INTRA-INSTRUMENT RELIABILITY OF 4 GONIOMETERS

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ABSTRACT

Background: Cervical spine ROM movements taken accurately with reliable measuring devices are important in outcome measures as well as in measuring disability.

Objective: To compare the active cervical spine ROM in healthy young adult population using 4 different goniometers.

Methods: Subjects were tested during active cervical spine ROM. The devices were a single hinge inclinometer, single bubble carpenter's inclinometer, dual bubble goniometers and Cybex EDI 320 electrical inclinometer. All subjects were tested for rotational limits along each of the orthogonal axes of movement. There are 3 trials for each movement direction, except rotation was not measured with the Cybex as per manual suggestions. The subjects were randomly assigned to the sequence of devices.

Subjects: Twenty-seven student volunteers (19 men and 8 women) were tested. Ages ranged from 21 to 41, mean age of 27.6 years of age.

Data: Active cervical spine ROM trials for each measurement was used to calculate mean and standard deviation. An overall analysis of variance (ANOVA) and Bonferroni adjusted T-test were determined in order to calculate reliability and significance.

Discussion: The cost of the instruments were not used in determining reliability or significance. The single hinge inclinometer was found to be a reliable measure but not likely valid. The Cybex EDI 320 was found to be the best measuring device; however, the 2 instruments whose cost were in-between the single hinge inclinometer and the electrical goniometer were just as reliable as the more expensive device. The AMA Guides of Impairment were used as the normative data to compare these devices.

Conclusion: Since the devices could measure reliably, whether expensive or more cost effective for students they would likely make adequate devices for training students on the methods for measuring ROM. There is previous data to suggest that older populations have gender differences and age differences with ROM. This study could not measure that and would make a useful follow-up study. (J Chiropr Med 2003;2:91–95)

KEY WORDS: Cervical Spine; ROM; Goniometers

INTRODUCTION

Active ROM testing is used in clinical practice for the measurement of movement and as an outcome measure for determining diagnosis, disability and treatment effects. There are many ways of performing ROM testing, including visual examination (1), tape measure (2), inclinometers of different varieties, (1–3) radiographs, (4–7) cinematographic analysis, (8) computerized motion analysis (5,9,10) and camera-generated movement analysis. (11) The studies that assess the reliability of range motion have demonstrated variable findings depending upon the joint location being measured and the instrument used on the joint.

The AMA Guides of Permanent Impairment use range of motion (ROM) as 1 of the determinants to estimate impairment. (12) Cervical spine ROM techniques have been used as a functional measurement of changes following "whiplash" trauma (13) and as clinical measure of treatment efficacy.

Cervical spine ROM has been used as an outcome measure in research for comparing cervical spine movement. For example, Askins and Eismont evaluated different cervical spine collars (orthoses) and used cervical spine ROM to evaluate which collar was superior. (14) Cervical spine ROM assessment has also been used to assess the effects of spinal manipulation. (15) Dvorak et al described a loss in ROM with aging process in both genders, except at the C1-C2 level. They also found slight increases that may compensate for losses at lower segments. (16) This decrease in ROM with respect to age was also described by others. (17,18)

The determination of active cervical spine ROM and flexibility of healthy spines may be useful in developing baseline norms. These baseline data can be used for the development of comparisons between elderly symptom-

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atic spines. (19) Magee and Reid, (20,21) 2 current orthopedic textbooks, describe active cervical spine ROM with some similarities and differences. They, however, make no comparison for the older population. (20–21) It should also be said that the *AMA Guides to Permanent Impairment* do not make changes for age-related loss. (12)

This study was inspired by a group of students during training of measuring active ROM, when they were unable to find information concerning comparative data for different inclinometers. They were concerned about cost of instruments and their ability to reliably measure ROM. This study attempted to measure reliability of 4 different goniometers. The goniometers were chosen based upon their cost and their ability to comply or not comply with *AMA Guides to Permanent Impairment* rules for measuring active ROM.

METHODS

Twenty-seven volunteer student subjects (19 men and 8 women) were recruited from the student body of a chiropractic college. Mean age of the group was 27.6 years with standard deviation of 6.6 years and age range from 21 to 41 years. All subjects were right-handed. Each subject read and signed an informed consent form prior to determining eligibility. Inclusion was determined by age greater than 18 years and less than 45 years. Subjects were excluded from the study if they complained of cervical spine pain within the previous 6 weeks. Each subject was randomly assigned an order of the series of goniometers to be measured.

The ROM devices were a single hinge joint inclinometer, dual bubble inclinometer, a single bubble carpenter's inclinometer and an electrical inclinometer (Cybex 320 EDI). Each subject was measured 3 times by each measuring device along each rotational axes. Due to recommendations, the rotational ROM was not measured with the electrical inclinometer. All measurements were taken at the end of active ROM and overpressure was not applied to avoid measuring passive ROM.

The measurements were taken by 4 student volunteers only. These student volunteers met earlier and a single training session was performed to standardize the measurements and standardize the instructions the subjects were given. The testers were given another volunteer to act as a recorder of the measurements. All the data recorded was input into the computer for analysis and was checked for accuracy.

The measurement guidelines are those as described in the *AMA Guides to the Evaluation of Permanent Impairment, 3rd Edition.* (12) These guidelines recommend the use of dual goniometers, not the use of single measuring devices. In this study, we used 2 single inclinometers: single hinge joint inclinometer and the single bubble carpenter's inclinometer. The measuring of active ROM methods were adapted to accommodate the use of single instead of dual inclinometers.

According to the methods recommended, the subjects were seated for measuring flexion-extension movements and lateral bending. For measuring flexion-extension the dual inclinometers were placed on the T1 spinous process and just superior to the occiput. If the inclinometers would contact 1 another during extension the T1 spinous process device was moved laterally and anchored there. For measuring lateral bending with the dual inclinometer method, the inclinometers were placed in the same areas, the orientation of the devices being the only difference. For flexion-extension the devices are placed in the sagittal plane and in the frontal plane during lateral flexion. Lastly, the dual goniometer method of rotation was required the use of only a single goniometer because the shoulders are not used in this movement. The subject was laid supine and this blocked shoulder movement. The inclinometer was placed on the forehead area for measurement. The total measurement for the movements was calculated by subtracting the 2 goniometer's measurements from 1 another and recorded.

The single bubble goniometer did not use the inferior measuring spot but only allowed for the superior spot placement and was recorded as such. The single hinge joint inclinometer used different anchoring points for measuring. For flexion-extension the hinge was placed on the humeral head and the top was lined up with the lobe of the ear and moved forward and backward with the flexion and extension measurement. Lateral bending was measured by anchoring the hinge at T1 and the superior point at the occiput and visually lined up with the occiput at the extremes of lateral bending. Lastly, rotation was performed with the subject supine and the hinge anchored at the intersection of the frontal and sagittal sinus' and the superior portion aligned with the tip of the nose.

The electrical inclinometer measured only flexion-extension and lateral bending. The subject was seated during each movement. The single electrical measuring device was placed on the occiput area for all movements but oriented along the plane of movement as with dual goniometers.

The data was manually recorded by a volunteer that worked with the tester. The date was entered into the computer for analysis and before the analysis was performed the data was checked for accuracy. The ROM data was put through ANOVA, Bonferroni adjusted t-test and ICC test. The data was also compared to normative date from an orthopedic textbook and the AMA guidelines numbers.

RESULTS

The average and standard deviation for males, females and combination of men and women for each ROM was calculated. (Table 1) No significant difference was found between men and women for any particular ROM.

The values of mean ROM and standard deviation were used to calculate Bonferroni adjusted t-tests. The scores for Bonferroni adjusted t-tests are shown in Table 2. The Bonferroni adjusted t-tests are conservative corrections used in this study. It appears that no single instrument appeared to be more reliable on all measurements but the electrical goniometer was found to be more reliable on 3 of the 4 measures it performed.

Lastly, the ICC were run for each instruments with respect to each movement. The ICC values are found in Table 3. The ICC values demonstrate a moderate to excellent reliability for each instrument for all movements measured. It appears that single or dual goniometers/inclinometers do not affect the reliability of measuring active ROM in this study.

DISCUSSION

The active ROM of the cervical spine in this study was similar to the normative data in orthopedic textbooks and the AMA guides. Also, the single hinge inclinometer was outside the range provided for my standard orthopedic textbooks but measured reliably, suggesting it was not a valid but was a reliable measure. The reliability was important in this study because the student could learn to measure the movements but not use the measurements for clinical or medically legal arenas.

The single hinge inclinometer measurements were the result of movement of the anatomical anchor site which were not part of the others. This appears to be a limitation of the validity of the measuring device. The interesting finding was that the single hinge device had high to moderate ICC values for reliability. The difference is likely due to the subtracting the movement occurring in the anchoring sites. This may make the single-hinge inclinometer a useful tool for quick measurements to determine efficacy and responses to treatment but not a tool for measuring impairment.

The cost of the tools were taken in consideration when choosing the devices. The consideration allowed for wide range of cost from $15 to $400 dollars. The expense of the tools did not appear to affect the ICC values but did decrease the validity of the measure with the least expensive tool. The AMA guides do make recommendation for dual and single inclinometers and these were the more expensive tools in this study and did

TABLE 1
AVERAGES AND STANDARD DEVIATION FOR ALL MOVEMENTS AND INSTRUMENTS, TOTAL (MALES AND FEMALE), MALES AND FEMALES AND REFERENCE TEXT RANGE OF MOTION FOR CERVICAL SPINE RANGE OF MOTION

	PLASTIC HINGE JOINT	SEARS AND ROEBUCK SINGLE GONIOMETER	DUAL BUBBLE GONIOMETER	CYBEX 320 EDI SINGLE GONIOMETER
FLEXION TOTAL	38.6 (10.8)	56.5 (16.3)	48.5 (12.2)	56.3 (12.0)
FLEXION MALES	39.6 (11.9)	53.0 (16.0)	44.9 (11.1)	56.5 (13.3)
FLEXION FEMALES	36.3 (7.6)	64.9 (14.1)	57.0 (10.7)	55.8 (8.3)
55.8 (8.3)	35.1 (9.7)	50.7 (11.2)	57.5 (14.5)	77.0 (13.2)
EXTENSION MALES	34.6 (10.5)	49.8 (12.4)	59.6 (15.4)	78.3 (13.9)
EXTENSION FEMALES	36.5 (7.6)	52.7 (7.6)	52.5 (10.7)	73.9 (10.9)
RLB TOTAL	42.2 (10.6)	48.4 (8.4)	46.9 (9.3)	53.9 (9.3)
RLB MALES	40.8 (11.4)	48.1 (9.0)	44.5 (9.2)	54.5 (10.3)
RLB FEMALES	45.6 (7.7)	49.2 (7.0)	52.7 (6.9)	52.7 (6.4)
LLB TOTAL	44.4 (11.1)	49.1 (9.0)	50.5 (7.7)	53.7 (6.7)
LLB MALES	43.4 (11.7)	48.0 (9.6)	50.9 (8.5)	54.6 (7.3)
LLB FEMALES	46.7 (9.3)	51.6 (7.0)	49.7 (5.7)	51.7 (4.6)
RR TOTAL	69.2 (18.5)	75.3 (12.1)	84.4 (13.4)	
RR MALES	71.5 (20.1)	75.2 (13.6)	83.0 (14.6)	
RR FEMALES	63.8 (13.0)	75.6 (7.8)	87.8 (9.7)	
LR TOTAL	69.9 (15.8)	76.7 (12.3)	84.0 (10.9)	
LR MALES	71.8 (17.1)	75.7 (13.5)	82.7 (12.5)	
LR FEMALES	65.6 (11.2)	79.1 (8.3)	87.0 (3.9)	

Table 2
Bonferroni Adjusted T-test

Flexion	Cybex EDI 320	.033	Plastic goniometer	.013
Extension	Cybex EDI 320	.007	Carpenter protractor	.000
Right lateral bending	Carpenters protractor	.002	Plastic goniometer	.008
Left lateral bending	Cybex EDI 320	.001	Bubble goniometer	.008
Right rotation	Carpenters protractor	.000		
Left rotation	Carpenters protractor	.001	Bubble goniometer	.002

Table 3
ICC Values for the 4 Measuring Devices

	Plastic Hinge Joint Goniometer	Sears and Roebuck Single Goniometer	Dual Bubble Goniometer	Cybex 320 EDI Electric Goniometer
Flexion	Single Rater .897			
	Mean Rater .963			
Extension	Single Rater .903			
	Mean Rater .966			
Flexion-Extension Combined	Single Rater .901	.918	.869	.893
	Mean Rater .965	.971	.952	.962
Lateral Bending Combined	Single Rater .967	.793	.828	.753
	Mean Rater .989	.920	.936	.901
Rotation Combined	Single Rater .973	.894	.919	
	Mean Rater .991	.962	.971	

appear to have higher reliability and measurements that were valid.

This study did not have an older population, which has been shown to have different active ROMs compared to a younger population. This study did not demonstrate any gender differences that previous studies have found. A follow-up study would be useful with a larger sample size and with a older population.

CONCLUSION

Cost does not seem to be a useful tool in determining reliability of measurements. Thus students could use any of the devices to learn to measure movement. But the single hinge inclinometer does not appear to be a valid measurement and should not be used for clinical practice. It is also a different tool and hand movements will thus be different, making the transfer of the skill from 1 tool to another less effective.

The other 3 tools were similar in the hand movements, reliability and validity. The electric goniometer appeared to be more reliable but for the purpose of learning the movements and to measure accurately for students the lower cost tools appear to be just as effective. The generalizability of this study is also affected by the lack of experienced impairment raters to compare to the 4 novices in this study. Also, this study lacked a symptomatic population to compare to the asymptomatic population.

For students the 3 goniometers appear to be as effective as one another in learning the hand placements and learning to measure active cervical spine ROM. But this is only effective for an asymptomatic population.

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