To the Graduate Council:

I am submitting herewith a thesis written by Bradley Allen Moore entitled "A Critical Examination of an Instrument to Measure Lumbar Rotation Range of Motion." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Human Performance and Sports Studies.

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# A Critical Examination of an Instrument to Measure Lumbar Rotation Range of Motion

A Thesis
Presented for the
Master of Science
Degree
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Bradley Allen Moore
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## Abstract

The purpose of this investigation was to determine the reliability of the Back Range of Motion (BROM) instrument in assessing lumbar rotation. One hundred subjects (50 males, 50 females) between the ages of 18-28 were measured by the investigator. A total of ten measurements per subject were obtained for left and right rotation. Five left and right rotations comprised the first set of scores; these were followed by five more measurements of left and right rotation that comprised the second set of scores. A Pearson $r$ of 0.97 was obtained for the correlation between the means of the five trials of each set. Intraclass correlation coefficients were computed to further determine the reliability between each set of measurements. Values of $r = 0.997$ and 0.998 were obtained for trials 1-5 and 6-10, respectively. An intraclass correlation coefficient was then calculated for the reliability between the two sets of scores ($r = 0.995$). Findings of this investigation indicate that the BROM instrument can be used to make reliable measurements of lumbar rotation.

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# Chapter 1

# INTRODUCTION

## Background

Low back pain is one of the most common medical problems affecting working age individuals today (3,13,16). Moreover, surgeries of the low back result in more than 200 million days of lost work annually (3). It has been estimated that 80% of all persons in the Western world will be afflicted with low back pain at some time in their lives (16). Given the importance of these facts it is imperative to study as many aspects of the lumbar region as possible relative to low back pain.

Spinal function is often assessed in clinical and research settings through measurements of mobility (7). Substantive research has suggested the need for reliable assessment tools in measuring lumbar rotation to further understand lumbar function and better treat patients (1,3,7,12,16,17). It is anticipated that reliable assessment instruments can be used for diagnostic purposes and to detect warning signs of future spinal dysfunction. Research has been conducted concerning various spinal movements in the sagittal plane (6,13,16,17) and in the frontal plane (7,8). From such studies normative data have been collected using diverse methods of measurement (5,7,10,13). However, data pertaining to range of motion (ROM) in the axial plane has been lacking due to the difficulties inherent in measuring lumbar rotation. Because annular fiber tears, as well as damage to the facet joint capsule, can limit ROM, this measurement is important. The current literature provides little additional information concerning reliable assessment devices for measuring low back rotation.

**Purpose**

Given the stated need for accurate and reliable assessment tools for measuring lumbar rotation, the objective of this study was to determine the reliability of the Back Range of Motion (BROM) instrument[1] for measuring lumbar rotation.

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# Chapter 2

# REVIEW OF LITERATURE

## Introduction

As was mentioned earlier, there are very few studies that have been conducted related to lumbar rotation due primarily to the difficulty in its measurement. In this chapter, the types of instrumentation used in the studies in which lumbar rotation measurements were made will be discussed.

## Radiographs

The gold standard relative to objectivity for measuring lumbar rotation are radiographic measures (10). The radiograph allows one to actually see the rotation of the spine firsthand with sequential x-rays. Degrees of rotation for each vertebra can be extrapolated from the radiographic image. Unfortunately, radiographs are expensive, time consuming, and impractical for use when measuring numerous subjects.

## Inclinometer

As part of a more complete study in which sagittal plane ROM was measured with an inclinometer, Keeley, Mayer, Cox, Gatchel, Smith, and Mooney (3), reported on a pilot study of lumbar rotation in which they used the same instrument to measure lumbar rotation. In their study subjects were instructed to flex their trunks forward until the twelfth thoracic vertebra (T12) and first lumbar vertebra (L1) interspace were at a 90-degree angle with the perpendicular; subjects were further instructed to keep their knees straight to control for pelvic motion. An inclinometer was placed transversely over the T12-L1 interspace, and readings were made as the subjects rotated their trunks to the left and to the right. Their intertester reliability for left rotation for their 22 subjects was satisfactory ($r$ =.89); however, their reliability for right rotation was much smaller ($r$ =.45) (3). The authors addressed the fact that measurements obtained from the 90-degree sagittally flexed position would likely be different from measurements obtained in an erect or seated position because the facet joints can distract more in the trunk-flexed position than in the trunk straight-position. Somewhat counterbalancing this factor, they also suggested that tension in the ligaments and capsules incumbent in the bending forward movement could possibly restrict rotation more so than in the upright position. The difficulty in maintaining the 90-degree flexed position while rotating would also appear to be a factor; however, this was not addressed in their study. The authors concluded by stating a need for more accurate measurement devices for assessing lumbar rotation.

**Other Methods**

Schenkman, Hughes, Bowden, and Studenski (11) developed a tool for measuring functional axial rotation (FAR). The authors defined FAR as movements necessary to allow one to look behind oneself. All vertebral segments (i.e. cervical to sacral) are considered when measuring FAR; furthermore, secondary movements such as flexion, extension, and lateral flexion are not restrained and thus can contribute to the movement. In the administration of FAR, subjects were seated on a non-rotating stool in the center of a suspended 1-m-diameter circular hoop. With a horizontal pointer affixed to the subjects' heads so that rotation could be measured, subjects were instructed to rotate right and left and to read the symbols placed around the hoop at eye level. Although this study showed high test-retest and interrater reliability (*r* = 0.95 and 0.97 respectively), true lumbar rotation was not measured because rotation of all vertebral segments contributed to the movement. White and Panjabi (15) have demonstrated that the lumbar region contributes a relatively small amount to total rotation of the spine (less than ten percent) when compared to the cervical and thoracic regions. The vertebral segments in the cervical and thoracic regions allow greater rotation per disc than the lumbar region. Given that the cervical and thoracic spine were greatly involved in the measurements made by Schenkman et al. (11) one can readily see the relatively insignificant role of the lumbar region in the FAR score. The practicality of setting up the equipment was also questionable for testing.

# Chapter 3

# MATERIALS AND METHODS

## Subjects

The subjects in this investigation were 100 healthy volunteers (50 males, 50 females) between the ages of 18 and 28 (mean age 21.9 yrs.). Subjects were chosen from the general population, including college students and employees of an area hospital. None of the subjects suffered from any acute back pain. Screening was carried out to ensure that none of the subject had recent back pain or soreness, or had undergone low-back surgery.

## Equipment

The BROM instrument is pictured in Figures 1 and 2. It consists of a compass fixed within a hard plastic frame designed to rest flush against the lumbar region. A velcro belt allows attachment of two encased magnets to be placed below the BROM device in order to provide a stable magnetic field for the compass and compensate for any unwanted hip movement. A non-rotating stool was used so that the measurements could be taken in the seated position; this minimized the chance for any significant hip movement. Adhesive markers were used to locate bony landmarks in order to ensure proper placement of the BROM instrument.

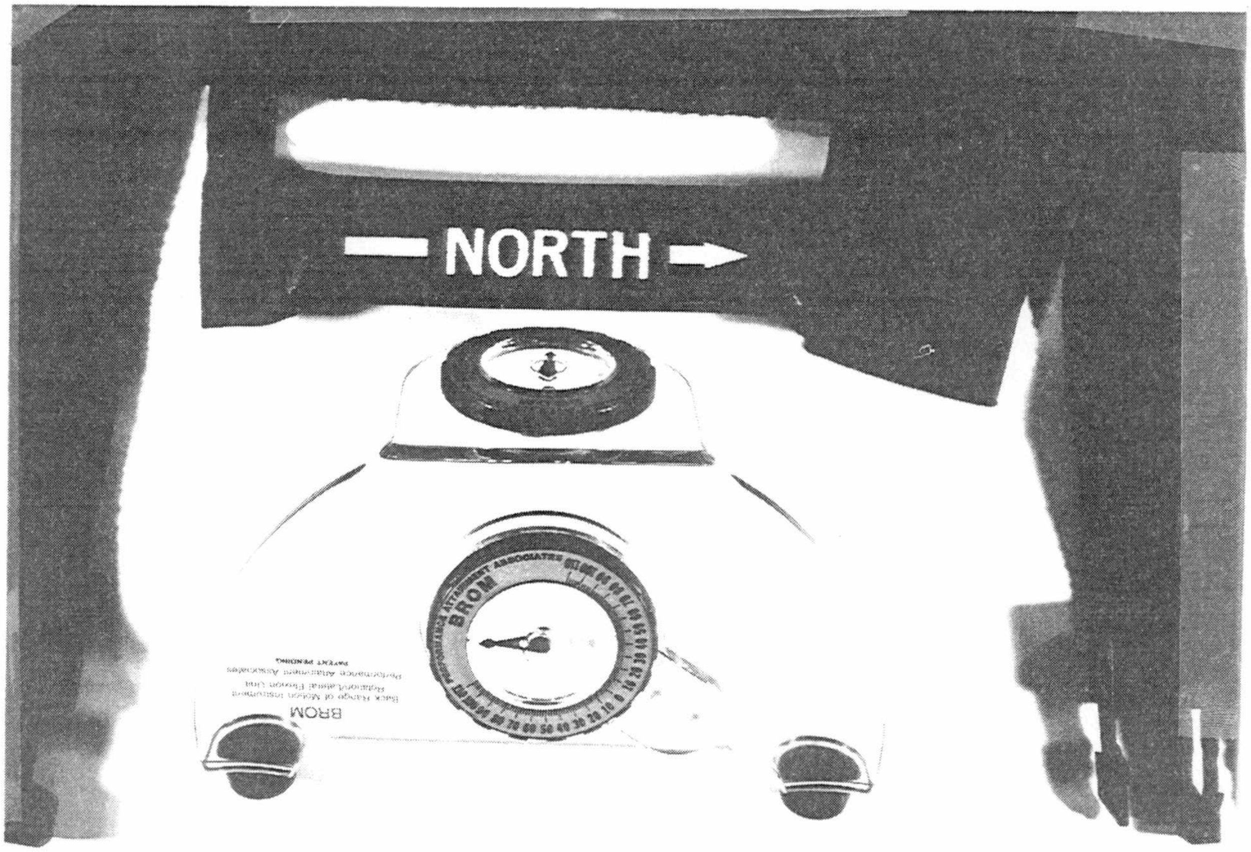


**Figure 1.** Photograph of the BROM instrument.

a. b.

**Figure 2.** Positioning of the BROM instrument-**a)** The velcro belt and magnetic attachment are secured to the seated subject; **b)** the BROM unit is firmly held level with T12. (Photographs used by permission from Performance Attainment Associates).

**Procedures**

After signing the informed consent form, subjects completed a standardized warm-up which consisted of stretches in all three planes of motion. Next, the rotation movement was demonstrated to the subjects by the principal investigator. The velcro belt was then snugly secured to the subjects' waists between the superior aspect of the sacrum (S1) and the twelfth thoracic vertebrae (T12), and the magnet was attached to the belt at the level of the sacrum. The magnet was situated approximately 2-3 inches below the belt; this created a stable magnetic field which is needed for reading the BROM instrument. The subjects were instructed to cross the arms over the chest while resting the hands on opposite shoulders and to perform the movement two times in each direction.

The purpose of this study was to determine the reliability of the BROM in measuring lumbar rotation. Because the BROM was recently developed and little research had been done on its use, there was concern that there might be a learning or warm-up effect as subjects were measured. For example, the rotation movement required in the BROM's protocol is one that is not typically done, nor were the subjects apt to have performed it previously in a structured setting as they would have in other structured flexibility measurements. Thus it seemed inappropriate to make just three measurements as is usually done when flexibility is the dependent variable (4), for following such a protocol would be of little aid in determining stability of the measurement protocol. For this reason the following protocol was adopted.

Adhesive markers were placed at the posterior superior iliac spine and at the T12-L1 interspace. The BROM device was then placed in line with T12, and the magnetic meter was zeroed. The investigator held the instrument firmly against the subject's back with his thumbs, and with his fingers firmly around the subject's rib cage to ensure that the instrument maintained a constant relationship with the subject's trunk. This step minimized movement of the BROMs independent of that of the subject.

The subjects were then told to slowly rotate their trunks to the right as far as possible, and then to the left as far as possible. The measurements were recorded and this procedure was repeated four times; thus there were five scores for rotation right and five scores for rotation left. The BROM instrument was then removed from the subject. After a short interval the BROM was again placed on the subject, using the adhesive markers as a reference. The test procedure just described was repeated five more times, resulting in a total of 10 rotation measurements in each direction.

# Chapter 4

# RESULTS

A total of ten measurements per subject were obtained for left and right rotation. Five left and right rotations comprised the first set of scores; these were followed by five more measurements of left and right rotation that comprised the second set of scores. The means and standard deviations of these data appear in Tables 1 and 2. A Pearson correlation was calculated for the means of the five trials of each set; this $r$ was 0.97. Intraclass correlation coefficients were computed to determine the reliability between each set of measurements. The $r$'s were 0.997 and 0.998 for trials 1-5 and trials 6-10, respectively. An intraclass $r$ was subsequently calculated between the two sets of scores; its value was 0.995.

Correlation matrices were generated for the two sets of rotation measurements. Table 3 presents these correlations between the ten measurements for left rotation, and Table 4 shows the correlations between the ten measurements for right rotation.

Inspection of the data revealed possible gender and directional effects. Although it was not an objective of this investigation, the data were further examined to see if any significant differences existed according to either gender or direction of rotation using a 2-way ANOVA. Gender and direction of rotation were analyzed as main effects as well as

**Table 1.** Setting One- Means and Standard Deviations of Measurements 1-5.

| Setting One | right rotation women | left rotation women | right rotation men | left rotation men |
|---|---|---|---|---|
| trial 1 | 8.70 (SD=1.59) | 9.46 (SD=1.05) | 9.22 (SD=1.58) | 9.30 (SD=1.46) |
| trial 2 | 8.78 (SD=1.56) | 9.34 (SD=1.10) | 9.40 (SD=1.31) | 9.40 (SD=1.41) |
| trial 3 | 8.74 (SD=1.65) | 9.42 (SD=.99) | 9.48 (SD=1.34) | 9.40 (SD=1.41) |
| trial 4 | 8.78 (SD=1.66) | 9.50 (SD=.95) | 9.34 (SD=1.42) | 9.40 (SD=1.41) |
| trial 5 | 8.78 (SD=1.61) | 9.50 (SD=.95) | 9.42 (SD=1.51) | 9.44 (SD=1.46) |

**Table 2.** Setting Two- Means and Standard Deviations of Measurements 1-5.

| Setting Two | right rotation women | left rotation women | right rotation men | left rotation men |
|---|---|---|---|---|
| trial 1 | 8.78 (SD=1.71) | 9.46 (SD=1.05) | 9.40 (SD=1.41) | 9.38 (SD=1.50) |
| trial 2 | 8.86 (SD=1.51) | 9.54 (SD=1.01) | 9.54 (SD=1.42) | 9.44 (SD= 1.34) |
| trial 3 | 8.86 (SD=1.57) | 9.46 (SD=.97) | 9.42 (SD= 1.46) | 9.36 (SD=1.43) |
| trial 4 | 8.90 (SD=1.57) | 9.52 (SD=.95) | 9.46 (SD=1.45) | 9.40 (SD=1.41) |
| trial 5 | 8.90 (SD=1.57) | 9.50 (SD=.95) | 9.46 (SD=1.45) | 9.40 (SD=1.41) |

**Table 3.** Measurement Correlations of Right Rotation

| Right | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 |
|---|---|---|---|---|---|---|---|---|---|---|
| T1 | 1.00 | .915 | .915 | .916 | .916 | .895 | .879 | .921 | .921 | .921 |
| T2 | | 1.00 | .945 | .963 | .963 | .919 | .951 | .962 | .980 | .980 |
| T3 | | | 1.00 | .982 | .982 | .947 | .964 | .972 | .990 | .990 |
| T4 | | | | 1.00 | 1.00 | .925 | .935 | .943 | .960 | .960 |
| T5 | | | | | 1.00 | .927 | .951 | .959 | .976 | .976 |
| T6 | | | | | | 1.00 | .902 | .930 | .943 | .932 |
| T7 | | | | | | | 1.00 | .975 | .940 | .958 |
| T8 | | | | | | | | 1.00 | .966 | .982 |
| T9 | | | | | | | | | 1.00 | .953 |
| T10 | | | | | | | | | | 1.00 |

**Table 4.** Measurement Correlations of Left Rotation

| Left | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 |
|---|---|---|---|---|---|---|---|---|---|---|
| T1 | 1.00 | .896 | .882 | .947 | .948 | .906 | .896 | .959 | .947 | .947 |
| T2 | | 1.00 | .885 | .923 | .912 | .883 | .872 | .936 | .923 | .923 |
| T3 | | | 1.00 | .933 | .921 | .868 | .879 | .920 | .933 | .933 |
| T4 | | | | 1.00 | .987 | .932 | .944 | .986 | 1.00 | 1.00 |
| T5 | | | | | 1.00 | .921 | .931 | .973 | .987 | .987 |
| T6 | | | | | | 1.00 | .896 | .921 | .918 | .921 |
| T7 | | | | | | | 1.00 | .918 | .940 | .944 |
| T8 | | | | | | | | 1.00 | .970 | .973 |
| T9 | | | | | | | | | 1.00 | .997 |
| T10 | | | | | | | | | | 1.00 |

the interaction between gender and direction. Table 5 presents the effects of gender and direction on degrees of trunk rotation. The directional effect was not significant ($p$ = .0802). Gender as a main effect was also not statistically significant ($p$ = .1185). However, the interaction between gender and direction was significant ($p$ = .0478). The effect of direction on degrees of rotation for females was statistically significant ($p$<.01) (Table 6). However, from Table 7 one can readily see for males this difference was not significant ($p$=.8730). Figure 2 depicts a plot of the interaction between gender and direction.

**Table 5.** 2-Way ANOVA of Men and Women Combined (with Direction and Gender as Main Effects)

| Source | df | F-value | P-value |
|---|---|---|---|
| Direction | 1 | 3.093 | .0802 |
| Gender | 1 | 2.459 | .1185 |
| Direction*Gender | 1 | 3.967 | .0478* |

**Table 6.** 2-Way ANOVA of Females with Direction as the Main Effect

| Source | df | F-value | P-value |
|---|---|---|---|
| Direction | 1 | 7.469 | .0074* |

**Table 7.** 2-Way ANOVA of Males with Direction as the Main Effect

| Source | df | F-value | P-value |
|---|---|---|---|
| Direction | 1 | .026 | .8730 |

*indicates significance

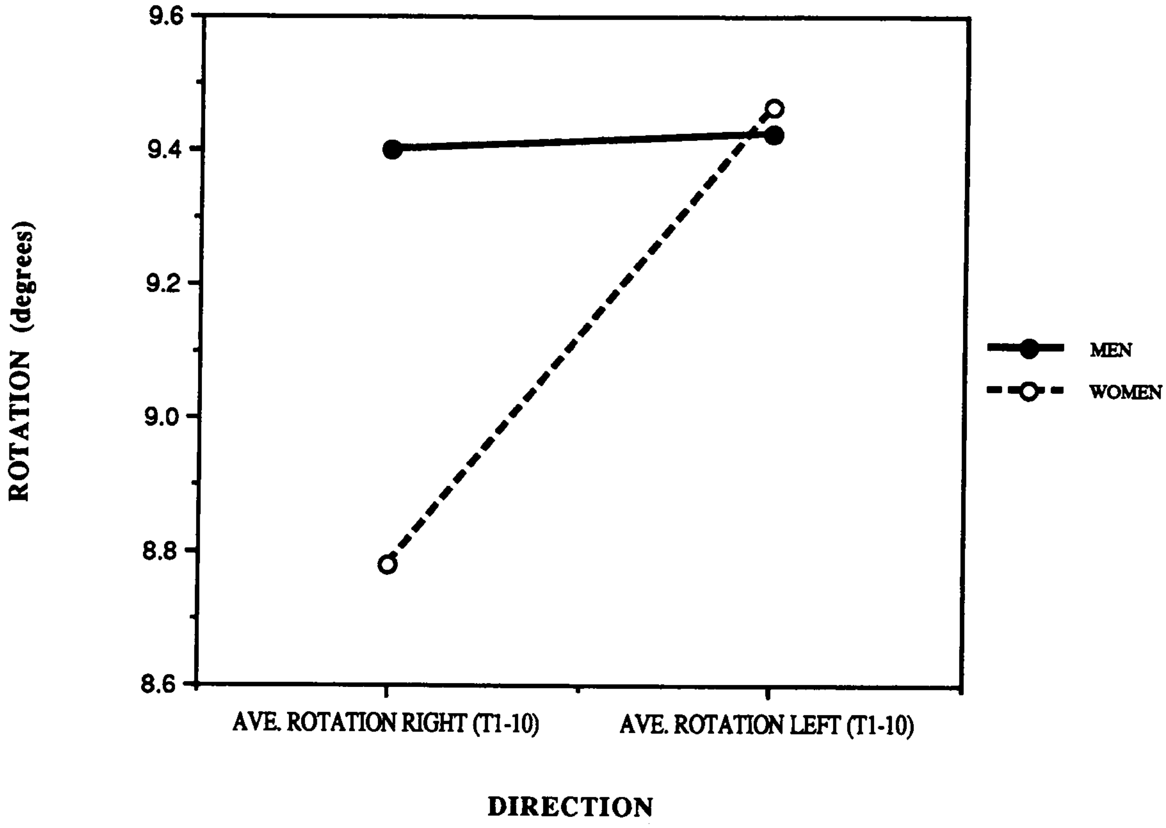


**Figure 3.** Interaction of Gender and Direction of Rotation on the Means of Measurements 1-10

# Chapter 5

# DISCUSSION

## Practicality of the BROM

The design of the BROM instrument makes it uniquely practical. The equipment is lightweight (less than 2 lbs.), and, assuming one knows the anatomical landmarks, the proper placement of the device can be readily made within 1-2 minutes. It required approximately 5 minutes to measure and to record both left and right rotation test scores. Although the BROM measurement protocol indicates that the rotation test can be made with the subject in the standing position if a non-rotating stool is not available, it would appear that sitting on the stool is most helpful in restricting unwanted hip movement.

## Data Interpretation

In this investigation there was very little difference between the means of the first five trials of each of the two sets of measurements (Tables 1 and 2). A Pearson (interclass) correlation was used to correlate the two means of the two sets of five trials; this coefficient was high. Similarly, Pearson coefficients were used to compare the means of all trials; these data are presented in Tables 4 and 5.

In estimating reliability across several trials, intraclass correlation coefficients have been shown to be more stringent than Pearson coefficients (2,9,14). The Pearson *r* is a bivariate statistic which is appropriate in the correlation of two different variables; however, reliability is viewed as an univariate statistic in that the comparison is between performances on the same variable (14). Moreover, the computations of Pearson *r* is limited to use with two variables; thus tests with multiple trials must be averaged together in order to give only two scores (2,9,14). The interclass correlation is further limited in that trial-to-trial variation within tests cannot be detected (2,14). However, if the intraclass correlation is used, one is able to analyze changes in means and standard deviations from trial to trial; moreover, intraclass correlation can be used to correlate several trials of univariate measures in determining reliability (14). Additionally, multiple scores do not need to be averaged to obtain intraclass *r* values.

The initial intraclass correlation coefficients that were computed in this investigation were between the scores made within the first and second sets of measurement; the resulting coefficients indicated consistency (*r*'s = .997 and .998, respectively). The next intraclass correlation coefficient computed was between the means of the measurements made in the first and second sets of scores; this correlation was also high (*r* = .995). All of these values indicate that very reliable trunk rotation flexibility scores can be obtained with the BROM instrument. However, it should be stated that to obtain good test-retest reliability there are other factors to consider. To facilitate having good reliability, the investigator practiced (a) finding the anatomical landmarks requisite for instrument placement on a number of individuals and (b) administering the trunk rotation test on a number of individuals. Another factor which may have contributed to the good reliability scores attained was the standardized warm-up that the investigator had each subject complete prior to administration.

Although the major objective of this study was to determine the reliability of the BROM instrument, it was interesting to note that the female subjects in this investigation tended to be less symmetrical than the male subjects with respect to rotation (Tables 5-7, Figure 2). There does not appear to be any reason for the asymmetry seen in the females. In this study females rotated significantly further to the left than to the right ($p<.01$). This resulted in a significant interaction between gender and direction ($p= .0478$). Further research may be desirable if similar differences are seen in other subject populations. Additionally, the results of this study may be difficult to extend to subjects with acute low back pain.

## Conclusion

The BROM instrument utilized in this study can be used to make reliable measurements of lumbar rotation. Moreover, many subjects may be quickly and accurately measured in a relatively short period of time.

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## REFERENCES


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# VITA

Bradley Allen Moore was born in Oak Ridge, Tennessee on May 28, 1972. He attended public and private primary schools in Tennessee and Texas. He graduated from Osborne High School in Marietta, Georgia in June, 1990. He entered the University of Tennessee, Knoxville, during the fall semester of 1990 where in May, 1994 he received the Bachelor of Science in Cell Biology. He entered the Master's program in Exercise Science in August of 1994. The Master of Science degree was received August, 1996. He is currently preparing to attend physical therapy school in January, 1997.