = .65, left P = .45). However, lateral rotation showed a direction bias ($P < .01$). A paired t test determined where the difference lay.

The paired t test established a significant difference ($P < .01$) between all 3 rotation trails except trial 2 vs 3 for rotation, right side (P = .51) (Table 4), which was reflected in the difference in mean (0.33°) for the same trial. Changes in mean for other rotation trials were larger. The typical error calculated for significant differences was less than 3.5°, and the CV was less than 4% for all movements (Table 4).

Discussion

A review of literature revealed no published literature on the cervical range of movement for an Indian population. A possible reason for lack of studies in India could be nonavailability of economically priced, reliable, and valid measuring instruments. Establishing the reliability of the Spin-T on a normal Indian population also facilitates research on symptomatic populations and in the development of a normal reference range.

The accuracy of the Spin-T has been established in a previous study.[23] For all planes of CROM, the coefficient of determination (R^2) revealed $R^2 > 0.99$. The Spin-T goniometer has the potential to reliably measure composite cervical movements, which can aid clinicians' assessment of cervical spine movements easily in routine clinical practice.

In the present study, the mean values in all directions were lower as compared with Haynes and Edmondston.[22] One possible explanation is that the mean age (29 years) of subjects was lower[22] compared with this study (mean age, 35 years). Previous research has established that CROM reduces with age.[4,6,25] The population of healthy subjects included physiotherapy students[22] who may be more aware of movement patterns and would possibly perform better than a population that included people from different backgrounds, as in this study. The age range in this study extended from 18 to 65 years, and hence, a dedicated study including a larger sample size with more subjects for each decade is required to establish a normal reference range for this population.

Past literature[11,20] reported higher reliability of total plane movements than separated into left and right. This is probably because the reliability coefficient (ICC) is a relative value and is range dependent. Therefore, ICC values increase as the range of measured values increase.

Standardization of the cervical neutral position is imperative for correct measurements. Comparisons of lateral movements, left vs right, are sometimes essential for clinicians. The concept of neutral position for spinal ROM is unclear and a potential source of error. To assume a neutral posture for lateral movements is comparatively easier because it can be based on body midline symmetry. For flexion-extension, there is no inherent axis of symmetry, and therefore, it is problematic and susceptible to error.[19] There is a lack of a satisfactory solution in establishing a cervical neutral and the neutral position set by the clinician seldom differs from the neutral position assumed by a healthy subject.[19] The common strategy is to have seated subjects sitting erect and looking ahead without any further attempt to standardize the resting neutral position.[12,19] In this study, the neutral position of the head was standardized with a laser pointer and concurrently aligned with a T square on the zero mark of the protractor. This minimized error between opposite direction movements, which was evident on adding the left and right rotation trials. Similar ICC values were achieved for total and rotation trials to right and left. The addition of a laser pointer to the Spin-T goniometer is a variation from the original design of the Spin-T[22] and confers an additional advantage of ensuring a repeatable starting position between trials. This simple and inexpensive strategy can be recommended to many other cervical spine range instruments as a means of reducing error. Zachman et al[12] measured the neutral cervical position by positioning the dial indicator of a rangiometer in the sagittal and coronal plane and noting the degrees of deviation from neutral. The dial indicator was then replaced with a vertical indicator arm for measurements of neutral in the axial plane. Pearson r was less than 0.45 for intertester reliability for neutral position assessment in all 3 planes.

Extreme protraction and retraction can affect cervical flexion-extension and rotation movements and need to be addressed during measurement.[19] The Spin-T measures natural composite cervical movement, which is a combination of glides and rotation.[22] Strapping the upper trunk and further asking the subjects to avoid upper trunk movement seemed to be effective in minimizing unintentional movements. Repeated instructions about chin to chest for flexion movements during familiarization prevented subjects from initiating flexion from the lower cervical spine and maintained uniformity of movement patterns.

The cervical spine comprises a complex series of multiaxial joints in which movements are controlled by numerous muscles attached segmentally and across several spinal segments.[9] Neck movements are easily influenced by pain, spasm, mental/physical stress, and the time of the day. Variability of cervical spine movements exists in a normal population even when assessed on the same day.[19] A higher ICC value was achieved for same day measurements (ICC = 0.95) vs 1 to 3 days (ICC = 0.90), although statistically insignificant.[19] In another study,[11] a higher interobserver reliability (flexion-extension >0.70, rotation >0.70, lateral flexion >0.60) for movements tested on the same day was obtained than for intraobserver reliability (>0.60) for all movements completed on different days. A source of variation (subject, observer, equipment, diurnal effects) exists for within-day reliability tests as well as between-day tests. Within-day variation is smaller than between day because of variability in symptom response and individual differences.[11]

Equipment limitations need to be accounted for in reliability studies and in clinical practice. In two separate studies,[17,18] reliability was found to be lower for flexion-extension compared with lateral movements using the same system, the CA 6000 Spine Motion Analyzer. This may be attributed to deficiencies of the instrument for measurements in the sagittal plane. One limitation of the Spin-T is that blinding the tester is not possible because the design of the Spin-T involves close reading of the protractors. For repeat measures, a tester bias may exist. Therefore, instead of repeating 3 consecutive movements in one direction, the applicable method in this intratester same time reliability trial was completion of one full cycle of measurements in all directions before the next cycle of measurements. This involved repositioning to neutral 18 times for 18 measurements. The Spin-T sits on the nose of an individual like a spectacle frame. With a small head circumference, it does not fit snug on the nose, which may contribute to error. A large head circumference makes it difficult to fit the two arms of the Spin-T along both sides of the head. In this study, two subjects had very small head circumference. These subjects were given padding along the sides of the head, above the ears, to secure the Spin-T.

Another source of variability to be considered is the effect of the order of testing motions. Although rotation trials showed a systematic trend, it perhaps cannot be ascribed to the order of measurements because rotation was measured between sagittal and frontal plane movement trials. Lantz et al[19] have also shown that the order of movements has no effect on the outcome of measurement.

The repeated-measures ANOVA and subsequent post hoc tests revealed differences in rotation trials. No such differences were noted for other movements. Comparing paired rotation trials, the difference noted for trial 3 vs trial 1 (both sides) was the highest. This may be due to the development of a bias on repeated testing with a minor increase in range effect or learning effect from trial 1 to trial 3. Another reason may be that on repeated best performances or moving the neck to end range, a biologic creep effect was observed, causing neck rotation range to increase. The reason for differences only in rotation trials and not other movements remains unclear. In a reliability study of the FASTRAK,[11] a systematic bias was detected in all directions except flexion and right rotation. Contrary to the current results, range of movement reduced from measurements 1 to 3. The authors[11] attribute this to initial subject enthusiasm and that subjects tend to stop their movements in the second and third trial based on experience rather than because of reaching the end range.

The 95% CI of the typical error provides a measure of the extent of variation between measurements obtained between trials. The 95% CI of the typical error for rotation was between 1.5° and 3.5°, which is a 2° difference. In the intratester trials, a typical error of 2.3° for left rotation for each examiner and 3.6° and 2.9° for right rotation for each examiner was reported for cervical spine reliability trials.[22] The authors did not report any confidence limits of the error. A wide CI does not reflect good reliability. Zachman et al[12] reported the intertester reliability of the rangiometer. The intertester standard error of estimate ranged from 5° to 12° for all movements of the cervical spine, with a large CI between the two testers (20°-48°). Based on these results, the authors advised caution in interpretation of results when using the rangiometer for future clinical trials.

The ANOVA detected no difference between the sagittal and coronal plane trials. The typical error for rotation trials was less than 3.5° with a CV less than 4%. These results were similar to previous studies.[15,17] A typical error of less than 3.9° for all motions was stated by Petersen et al[17] and CV between 2.4% and 10.9% by Christensen and Nilsson.[15] This study has shown that changes in CROM of greater than 4° can be detected by the Spin-T system. This magnitude of change is likely to be less than what is clinically significant and therefore suggests that the instrument is of sufficient accuracy to be clinically useful. This article confirms, independently from the developers of the Spin-T, that the errors associated with the assessment of CROM are relatively small.

Conclusion

The Spin-T goniometer tested on this asymptomatic Indian population proved to be a reliable measuring tool for assessing composite CROM in an asymptomatic Indian population. The addition of a laser pointer to the Spin-T device provided a simple and reliable method to ensure consistency of the neutral start position between trials.

Acknowledgments

The authors thank Professor Kamles Bhaumik, PhD, for statistical support; all subjects who volunteered to participate in this study; and Ms Reema Debnath for secretarial assistance.

References

1. Cassidy JD, Quon JA, LaFrance LJ, Yong-Hing K. The effect of manipulation on pain and range of motion in the cervical spine: a pilot study. J Manipulative Physiol Ther 1992;15:495-500.
2. Jordan A, Mehlsen J, Ostergaard K. A comparison of physical characteristics between patients seeking treatment for neck pain and age-matched healthy people. J Manipulative Physiol Ther 1997;20:468-75.
3. Hole DE, Cook JM, Bolton JE. Reliability and concurrent validity of two instruments for measuring cervical range of motion: effects of age and gender. Man Ther 2000;1:36-42.
4. O'Driscoll SL, Tomenson J. The cervical spine. Clin Rheum Dis 1982;8:617-26.
5. Wolfenberger VA, Bui Q, Batenchuk GB. A comparison of methods of evaluating cervical range of motion. J Manipulative Physiol Ther 2002;25:154-60.
6. Youdas JW, Garrett TR, Suman VJ, Bogard CL, Hallman HO, Carey JR. Reliability of measurement of cervical spine range of motion—comparison of three methods. Phys Ther 1992; 72:770-80.
7. Osterbauer PJ, Long K, Ribaudo TA, Petermann EA, Fuhr AW, Bigos SJ, et al. Three-dimensional head kinematics and cervical range of motion in the diagnosis of patients with neck trauma. J Manipulative Physiol Ther 1996;19:231-7.
8. Viitanen JV, Kokko ML, Heikkila S, Kautiainen H. Neck mobility assessment in ankylosing spondylitis: a clinical study of nine measurements including new tape methods for cervical rotation and lateral flexion. Br J Rheumatol 1998;37: 377-81.
9. Youdas JW, Carey JR, Garrett TR. Reliability of measurements of cervical spine range of motion. Phys Ther 1991;71:98-104.
10. Nilsson N, Christensen HW, Hartvigsen J. The interexaminer reliability of measuring passive cervical range of motion, revisited. J Manipulative Physiol Ther 1996;19:302-5.
11. Jordan K, Dziedzic K, Jones PW, Ong BN, Dawes PT. The reliability of the three dimensional FASTRAK measurement system in measuring cervical spine and shoulder range of motion in healthy subjects. Rheumatology (Oxford) 2000;39:382-8.
12. Zachman ZJ, Traina AD, Keating JC, Bolles ST, Braun-Porter LJ. Interexaminer reliability and concurrent validity of two instruments for the measurement of cervical ranges of motion. J Manipulative Physiol Ther 1989;12:205-10.
13. Van Mameran H, Drukker J, Sanches H, Beusgens J. Cervical spine motion in the sagittal plane (I) range of motion of actually performed movements, and (II) x-ray cinematographic study. Eur J Morphol 1990;28:47-68.
14. Bulgheroni MV, Antonaci F, Ghirmai S, Sandrini G, Nappi G, Pedotti A. A 3D kinematic method for evaluating voluntary movements of the cervical spine in humans. Funct Neurol 1998;13:239-45.
15. Christensen HW, Nilsson N. The reliability of measuring active and passive cervical range of motion: an observer-blinded and randomized repeated-measures design. J Manipulative Physiol Ther 1998;21:341-7.
16. Christensen HW, Nilsson N. Natural variation of cervical range of motion: a one-way repeated-measures design. J Manipulative Physiol Ther 1998;21:383-7.
17. Peterson CM, Johnson RD, Schuit D. Reliability of cervical range of motion using the OSI CA 6000 spine motion analyser on asymptomatic and symptomatic subjects. Man Ther 2000;5:82-8.
18. Solinger AB, Chen J, Lantz CA. Standardized initial head position in cervical range of motion assessment: reliability and error analysis. J Manipulative Physiol Ther 2000;23:20-6.
19. Lantz CA, Klein G, Chen J, Mannion A, Solinger AB, Dvorak J. A reassessment of normal cervical range of motion. Spine 2003;28:1249-57.
20. Dvir Z, Prushansky T. Reproducibility and instrument validity of a new ultrasonography based system for measuring cervical spine kinematics. Clin Biomech (Bristol, Avon) 2000; 15:658-64.
21. Garrett TR, Youdas JW, Madson TJ. Reliability of measuring the forward head posture in a clinical setting. J Orthop Sports Phys Ther 1993;17:55-60.
22. Haynes MJ, Edmondston S. Accuracy and reliability of a new, protractor based neck goniometer. J Manipulative Physiol Ther 2002;25:579-86.
23. Agarwal S, Allison GT, Singer KP. Validation of the Spin-T goniometer: a cervical range of motion device. J Manipulative Physiol Ther 2005;28:in press.
24. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull 1979;86:420-8.
25. Holmes A, Wang C, Han ZH, Dang GT. The range and nature of flexion-extension motion in the cervical spine. Spine 1994; 15:2505-10.