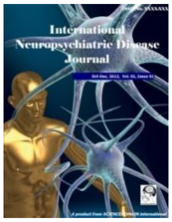

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Normative Values for Active Lumbar Range of Motion Using the Back Range-of-Motion Measurement (BROM) Device in School Age Children: A Cross-Sectional Study

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Authors' contributions

This work was carried out in collaboration between authors VCV, SG and KVK. Author VCV designed the study and wrote the protocol. Author SG preformed the statistical analysis, managed the literature search and wrote the first draft of the manuscript with assistance from authors VCV and KVK. Both authors read and approved the final manuscript.

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ABSTRACT

Background: Quantifying changes in spinal mobility throughout the child's development, and/or during a course of therapy is a valuable component in the pediatric physical therapy management. The purpose of this study was to establish normative values of lumbar spinal mobility on healthy schoolchildren between the ages of 6-12 years.
Methods: 294 children within the age group of 6-12 years were selected from two government schools and two private schools of Mangalore, Karnataka, India. Normative values for each movement of lumbar spine in all the cardinal planes were measured using BROM measurement procedure.

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Results: Age and gender had a highly significant effect on the lumbar ranges of motions in flexion, lateral flexion and rotations with p<.05 except for the effect of gender on Extension range. There was no correlation was found between body mass index and hamstring length with lumbar ranges in males and females of any of the age groups.
Conclusion: We developed normative values of spinal mobility for each sex and age grouping from 6-12 years of healthy children. These measures of spinal mobility might help the therapist to identify early restrictions in back mobility in children with neuromusculoskeletal problems and other pediatric populations who are at risk for restrictions in spinal mobility. Early identification could lead to better prevention and also more timely effective treatment programs.

Keywords: Back; child development; normative values; lumbar spine.

ABBREVIATIONS

BROM-Back Range-Of-Motion Measurement; BMI – Body Mass Index; RHS – Right Hand Side; LHS – Left Hand Side.

1. INTRODUCTION

The process of development and growth influences structure, function of individual vertebrae which contributes for mature spinal posture and mobility in adults [1]. Throughout infancy and early childhood, bone growth occurs rapidly and factors such as genetic makeup, nutrition, general health and hormonal levels affect the rate of bone growth [2]. Spinal mobility in the developing child may be affected by diseases, disorders and/or injuries of the neuromuscular or musculoskeletal systems. Abnormal spinal mobility may develop in response to a variety of factors such as muscle weakness, Protective pain mechanisms in musculoskeletal disorders may cause low back pain and muscle guarding, resulting in limited spinal motion. There are various other factors that affect the lumbar spine mobility such as in developmental disorders presenting with tone abnormalities, disturbances in equilibrium reactions, persistence of primitive reflexes, sensory deficits and positional factors [3-10]. This development of abnormal spinal mobility may contribute to further compensation, and secondary deformities as the child's spine matures. Hence assessment and management of abnormal lumbar spine mobility is essential in the clinical setting.

Earlier studies on spinal mobility in children from western population showed that they vary in measurement methods, spinal motions measured, and age groups of their young subjects. These studies stated that lumbar spine mobility is greater in children than in adults which suggesting that the spinal mobility of children cannot be directly compared with adult normative data [11-13]. A reliable method for measuring and monitoring spinal mobility at key points in a child's development, and/or during a course of physical therapy is needed for pediatric physical therapy practice. BROM II device is an instrument used to measure lumbar range of motion which has its psychometric properties established [14]. There are studies stating normative values of lumbar ranges using BROM II device in adults [15,16] but little information is available for children.

A study by Kondratek et al. [17] to find normative lumbar ranges in children between five to eleven years of age, using BROM II stating the values in Western population. This study stated that active lumbar flexion in the girls aged eleven years was reduced as compared to five years. Side bending and Rotation were reduced in both girls and boys. There are studies stating that there is difference between the anthropometric values of children belonging to different countries as environment plays an important role in the height and weight of the children [18]. So the aim of this present study was to establish the normative data for active lumbar flexion, extension, side bending and rotation with the help of BROM II device in school going children and to find any correlation between body mass index, hamstring length and lumbar ranges obtained by BROM II device.

2. METHODOLOGY

The study was approved by Institutional Ethical Committee Kasturba Medical College, Mangalore, Manipal University, Karnataka, India. Permission from the Block Education Officer

(BEO) of Mangalore city was taken to select four schools from the list randomly. 294 children within the age group of 6-12 years (147 boys and 147 girls) was selected from two government schools and two private schools of Mangalore city. Sampling was done according to stratified random sampling for each age and sex. Permission from the school authorities to carry out the study was taken. A call for staff member in each of the four schools to identify the target group. Parental consent form, subject assent form, and screening form were sent home with every six-, seven, eight ,nine, ten ,eleven and 12-year-old child in every elementary school. A screening form with questions specific to each exclusion criterion was completed by the parent or guardian of each subject prior to admission to this study. Once the required forms were completed and consent/assent was given, data collection was carried out during teacher approved, nonacademic times within the school day. Children within the age group of 6-12 years were screened and exclusion criteria included with any history of disorders or activity that may affect spinal posture or mobility, any history of neurological or musculoskeletal disorder present, any history of surgery confined to thoracic, lumbar or abdominal region, obese children (BMI>27.8 for males and BMI>27.3 for females) [19] and any history of low back pain.

The documentation of age (years, months and days) from date of birth mentioned in admission certificate/school register, weight in Kilograms (kg) measured by calibrated weighing machine, height measured in centimeters (cm) by measuring tape was done. Hamstring muscle length was also assessed with the use of Sit and Reach test [20]. The lumbar flexion, extension, side bending and rotation ranges were measured according to the procedure mentioned by BROM II device manual (Performance Attainment associates) [17]. This is a modified inclinometer that eliminates the need to measure sacral flexion. It has a pivot that is the part of the base, which is placed on the sacrum so all readings are relative to the sacrum. It has a movable arm that is placed at the T12 spinous process level where the range of motion has to be measured. The order of doing the test was in a uniform sequence. During the testing, verbal commands like "bend as far as you can" were given to the subject in order to gain a maximal effort. The subject was asked to repeat each movement 6 times. First 3 repetitions served as warm-up and as training for the movement. The mean of the next three readings was considered for data analysis. Rest period of approximately 1 minute was given in between the trials

2.1 Procedures for Measuring Lumbar Range of Motion Using BROM II

Marking of the axis for measurement of the lumbar ranges on T12 and S1 was done by non-permanent washable marker.

2.1.1 Flexion/extension measurements

For lumbar measurements palpate and mark S1 and T12.

Place the BROM flexion/extension unit on the sacrum with pivot point on S1have the subject stretch the Velcro straps across the lower abdomen. Check that both contact points on the unit are held firmly against the sacrum. The downward pull of the straps is essential to maintain the contact points against the sacrum during flexion and extension. Demonstrate and have the subject perform flexion and extension movements. Emphasize the importance of smooth steady movements that go to the end range. Check that both contact points remain on the sacrum and the pivot point remains on S1 during patient flexion and extension.

Have the subject stand erect. Feet should be shoulder width apart. Place the movable arm on the upper measuring point T12 and record the arm reading. This reading is the distance in cm between S1 and T12 and can be used to position the arm during future measurements to assure that the same segment of spine is measured. With the arm tip on T12 record the initial reading from the outer scale. Remove the arm from T12 and place a finger securely on T12. Have the subject slowly bend forward trying to lay the palms of the hand on the floor. Replace the arm tip on T12 and record the full flexion reading. Subtract the initial flexion reading from the full flexion reading to obtain true flexion (Figs. 1 and 2).

Extension measurements: check that the patient is standing erect. Have the patient put their arms across the chest with hands on their shoulders. Place the arm tip on T12 and record the initial reading from the outer scale. Remove the arm tip from T12 and have the patient extend backward. Place the arm tip on T12 and record the full extension reading. Subtract the full extension reading from the initial reading to obtain true extension.

Fig. 1. Measuring lumbar flexion using BROM

Fig. 2. Measuring lumbar extension using BROM

2.1.2 Rotation movements

The magnetic angel meter measures to the magnetic reference placed on the spine thus eliminating unwanted spine movements below that point. An added advantage of this method is that measurements are made with the trunk in the vertical position. Utilize the markings made for S1 and T12 made during the flexion/extension measurements. Place the belt between S1 and T12 with the Velcro side out. Place the magnetic reference over the sacrum and attach the Velcro straps. Have the subject stand erect facing west so that the arrow on the magnetic reference points north. Feet should be flat on the floor. The subject's arms should be placed against head. Demonstrate and have the subject do rotation movements. Place the rotation/lateral flexion unit so the unit's feet are in line with T12. Hold the center of the unit firmly against the patients back and zero the magnetic meter. Place the thumbs over the back of the unit's feet and grasp the rib cage with the fingers. Check that the meter is still zero. Have the patient slowly turn the shoulders to the right making sure they go to full range. Record the reading. Have the patient slowly turn the shoulders to the left making sure they go to full range. Record the reading.

2.1.3 Lateral flexion measurements

The meter unit is designed so when the examiner grasps the rib cage the unit becomes the part of the patient, thus eliminating tracking errors. The protocol eliminates unwanted hip rotation and flexion. Demonstrate and have the patient do lateral flexion movements. Emphasize the importance of smooth steady movements that go to end range. Have the patient stand erect with nose nearly touching the wall. This position will keep the patient from bending forward during lateral flexion measurements. Place the rotation/lateral flexion unit so the unit's feet are in line with T12. Place the thumb over the back of the unit's feet and grasp the rib cage with the fingers. Adjust the unit's position on the back until the inclinometer read zero.

For right lateral flexion have the patient slide their right hand down the back of their leg with the body weight shifted to the left foot and keeping the leg straight. Record the reading.

For left lateral flexion have the patient slide their left hand down the back of their leg with the body weight shifted to the right foot and keeping the leg straight. Record the reading.

2.2 Procedure to Measure Hamstring Flexibility

Participants' position: The participants' sat at the SR box and fully extended both legs so that the sole of the feet were flat against the end of the box. The hands were put on top of each other with their palms down.

Movement/measurement

The participants slowly reached forward while sliding their hands along the box scale as far as possible. Reading of the distance reached along the scale after the subject held the position for two seconds was recorded to the nearest centimeter. Average of three trials on each limb was recorded for analysis.

2.3 Data Analysis

Statistical Package for Social Science (SPSS) Version 13.0 was used for analysis. Descriptive statistics was used to obtain normal values of lumbar ranges for each age group with 95% confidence interval based on mean and standard deviation (SD). Two way Analysis of Variance (ANOVA) was used to find out relation of age and gender on the lumbar ranges measured by BROM II device. Spearman's correlation co-efficient was used to check correlation between BMI and hamstring length with lumbar ranges obtained from BROM II device.

3. RESULTS

Table 1 showed Total number of children included in the study. The study included total 294 children aged between 6-12 with each age group consisting of 21 males and 21 females.

Table 1. Total Number of Children included in the study

Age (Yrs)	Gender		Total
	Female	Male	
6	21	21	42
7	21	21	42
8	21	21	42
9	21	21	42
10	21	21	42
11	21	21	42
12	21	21	42
Total	147	147	294

Table 2 the normative data of lumbar range of motion measured by BROM II device. Descriptive statistics was used to obtain the mean and SD of lumbar range of motion by using BROM II device in children belonging to 6-12 years of age.

Table 3 showed the two way ANOVA results to compare ranges between different age and gender. Results showed that there was highly significant effect of age and gender on all ranges except for the effect of gender on extension range which is non-significant

Table 4 showed the mean and SD of BMI & Hamstring length according to age and gender

Table 5 showed the correlation between BMI & Hamstring length with ranges of motion by BROM II device

4. DISCUSSION

Quantifying changes in spinal mobility throughout the child's development, and/or during a course of therapy is a valuable component in the physical therapy management of abnormal spinal mobility [21]. The anthropometric measurements such as height and weight of the subjects included in the present study were in agreement with the Indian norms for the respective age groups except for males whose BMI was more than the normal values [22].

Age and gender had a highly significant effect on the lumbar ranges of motion except for the effect of gender on extension range. One explanation for this is that extension is performed less commonly in activities of daily living than anterior trunk flexion and lateral flexion. No correlation was found between body mass index and hamstring length with lumbar ranges in males and females of any of the age groups. Several studies have been done to evaluate lumbar ranges of motion using different methods and on different age groups [11,13,15-17,23]. Close examinations of patterns within the data reveals similarity in the values of lumbar ranges. In the present study variations were found between values of lumbar flexion and extension range of motion in males and females. These results were similar to that of the previous studies [13,17]. As compared to the previous studies the values of lumbar flexion and extension ranges in the present study were more in males than in females in all the age groups. This increase in lumbar ranges can be attributed to many factors like increase in level of physical activities [24], early attainment of skeletal and hormonal maturity [25] and cross sectional variations like anthropometric values among western and Indian children [18].

Results of the present study depicted that lumbar side flexion and rotation ranges followed an increasing trend with age. Haley et al. [13] measured lumbar flexion and side flexion ranges using tape method and suggested an increase in ranges of lumbar spine with increase in age, which was similar to the results of the present study. Contradictory to the results of the present study, study done by Kondratek et al. [17] stated a decrease in the lumbar side flexion and rotation ranges with increase in age. The increase in lumbar side flexion and rotation ranges in the present study can be attributed to the sagittal orientation of lumbar facets that are achieved as age increases, [26,27] the sagittal orientation of the zygapophyseal joints leads to increase in these two ranges which take place in frontal and transverse plane respectively [28].

Table 2. Normative data of lumbar range of motion measured by BROM II device

Age in years	Flexion (in degrees)		Extension (in degrees)		RHS flexion (in degrees)		LHS flexion (in degrees)		RHS rotation (in degrees)		LHS rotation (in degrees)	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
6	38.19±5.8	37.22±5.8	13.33±2.4	13.73±1.6	32.52±2	27.89±3	32.78±2.9	27.90±3.1	13.71±2.9	14.00±1.7	14.79±2.7	13.08±1.5
7	37.95±3.1	34.19±7.1	13.32±1.5	11.92±1.9	33.33±2	29.59±3	33.40±3.1	28.67±3.9	15.11±2.7	15.70±3.1	15.89±2.7	14.78±2.6
8	39.56±3.1	37.95±4.1	12.46±1.3	13.59±2,4	35.19±2	30.06±4	34.94±1.9	27.94±3.9	14.03±2.0	17.02±2.2	14.33±1.8	16.83±2.4
9	38.43±3.3	36.70±5.6	12.92±1.4	12.84±1.8	35.51±2	31.44±2	34.43±2.3	31.60±3.1	15.52±1.4	13.14±1.7	16.03±1.2	13.08±1.3
10	39.35±3.3	38.46±4.3	13.37±1.3	13.84±1.9	33.17±1	31.52±3	33.43±1.6	31.49±2.8	15.92±1.3	15.83±2.7	15.76±1.0	16.83±2.7
11	40.40±4.6	39.46±2.5	14.14±1.3	13.87±0.9	37.49±2	37.62±2	37.37±1.5	37.62±2.7	16.97±1.0	14.22±1.2	17.40±0.8	14.19±1.5
12	39.25±2.8	40.27±2.2	13.51±1.8	12.79±1.5	35.11±2.	40.32±2	36.08±2.3	40.19±2.5	16.73±1.3	13.70±1.5	18.49±1.7	13.48±1.3

Table 3. Two way ANOVA results to compare ranges between different age and gender

Parameter	Source	F value	p value
Flexion range	Main effect of age	4.36	0.00**
	Main effect of gender	6.58	0.01*
Extension range	Main effect of age	3.10	0.02*
	Main effect of gender	0.10	0.74
RHS flexion range	Main effect of age	46.27	0.00**
	Main effect of gender	37.34	0.00**
LHS flexion range	Main effect of age	51.40	0.00**
	Main effect of gender	53.94	0.00**
RHS rotation range	Main effect of age	5.36	0.00**
	Main effect of gender	6.82	0.03*
LHS rotation range	Main effect of age	7.58	0.00**
	Main effect of gender	42.48	0.00**

**- significant, **- highly significant*

Table 4. The mean and SD of BMI & Hamstring length according to age and gender

Age (yrs)	BMI (kg/m^2)		Hamstring length (cm)	
	M	F	M	F
6	16.78±2.97	14.83±2.44	25.61±2.13	25.95±2.08
7	15.85±1.73	14.69±2.83	25.66±2.43	26.14±1.65
8	18.30±1.55	16.16±2.95	24.76±1.84	26.19±2.80
9	20.41±2.97	15.48±3.32	23.19±1.12	27.80±1.96
10	22.28±2.88	16.43±2.25	23.23±1.22	25.04±1.62
11	17.02±2.11	15.45±2.34	24.90±1.64	26.83±2.76
12	17.22±1.44	15.23±2.63	24.47±1.56	26.00±2.52

BMI – Body Mass Index, F- Females, M – Males

Table 5. Correlation between BMI & Hamstring length with ranges of motion by BROM II device

Brom ranges	BMI		Hamstring length	
	r value	p value	r value	p value
Flexion range	0.02	p>0.05	0.02	p>0.05
Extension range	-0.09	p>0.05	0.06	p>0.05
RHS flexion range	0.03	p>0.05	-0.00	p>0.05
LHS flexion range	0.03	p>0.05	-0.05	p>0.05
RHS rotation range	0.17	p<0.05*	-0.10	p>0.05
LHS rotation range	0.18	p<0.05*	-0.15	p<0.05*

** - significant, BMI – Body Mass Index*

In the present study, males had more lumbar flexion, extension, side flexion and rotation ranges than females. Normal developmental changes in ligament for more stability in spinal structures requiring increase in collagen fibers and reduction in elastin fibers take place earlier in females. This may contribute to greater stiffness of the soft tissues and increased resistance to lumbar ranges [26].Age and gender had highly significant effect on the lumbar range of motion in the present study which was correlating with studies done by Mc Gregor et al. [16] Fitzgerald et al. [29] Abdelmonem A and Hegazy [30]. A recent systematic review on the effect of age on lumbar range of motion by Intolo P have also concluded that age had significant changes in lumbar spine mobility [31]. Increased loading on lumbar spine with an increase in age may affect the lumbar ranges. The increase in level of physical activity and early onset of skeletal maturity in males and females might also contribute to change in lumbar range of motion.

Body mass index of the males included in this study was found to be more than the normal values of Indian children [19]. This correlates with the studies [32,33] which concluded that there was rise in the weight among school going children. The children recruited in the present study belonged to varied economic strata. Hence change in lifestyle and lack of nutrition education might play an important role in increase in BMI. In the current study there was no correlation found between BMI and lumbar ranges obtained by BROM II device except for those on rotations which can be supported by the study done by Mc Gregor et al. [16]. Another study done to correlate BMI with all lumbar ranges showed similar results as depicted in the present study. The lumbar ranges of motion depend on various articulating structures while non-articular structures like body fat might not have any contribution in the lumbar ranges. The changes in the lumbar ranges can be attributed to the normal anatomical growth of the children rather than BMI [13].

There was no correlation between Hamstring muscle length and the lumbar range of motion in the present study except in left hand side rotation. Results of the present study were contradictory to the previous study [34] investigating the relationship between hamstring flexibility and pelvic rotation during forward bending in healthy individuals which concluded that decreased hamstring flexibility was observed with limited movement of the lumbar spine. But study done by Johnson EN et al. [35] and Norris CM [36] gave conclusions supporting the results obtained in the present study. When two body segments move, the segment that was more mobile moved first which could be termed as relative flexibility [37]. Forward bending involves lumbar flexion as well as pelvis tilting hence correlations may exist between hamstring tightness and pelvic motion, not in terms of total motion range, but rather motion ratio or temporal pattern. Individuals with tighter hamstrings might have begun the movement from a position of reduced anterior tilt. If hamstring muscle was tight, anterior tilt of the pelvis would be reduced because the hamstrings attach to the ischial tuberosity. However, the line of action of the hamstrings and attachment of hamstrings to the ischial tuberosity are slightly posterior to the femoral head. These minimal posterior forces tend to posteriorly rotate the pelvis and are outweighed by activity of the hip flexors tending to anteriorly rotate the pelvis. Therefore, any change in the length of the hamstrings may not alter the total range of pelvic tilt [36].

5. CLINICAL IMPLICATION

The present study established normal values of lumbar range of motion in children from age 6 to 12 years. The normal values developed in the present study can be used as baseline data for comparing the spinal motion of a child whose spinal mobility is hampered.

6. LIMITATIONS

Normal values of lumbar ranges obtained in the present study may not be generalized to all Indian children and also limited to BROM values. Relationship between core muscle strength and lumbar mobility was not addressed. Further studies can be done to correlate the normative values of lumbar range of motion with ranges evaluated by radiographs in children with and without disabilities. Studies can be done to evaluate the relationship between core muscle strength and lumbar mobility. Lumbar range of motion in obese children can be studied.

7. CONCLUSION

Normative values of lumbar range of motion for children from 6-12 years of age was established in the present study which can be used as a baseline for evaluation and monitoring progress during periods of physical therapy intervention. Age and gender has an effect on the lumbar ranges. BMI and hamstring length has no contribution to the change in the lumbar range of motion.

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DISCLAIMER

The contents of this article are solely the responsibility of the authors.

What is already known	What is this study Adds
Quantifying changes in spinal mobility throughout the child's development, and/or during a course of therapy is a valuable component in the pediatric physical therapy management. There are studies stating normative values of lumbar ranges using BROM II device in adults but little information is available for children.	We developed normative values of spinal mobility for each sex and age grouping from 6-12 years of healthy children. Hence these measures of spinal mobility will provide the therapist to help identify early restrictions in back mobility in children with neuromusculoskeletal problems and other pediatric populations who are at risk for restrictions in spinal mobility.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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