Send Orders for Reprints to reprints@benthamscience.net

The Open Orthopaedics Journal, 2014, *8*, 355-360

Open Access

The Reliability and Validity of the Computerized Double Inclinometer in Measuring Lumbar Mobility

Joy Christine MacDermid[*,1], Vanitha Arumugam[2], Joshua Israel Vincent[2] and Krista L. Carroll[3]

[1]*McMaster University, School of Rehabilitation Science, Hamilton, Ontario, Canada; Roth-MacFarlane Hand and Upper Limb Center, St. Joseph's Hospital, London, Ontario, Canada*

[2]*University of Western Ontario, Health and Rehabilitation Sciences, Faculty of Health Sciences, London, Ontario, Canada*

[2]*School of Rehabilitation Science, McMaster University, Hamilton, Ontario, Canada*

Abstract: *Study Design*: Repeated measures reliability/validity study.

Objectives: To determine the concurrent validity, test-retest, inter-rater and intra-rater reliability of lumbar flexion and extension measurements using the Tracker M.E. computerized dual inclinometer (CDI) in comparison to the modified-modified Schober (MMS)

Summary of Background: Numerous studies have evaluated the reliability and validity of the various methods of measuring spinal motion, but the results are inconsistent. Differences in equipment and techniques make it difficult to correlate results.

Methods: Twenty subjects with back pain and twenty without back pain were selected through convenience sampling. Two examiners measured sagittal plane lumbar range of motion for each subject. Two separate tests with the CDI and one test with the MMS were conducted. Each test consisted of three trials. Instrument and examiner order was randomly assigned. Intra-class correlations (ICCs 2, 2 and 2, 2) and Pearson correlation coefficients (*r*) were used to calculate reliability and concurrent validity respectively.

Results: Intra-trial reliability was high to very high for both the CDI (ICCs 0.85 - 0.96) and MMS (ICCs 0.84 - 0.98). However, the reliability was poor to moderate, when the CDI unit had to be repositioned either by the same rate (ICCs 0.16 - 0.59) or a different rater (ICCs 0.45 - 0.52). Inter-rater reliability for the MMS was moderate to high (ICCs 0.75 - 0.82) which bettered the moderate correlation obtained for the CDI (ICCs 0.45 - 0.52). Correlations between the CDI and MMS were poor for flexion (0.32; $P<0.05$) and poor to moderate (-0.42 - -0.51; $P<0.05$) for extension measurements.

Conclusion: When using the CDI, an average of subsequent tests is required to obtain moderate reliability. The MMS was highly reliable than the CDI. The MMS and the CDI measure lumbar movement on a different metric that are not highly related to each other.

Keywords: Computerized dual inclinometer, low back pain, modified-modified Schober, reliability, construct validity.

INTRODUCTION

Physical impairment evaluation is a routine and an important aspect of management in low back pain [LBP] as it helps clinicians and researchers alike to determine the progress that has resulted from an intervention. Lumbar range of motion (ROM) measurements is an important indicator of the level of impairment in an individual with LBP [1]. Hence the instruments used to quantify lumbar ROM should be reproducible between trials, raters and even within the same rater at different occasions amongst other clinical measurement properties. Previous studies have addressed the reliability and validity of different methods of measuring spinal range of motion, with variable conclusions [2-5]. Littlewood and May [6] conducted a systematic review on the validity of instruments used to measure lumbar ROM; out of the 4 studies that were included on the review 3 were on dual inclinometry and 1 was on modified-modified Schober test. They found that there was little evidence to support the current methods of measuring lumbar ROM.

Many clinicians use a version of the Schober skin distraction technique [7] to measure spinal mobility, because it is easy, takes little training, and the equipment needed is inexpensive. The modified Schober technique uses marks 10 cm above and 5 cm below the posterior superior iliac spine (PSIS) which on average only encompasses 3.5 of the 5 lumbar segments [8]. Many reliability and validity problems have been documented with the modified Schober technique [9]. The modified-modified Schober (MMS) described by Van Adrichem and VanDer Korst [10] was chosen for this study for several reasons. The points of measurement are the

*Address correspondence to these authors at the DB-222 Roth – MacFarlane Hand and Upper Limb Center, St Joseph's Healthcare London, London, ON N6A 4L6, Canada; Tel: +1-519-646-6100, Ext. 64636;
Fax: +1-519-646-6049; E-mail: jmacderm@uwo.ca

1874-3250/14

spinal intersection of the PSIS and a mark made 15 cm above. The elimination of the lower mark may reduce the measurement error. Van Adrichen and Van der Krost [10] determined that 15cm was optimal after evaluating 5 cm intervals above the PSIS (i.e. 5, 10, 15 and 20 cm), and suggested that this length was realistic approximation of the average length of the lumbar spine. One theoretical disadvantage of the MMS is that it measures linear motion whereas spinal motion occurs in an angular path.

Innovations in instrument technology and modification of techniques may provide improved evaluation of lumbar ROM but is not known whether this is true until demonstrated through scientific studies. The computerized dual inclinometry (CDI) system (Tracker M.E. CDI software system)[1] developed by the J tech industries is in line with AMA's "Guides to the Evaluation of Permanent Impairment" [11,12]. The Tracker's Dual inclinometer is considered more valid than a single inclinometer, as it can extract extraneous motion, and is preferred when documenting spinal ROM. The concurrent validity and reliability of this system is yet to be determined in LBP patients. There has been a previous reliability study comparing a manual dual inclinometer and the modified-modified Schober test and found that the MMS test was the more reliable of the two methods [5]. However, they did not use a computerized double.

Validity is the extent to which a measurement conveys the true status of the trait measured [13]. Radiographic examinations would be considered to be the 'gold standard' for measuring spinal motion, but they are expensive and require exposure to harmful radiation [14]. However, if two different tests of spinal motion are highly correlated, this would support the validity of both tests as measuring spinal motion.

The purpose of this study was to evaluate the intra-trial, intra-rater and inter-rater reliability of lumbar flexion and extension measurements using the Tracker M.E. CDI and the MMS. Secondly, we wish to determine the concurrent validity of the CDI in relation to the MMS (Figs. **1**, **2**).

METHODS

Forty subjects with a mean age of 26.15 years and SD of 7.87 were recruited for this study through convenience sampling. The group consisted of 20 subjects who have experienced LBP within the preceding month and 20 subjects without LBP (see Table **1**). A letter of explanation was read by each subject, and a written consent was obtained once they agree to participate in the study. Each subject was asked to complete a set of three lumbar flexion and extension stretches prior to testing. Two separate tests with the CDI and one test with the MMS were conducted. Each test consisted of three trials. Instrument and examiner order was randomly assigned. Adhesive marks were removed between tests. The subjects were instructed to rest as needed throughout testing.

Computerized Dual Inclinometry (CDI)

Tracker M.E. software and user guide recommends testing lumbar motion using the T12 spinous process and the

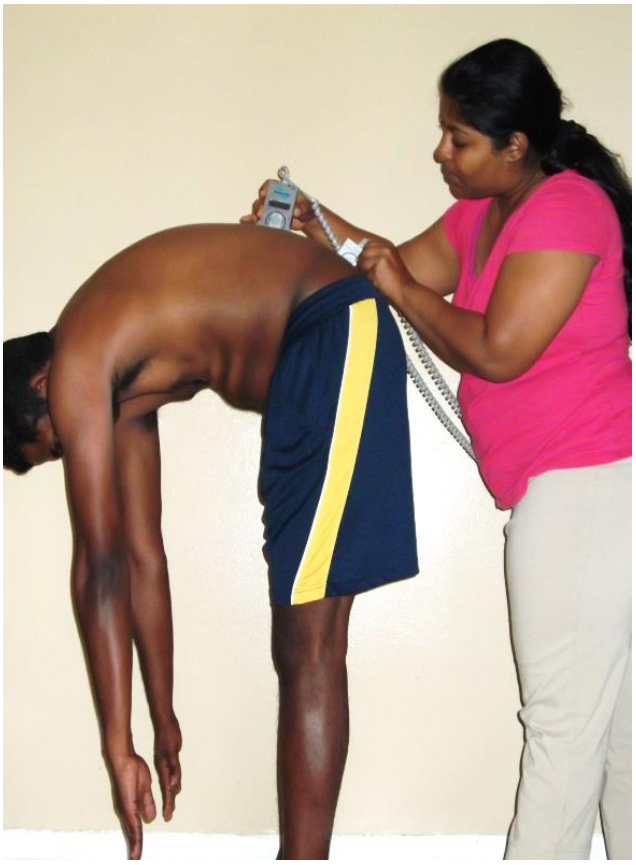

Fig. (1). Measuring lumbar flexion.

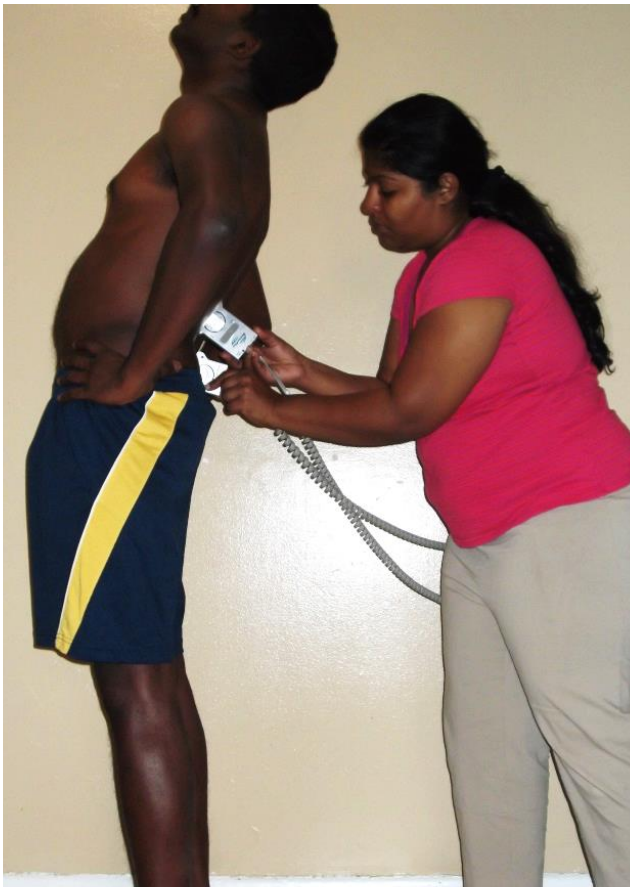

Fig. (2). Measuring lumbar extension.

[1]Tracker M.E. J-Tech Medical Industries, Utah, USA.

Table 1. Descriptive statistics of subjects.

	No Lumbar Pain (n=20)	Lumbar Pain (n=20)
Age mean, sd	26.15, 7.87	
Male	28.83	24.00
Female	25.07	27.00
Sex		
Male	6	6
Female	14	14

sacral midpoint as landmarks for inclinometer placement. These original landmarks were modified to the spinal interspaces between T12-L1 and L5-S1 as an attempt to isolate the lumbar spine, and because it was thought that these landmarks are more easily palpated. The inclinometer units were calibrated before each testing period. Measurements were recorded to the nearest degree. In order for three trials to be accepted by the Tracker system the values must be within $\pm$ 5 degrees or $\pm$ 10 degree % whichever is greater. A maximum of six attempts can be made to achieve three acceptable trails. If this is not achieved the test is considered invalid. Trials that were determined invalid were not excluded in this study because we were interested in the reliability of all trials.

1. The trial began with the subject in a neutral standing position, with the lumbar spine exposed and feet placed shoulder width apart.
2. Landmarks were palpated by the examiner. An adhesive mark was placed on the T12-L1 and L5-S1 spinal interspaces.
3. The examiner centered the slave and master inclinometer units over the adhesive marks and enters the neutral lumbar position. The computer uses this point as the zero reference point. A constant pressure is maintained under the inclinometer units throughout the test.
4. The subject was asked to bend forward as far as possible, keeping their legs straight. This point was entered a maximum flexion.
5. The subject was then asked to extend back as far as possible with their hands on their hips. This point was entered as maximal extension.

The Modified-Modified Schober (MMS) Technique

All measurements in the MMS were completed using a cloth measuring tape. Results were recorded to the closest millimeter.

1. The trial began with the subject in a neutral standing position, with the lumbar spine exposed and feet placed shoulder width apart.
2. The PSIS were palpated bilaterally and an adhesive mark was placed at their spinal intersection.
3. The second adhesive mark was placed along the superior spine at a distance of 15 cm.
4. The subject was asked to bend forward as far as possible, keeping their legs straight. The new distance between the two adhesive marks was recorded as maximum flexion.
5. The subject was then asked to extend back as far as possible with their hands on their hips. The new distance between the two adhesive marks was recorded as the maximum extension.

Statistical Analysis

Reliability: Test-retest, inter-rater and intra-rater reliability was calculated using intra class correlations ICCs (2,1 and 2,2) [15,16]. The ICC values ranges from 0 to 1, where, 1 = perfect reliability, 0.90 to 0.99 = very high reliability; 0.70 to 0.89 = high reliability; 0.50 to 0.69 = moderate reliability; 0.26 to 0.49 = low reliability and 0.00 to 0.25 = little, if any, reliability [13].

Concurrent Validity: Pearson (r) correlation coefficients were calculated to determine concurrent validity between the CDI and the MMS [17]. The r values yield the degree of correlation between two measures where, 0= no correlation between two scores and 1 or –1 = the absolute correlation between two scores. Pearson's correlation coefficients are interpreted as follows: 0.00 to 0.19 = very weak correlation; 0.20 to 0.39 = weak correlation; 0.40 to 0.69 = moderate correlation; 0.70 to 0.89 = strong correlation; and 0.90 to 1 = very strong correlation [17,18].

RESULTS

Reliability

Intra-trial reliability: The intra-trial reliability was high to very high for both the flexion and extension measurements with CDI (ICCs 0.85 - 0.96) and MMS (ICCs 0.84 - 0.98) (see Table **2**).

Intra-rater reliability: The intra-rater reliability for the CDI was moderate for all tests (see Tables **3** and **6**). It should be noted that the reliability was higher but still in a moderate range when two trials were averaged, as shown by the average measure ICCs (2,2) (see Table **4**). The intra-rater reliability for extension with rater 2 was poor.

***Inter-rater reliability*:** The inter-rater reliability was moderate for the CDI and excellent for the MMS (see Table **4**). Again, when the trials were averaged the reliability increased. ICCs were also evaluated separately for subjects with LBP and those without LBP to see if there is a difference in reliability. The data did not demonstrate any substantial differences between the two groups (see Table **5**).

Concurrent Validity

The correlation between the CDI and the MMS (see Table **7**) was poor for lumbar flexion. Lumbar extension was moderately correlated for three tests and poorly correlated for one.

DISCUSSION

This study suggests that the CDI is a valid instrument to measure lumbar mobility in the sagittal plane, however reliability was sub-optimal. The 4th and 5th edition of the

Table 2. Test-retest reliability of the CDI and the MMS (95% confidence intervals).

	Rater 1		Rater 2	
	Test 1	**Test 2**	**Test 1**	**Test 2**
CDI				
Flexion	0.94 (0.90-0.96)	0.89 (0.82-0.94)	0.96 (0.94-0.98)	0.96 (0.94-0.98)
Extension	0.87 (0.82-0.93)	0.89 (0.82-0.93)	0.85 (0.76-0.91)	0.91 (0.85-0.95)
MMS				
Flexion	0.97 (0.96-0.99)		0.98 (0.97-0.99)	
Extension	0.86 (0.77-0.92)		0.84 (0.74-0.90)	

Table 3. Single and Average Measure Intra-rater reliability for the CDI with 95% confidence intervals.

	Rater 1		Rater 2	
	Single (2,1)	**Average (2,2)**	**Single (2,1)**	**Average (2,2)**
Flexion	0.56 (0.31-0.74)	0.72 (0.47-0.85)	0.59 (0.34-0.75)	0.74 (0.51-0.86)
Extension	0.59 (0.34-0.76)	0.74 (0.51-0.86)	0.16 (-0.15-0.44)	0.27 (-0.36-0.62)

Table 4. Single and Average Measure Inter-rater reliability for the CDI and the MMS with 95% confidence intervals.

	Test 1		Test 2	
	Single (2,1)	**Average (2,2)**	**Single (2,1)**	**Average (2,2)**
CDI				
Flexion	0.52 (0.25-0.71)	0.68 (0.40-0.83)	0.47 (0.19-0.68)	0.64 (0.32-0.81)
Extension	0.48 (0.21-0.69)	0.65 (0.34-0.82)	0.45 (0.16-0.66)	0.62 (0.28-0.80)
MMS				
Flexion	0.75 (0.58-0.86)	0.86 (0.76-0.92)		
Extension	0.82 (0.68-0.90)	0.90 (0.81-0.95)		

Table 5. Inter-rater reliability of the CDI and the MMS for LBP and no LBP groups.

	Test 1			Test 2		
	No LBP*	**LBP***	**Combined**	**No LBP***	**LBP***	**Combined**
CDI						
Flexion	0.52	0.51	0.52	0.29	0.50	0.47
Extension	0.58	0.41	0.48	0.58	0.40	0.45
MMS						
Flexion	0.70	0.83	0.75			
Extension	0.84	0.85	0.82			

*LBP = Low back pain.

Table 6. Intra-rater reliability of the CDI for LBP and no LBP groups.

	Rater 1			Rater 2		
	No LBP*	**LP**	**Combined**	**No LBP***	**LBP***	**Combined**
Flexion	0.40	0.64	0.56	0.61	0.50	0.59
Extension	0.46	0.67	0.59	-0.08	0.41	0.16

LBP = Low back pain.

Table 7. Concurrent validity between the CDI and the MMS.

	Rater 1		Rater 2	
	Test 1	Test 2	Test 1	Test 2
Flexion	0.02	0.01	0.32*	0.15
Extension	-0.50**	-0.42**	-0.51**	-0.13

*Correlation is significant at the 0.05 level.
**Correlation is significant at the 0.01 level.

American Medical Association (AMA) guidelines for assessing permanent impairment levels recommended the measurement of lumbar range of motion (ROM) as an indicator of impairment due to back pain and it recommended the use of multiple measures of ROM while specifically recommending the dual inclinometer and modified – modified Schober test [11,12]. However because of the variability in results and due to lack of literature support through high quality evidence ROM has been removed from this list in the latest edition [1]. At this juncture, it is important to determine the validity of using instruments and techniques like the CDI and MMS to measure ROM as a function of impairment.

Reliability for the CDI, between raters and within raters, was between poor and moderate. The reasons could be differences in expertise, palpation skills and techniques cause difficulties in performing these tests and interpreting their results in a consistent manner, as with any other objective tests involving clinician skills and judgment. In a study by Nitschke *et al*. [3] the reliability of the J. Tech CDI was evaluated according to the AMA Guides. Inter-rater reliability was found to be poor as demonstrated by the large random error (95 % CI diff of +/-28.46 degrees for flexion). Intra-rater reliability also demonstrated a large random error with (95 % CI diff of $\pm$16.17 degrees for flexion). However, we found that the reliability increased when the average scores were tested for reliability. Thus the average of three trials would increase the reliability significantly and could make it more appropriate clinical tool by reducing the variability between trials to a considerable extent.

In the current study, inter-rater reliability of the MMS was found to be higher than the CDI. William *et al*. [5] compared reliability of the MMS and a non-computerized dual inclinometer (NCDI) in LBP subjects. They found the MMS to be more reliable and more preferred than the NCDI. These results are comparable to our study despite the fact they studied only LBP subjects. Difference in land marking, instruments and procedures must be accounted when comparing the two methods. We compared the reliability obtained for normal subjects against LBP patients and found no difference in reliability between the groups, indicating that the CDI is good for measurement of lumbar ROM in both normal and LBP patients.

Sources of error for the CDI include palpation skills, movement of the two measurement units, and awkwardness of handling the units. In previous studies to measure the reproducibility and repeatability of palpation of spinal levels findings of variable results in terms of the ability of clinicians to palpate the spinal levels and repeatability between clinicians have been reported [19-22]. Mc Kenzie and Taylor (1997) [23] studied the reliability of physiotherapist in locating lumbar spine levels by palpation. They found that inter-rater reliability (n = 13 physiotherapists) had a percentage agreement of 56%. Intra-rater reliability was much higher with a percentage agreement varying between 84 and 96 %. A suggestion, which would decrease the error caused by palpation, would be to use a standard measured distance between the units. The landmarks used for the MMS would be ideal. The PSIS is more easily palpable than a specific level of the lumbar spine. It is also over an immobile area and still relatively locatable in obese patients. The standard distance between the two units would ensure greater consistency between measurements.

Skin distraction and contraction occurs under the base of the units causing them to change places slightly between measurements. The slave and master measurement units can slip or move during assessments contributing to measurement errors. Further, the unit can cause mechanical interference when measuring extension and it can be more challenging to avoid moving the device. Decreasing the size of the units might increase the ease of application and decrease movement of the units between measurements.

There was no clinically significant correlation between the CDI and MMS measurements which indicates they measure spinal motion on a different metric and cannot be directly compared. The CDI measures the lumbar mobility in angular degrees whereas the MMS measures in linear units. The lumbar spine movements are angular therefore; the CDI has greater face validity. Further investigations comparing both the CDI and MMS to radiographic measures, or other imaging, are required to determine the extent to which each test measures true lumbar spine range of motion. One of the strengths of the current study is the inclusion of both LBP and normal subjects. This helped us to compare and inferif the disease process by itself had any effect in ROM measurement. The randomization of raters and tests helped us to prevent any error that could have been caused due to the recall or familiarity bias. Our limitation was our low sample size with only 20 people in each group, as a larger sample would have given us a better estimate of the validity and reliability of these measures.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

ACKNOWLEDGEMENTS

This study was approved by the Health Sciences Research Ethics Board (HSREB) of the University of

Western Ontario in London, Ontario, Canada. No funds were received in support of this study.

REFERENCES

[1] Rondinelli RD, Genovese E, Brigham CR, American Medical Association. Guides to the Evaluation of Permanent Impairment. 6th ed. Chicago: American Medical Association 2008.

[2] Mayer TG, Kondraske G, Beals SB, Gatchel RJ. Spinal range of motion. Accuracy and sources of error with inclinometric measurement. Spine (Phila Pa 1976) 1997; 22(17):1976-84.

[3] Nitschke JE, Nattrass CL, Disler PB, Chou MJ, Ooi KT. Reliability of the American Medical Association guides' model for measuring spinal range of motion. Its implication for whole-person impairment rating. Spine (Phila Pa 1976) 1999; 24(3):262-8.

[4] Saur PM, Ensink FB, Frese K, Seeger D, Hildebrandt J. Lumbar range of motion: reliability and validity of the inclinometer technique in the clinical measurement of trunk flexibility. Spine (Phila Pa 1976) 1996; 21(11):1332-8.

[5] Williams R, Binkley J, Bloch R, Goldsmith CH, Minuk T. Reliability of the modified-modified Schober and double inclinometer methods for measuring lumbar flexion and extension. PhysTher 1993; 73(1):33-44.

[6] Littlewood C, May S. Measurement of range of movement in the lumbar spine—what methods are valid? A systematic review. Physiotherapy 2007; 93(3): 201-11.

[7] Schober VP. Lendenwirbelsäule und Kreuzschmerzen (The lumbar vertebral column and backache). Munch Med Wsclir 1937; 84: 336-8.

[8] Macrae IF, Wright V. Measurement of back movement. Ann Rheum Dis 1969; 28(6): 584-9.

[9] Miller SA, Mayer T, Cox R, Gatchel RJ. Reliability problems associated with the modified Schober technique for true lumbar flexion measurement. Spine (Phila Pa 1976) 1992; 17(3): 345-8.

[10] Van Adrichem JA, van der Korst JK. Assessment of the flexibility of the lumbar spine. A pilot study in children and adolescents. Scand J Rheumatol 1973; 2(2): 87-91.

[11] Doege TC, Association AM, Houston TP. Guides to the evaluation of permanent impairment. 4th ed. Chicago: American Medical Association 1993.

[12] Cocchiarela L, Anderson GBJ. Guides to the Evaluation of Permanent Impairment. 5th ed. Chicago: American Medical Association 2001.

[13] Portney L, Watkins M. Foundation of Clinical Research: Applications to practice. Upper Saddle River, NJ: Prentice-Hall 2000.

[14] Fitzgerald GK, Wynveen KJ, Rheault W, Rothschild B. Objective assessment with establishment of normal values for lumbar spinal range of motion. Phys Ther 1983; 63(11):1776-81.

[15] Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull 1979; 86(2): 420-8.

[16] Fleiss JL. Design and Analysis of Clinical Experiments. New York: Wiley 2011.

[17] Fowler J, Chevannes M, Jarvis P. Practical statistics for nursing and health care. New York: Chichester: Wiley 2002.

[18] Streiner DL, Norman GR. Health measurement scales: A practical guide to their development and use. 4th ed. Oxford: Oxford University Press 2008.

[19] Billis EV, Foster NE, Wright CC. Reproducibility and repeatability: errors of three groups of physiotherapists in locating spinal levels by palpation. Man Ther 2003; 8(4): 223-32.

[20] Binkley J, Stratford PW, Gill C. Interrater reliability of lumbar accessory motion mobility testing. Phys Ther 1995; 75(9):786-92; discussion 793-5.

[21] Harlick JC, Milosavljevic S, Milburn PD. Palpation identification of spinous processes in the lumbar spine. Man Ther 2007; 12(1):56-62.

[22] Downey B, Taylor N, Niere K. Can Manipulative Physiotherapists Agree on which Lumbar Level to Treat Based on Palpation? Physiotherapy 2003; 89(2):74-81.

[23] McKenzie AM, Taylor NF. Can Physiotherapists Locate Lumbar Spinal Levels by Palpation? Physiotherapy 1997; 83(5): 235-9.

Received: April 23, 2014 Revised: August 27, 2014 Accepted: September 3, 2014