Normative Values for Active Lumbar Range of Motion in Children and Confounding Factors That Affects the Active Lumbar Range of Motion

Sanjeevni Sawale*, Richa Bisen and Senthil Kumar E

Department of Physiotherapy, Sinhgad Society’s SKN College of Physiotherapy, Pune, India

Abstract

Purpose: The purpose of this study was to establish normative values for active lumbar movement in children five, seven, nine, and 11 years of age and to find the confounding factors that affect the lumbar range.

Method: End range active flexion, extension, and right- and left-side bending of the lumbar spine were measured for 400 normally developing children (200 girls, 200 boys) using dual inclinometric technique. Means were determined for each motion by age and sex. Group relationships were explored.

Results: Normative values for lumbar spine cardinal plane movements were identified. Reduced lumbar movement was found in the 11-year-old group compared with the 5-year-old group in both girls and boys. Flexibility levels were defined using percentiles as poor (<25th), moderate (between 25th and 75th), good (between 75th and 95th), and very good (>95th) respectively. The mean value for forward flexion, extension right and left lateral flexion for all participants was 55.9 ± 17, 21.8 ± 6, 15.2 ± 5.1 and 14.9 ± 5.

Conclusion: Normative data for cardinal plane movements of the lumbar spine provide therapists with a baseline for assessing spinal mobility of children of these ages.

Keywords: Normative value; Lumbar ranges; Children

Introduction

Adequate Range of Motion (ROM) is necessary for maintenance of normal spinal movement patterns in the developing child [1]. During the growth and maturation process, there forces that contributes to the shape of the individual vertebra which leads to changes in the posture and mobility of the mature spine [2]. Patterns of change across the adult life span and the proposed reasons for these changes provide a valuable perspective for beginning exploration of spinal mobility in children [3-6]. Quantifying spinal mobility is an important component of the physical therapy examination process for both adults and children who experience limited spinal mobility as the result of spinal disorders or injury [3,4-11].

Two important developmental milestones in the lumbar vertebrae are achieved between seven and 11 years of age. First, the lumbar spine completes primary ossification between approximately seven and nine years [12,13]. As the percentage of bone increases relative to the percentage of cartilage, the bone becomes less malleable in response to both external and internal forces. Second, the lumbar facet joints change from a relatively frontal to a sagittal plane, and the shape changes from relatively flat at birth to curve by approximately 11 years of age [14]. This change in lumbar facet orientation is thought to play a role in the quantity and direction of lumbar movement.

The confounding factors that affects the spinal mobility involves not only the ROM of a joint or series of joints but it is also affected by internal influences such as the type of joints, the elasticity of muscle tissues, tendon, ligaments, and length of musculature and also by external influences such as age, gender, height, weight [3,9].

Lumbar range in children is important because spinal mobility in the developing child may be affected by diseases, disorders and/ or injuries of the neuromuscular or musculoskeletal systems [10]. Numerous techniques have been developed to assess spinal flexibility such as visual estimation [11,12] finger-to floor distance [13], sit-and-reach measurements [14,15] standard or modified Schober's methods [13], subjective reports through questionnaires [16] and the use of devices such as flexi-curves [17], protractors and goniometers and inclinometers [18,19]. The preference of technique of spinal ROM evaluation in routine clinical practice is often based on its reliability, validity, simplicity, cost, level of invasiveness and technicality [11,12]. Establishment of reference norms for spinal flexibility requires assessment techniques with high level of validity and reliability. In light of this, the inclinometric technique has been found to be valid and reliable [19] and has been recommended as a valuable tool in routine clinical for assessment of spinal ROM. It is believed that the inclinometric technique could measure and differentiate movements of the hip from those of the lumbar spine [20] and could be learned quickly within a short period of time [19]. Normative values of spine Range of Motion (ROM) are essential for proper diagnosis of spinal impairments and in the monitoring of effect of treatment and patient's recovery [21,22].

Normative values are also useful for physical therapists to estimate the active end-range spinal position achieved in each cardinal plane motion as they do not have direct access to radiographs as physicians quantify spinal mobility using radiographs [23]. They are also essential for proper diagnosis of spinal impairments. Early identification and management of abnormal lumbar spinal mobility is essential to prevent further deformity. Normative data and confounding factors that affects

*Corresponding author: Sawale Sanjeevni, Department of Physiotherapy, Sinhgad Society’s SKN College of Physiotherapy, Pune, India, Tel: 020 2410 6137; E-mail: Intern.sanjeevnisawale@gmail.com.

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lumbar range is a valuable component in prevention of deformities [23].

Adult lumbar spine mobility is frequently addressed in the literature and normative values for adult spinal mobility have been established using a variety of measurement devices [11] little information is available regarding normal lumbar spine mobility for children five to 11 years of age. The purposes of this study were to establish normative values for active lumbar flexion, extension, side bending in children five, seven, nine, and 11 years of age; to find the confounding factors that affect the lumbar range.

Materials and Method

Four hundred healthy children participated in this study. Children who were 5, 7, 9 and 11 years of age were included in this study. Exclusion criteria included a history of disorders or activities that may affect spinal posture and mobility, such as back pain or injury, scoliosis, musculoskeletal disease, neuromuscular disease [11]. Parental assent was filled and need of the study was well explained to parents and children. Permission from Institutional Ethical Committee (IEC) was taken (Ref: SKNCOPT Academic/2014/IEC/205).

Materials

2 bubble inclinometer, measuring tape, weighing scale, audiometer, sit and reach box, pen and paper.

Measurments

Anthropometric measurements included height, weight, Body Mass Index (BMI), Limb Length (LL), Trunk Length (TL) and hamstring flexibility.

1. Height was measured using a stadiometer. The subject stood barefooted on the platform of the scale looking straight ahead while the horizontal bar attached to the height meter was adjusted to touch the vertex of the head (Figure 1).

2. Weight was measured on weighing scale standing in an erect posture looking straight ahead (Figure 2).

LL was measured by taking the distance between the anterior superior iliac spine and the sole of the foot with the participant in a supine position (Figure 3).

TL was measured by taking the distance from the anterior superior iliac spine to the acromion process with the participant in an erect position sitting on stool (Figure 4).

3. Hamstring flexibility- The participants sat at the sit and reach 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. 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 2s was recorded to the nearest centimeter. Average of three trials on each limb was recorded for analysis. 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 (Figure 5).

Procedure for measuring lumbar ranges using dual inclinometer

Dual inclinometric technique was used to assess spinal ROM in flexion, extension, right and left lateral flexion. The assessment procedure for spinal ROM was explained and demonstrated to each consecutive participant at inclusion. Prior to the test, the participants were required to warm up with back stretches and a 5-minute walk at self-determined pace around the research venue. Measurements
The mean of three consecutive movements was used in the final analysis to determine spinal ROM.

**For flexion and extension**

The upper edge of the sacrum (S1 vertebra) and the lower edge of the T12 vertebra was palpated in the participant in a standing position. The middle of the platform of the first inclinometer was put on the sagittal plane of the spinous process of T12, and the second inclinometer was set on the sagittal plane of the spinous process of S1.

In the neutral position, the participant was asked to stand erect with their hands hanging without any effort toward the ground. From this position, the participant was then asked to flex forward as far as possible with their knees straight. Readings were taken.

To get the true lumbar ROM, the readings of the lower inclinometer was subtracted from those of the upper inclinometer (Figure 6). The flexion protocol was repeated for extension having the participants extends back for full extension instead of flexing forward (Figure 7).

**Lateral flexion measurement**

The inclinometers was placed on the frontal planes of the both the S1 and T12 vertebrae so that the bases of the inclinometers line up with the lines drawn at this planes. The two inclinometers was held upside down and not pressed against the back, so that the gravity dependent pendulum swung freely. The participants were then asked to stand erect against a wall with nose nearly touching the wall. This position kept the participants from bending forward during lateral flexion measurements. The participants were asked to laterally flex to the right by running their right hands down the lateral thigh towards the right knee. The readings were then taken from the two inclinometers. The difference between the T12 and the S1 inclinometers gave the true right lateral flexion value. The right lateral flexion procedure was repeated for left lateral flexion the participants had to bend to the left instead of bending to the right (Figure 8).

The study was carried out in a school in India among 400 students between 5-11 years of age. Descriptive statistics of mean and standard deviation, in which mean age was 8 ± 2, mean BMI was 17.62 ± 3, mean trunk length was 66.69 ± 6, mean limb length was 69.14 ± 9.5, mean hamstring flexibility was 24.54 ± 6.6, mean flexion was 55.9 ± 17, mean extension was 21.8 ± 6, mean right flexion was 15, mean left flexion was 14.9 ± 5 is shown in Table 1. The physical characteristics of all participants in both males and females show that limb length is more in males than in females. Active lumbar flexion was more in females than in males. Active
lumbar extension was more in males than in females. Limb Length in males is more than female is shown in Table 2. Comparison of general characteristics and spinal flexibility values across different age groups show significant difference across different age groups which is shown in Table 3. Correlation which determined the relationship between spinal flexibility and age, BMI, trunk length, limb length and hamstring flexibility shows significant correlation. Significant correlations were found between trunk length and age ($r=0.780; p=0.0001$), trunk length and BMI ($r=0.182; p=0.0001$), limb length and age ($r=0.888; p=0.0001$), limb length and BMI ($r=0.181; p=0.0001$), limb length and trunk length ($r=0.861; p=0.0001$), hamstring flexibility and age ($r=0.586; p=0.0001$), hamstring flexibility and BMI ($r=-0.162; p=0.001$), hamstring flexibility and trunk length ($r=-0.414; p=0.0001$), hamstring flexibility and limb

| Characteristic | Mean   | SD      | Skewness |
|----------------|--------|---------|----------|
| Age            | 8      | 2.239   | 0.001    |
| BMI            | 17.62  | 3.254   | 0.984    |
| TL             | 66.69  | 6.124   | -135     |
| LL             | 69.14  | 9.571   | -268     |
| Hamstring Flexibility | 24.54  | 6.609   | 1.204    |
| Flexion        | 55.92  | 17.11   | 0.049    |
| Extension      | 21.8   | 6.122   | 0.496    |
| Rt. Flexion    | 15.21  | 5.119   | 0.597    |
| Lt. Flexion    | 14.93  | 5.08    | 0.664    |

Table 1: Descriptive statistics of mean and standard deviation. BMI: Body Mass Index; TL: Trunk Length; LL: Limb Length; HF: Hamstring Flexibility.
Table 2: Independent F test - Difference between males and females. BMI: Body Mass Index; TL: Trunk Length; LL: Limb Length; HF: Hamstring Flexibility.

|                | Male              | Female             | F-ratio | P value |
|----------------|-------------------|--------------------|---------|---------|
| Age            | 8 ± 2             | 8 ± 2              | 0.000   | 1.000   |
| BMI            | 17.8 ± 3.3        | 17.47 ± 3.3       | 1.184   | 0.277   |
| TL             | 66 ± 6            | 67 ± 5             | 6.508   | 0.011   |
| LL             | 68 ± 10           | 70 ± 8.9           | 2.919   | 0.089   |
| Hams flexi     | 25 ± 6            | 23.9 ± 6           | 0.123   | 0.726   |
| Flexion        | 57 ± 15           | 54.5 ± 18.6       | 7.508   | 0.006   |
| Extension      | 21.9 ± 6.5        | 21.6 ± 5.6        | 7.172   | 0.008   |
| Rt. Flexion    | 15.2 ± 4.8        | 15 ± 5.3          | 1.541   | 0.215   |
| Lt. Flexion    | 14.9 ± 4.8        | 14.9 ± 5.2        | 1.875   | 0.172   |

Table 3: Analysis of Variance (ANOVA) – to compare general characteristics and spinal flexibility values across different age groups. BMI: Body Mass Index; TL: Trunk Length; LL: Limb Length; HF: Hamstring Flexibility.

|                | 5 ± 0.00          | 7 ± 0.00          | 9 ± 0.00          | 11 ± 0.00         | F-ratio | P-value |
|----------------|-------------------|-------------------|-------------------|-------------------|---------|---------|
| Age            | 5 ± 0.000         | 7 ± 0.000         | 9 ± 0.000         | 11 ± 0.000        |         |         |
| BMI            | 17.7 ± 3.36       | 16.3 ± 2.1        | 18.0 ± 3.3        | 18.2 ± 3.6        | 7.224   | 0.0001* |
| TL             | 59.9 ± 3.86       | 65.1 ± 3.8        | 68.6 ± 3.0        | 72.9 ± 3.8        | 207.521 | 0.0001* |
| LL             | 56.7 ± 4.51       | 65.6 ± 3.7        | 75.4 ± 3.9        | 78.7 ± 4.2        | 585.729 | 0.0001* |
| Hams flexi     | 18.6 ± 3.1        | 22.3 ± 7.6        | 29.2 ± 3.4        | 27.8 ± 4.7        | 95.646  | 0.0001* |
| Flexion        | 36.8 ± 10.7       | 68.4 ± 13.6       | 61.1 ± 13.6       | 57.3 ± 11.2       | 118.279 | 0.0001* |
| Extension      | 18.8 ± 5.11       | 24.6 ± 6.2        | 23.9 ± 6.1        | 19.8 ± 4.8        | 26.186  | 0.0001* |
| Rt. Flex       | 12.9 ± 3.3        | 18.5 ± 4.9        | 14.6 ± 4.9        | 14.7 ± 5.3        | 24.992  | 0.0001* |
| Lt. Flex       | 12.9 ± 3.3        | 18.4 ± 4.8        | 14.3 ± 5.0        | 14 ± 5.1          | 26.399  | 0.0001* |

Discussion

This study established the normative data and correlates of spinal flexibility in children using the dual inclinometer. Normative values for each cardinal plane movement of the lumbar spine were identified. Participants in this study were children with the mean age of 8 ± 2.23 years.

A statistically significant difference in lumbar ranges was seen in both genders & was found in children between 5 and 11 years of age, with older subjects demonstrating reduced movements. Some authors [3,5] propose that an age related decline in ligamentous and muscle fiber elasticity results in soft-tissue limitation of lumbar flexion. Extension, which may be limited by bony approximation [5,7] has little variability within age groups or between sexes, and decreases in small amounts with increasing age [3,8].

The male participants had significantly higher limb length than female participants. Literature is replete on the gender dependent differences in body segment proportions between male and female [11].

Active lumbar flexion was more in females than males in our study, which may be related to earlier maturation in females than in males [24-27] and these results corroborates with previous studies that suggest that females are more flexible than males [28].

In addition to structural differences, males appear to have greater stiffness and decreased segmental motion in the lumbar spine compared to females, 25 however, Mellin and Poussa (1992) [28] who found no significant differences in forward flexion of the lumbar spine between male and female our study found there is a difference in forward flexion between male and female. Although conclusive evidence is lacking, several factors, including anatomical and physiological differences, may account for the difference in flexibility between the sexes. Additional factors could be smaller muscle mass, joint geometry, and gender-specific collagenous muscle structure [25,27]. Active lumbar range of motion affects the active lumbar range of motion.
Trunk Length; Limb Length; Hamstring Flexibility.

Methods and age groups studied, close examination of patterns within the study to other study results because of the differences in measurement spine [28].

and decrease hamstring flexibility will limit the movement at lumbar is most influential when approaching the end of pelvic rotation range [28,29]. This means it is likely that hamstring ratio between 60° and 90° [28,29].

that Forward Bending motion occurs mainly at the hips, with a 2:1 ratio of lumbar spine to hip motion between 0° and 30°, building to a 1:2 ratio between 60° and 90° [28,29]. This means it is likely that hamstring is most influential when approaching the end of pelvic rotation range and decrease hamstring flexibility will limit the movement at lumbar spine [28].

Although it is not possible to directly compare the data from this study to other study results because of the differences in measurement methods and age groups studied, close examination of patterns within the data reveals similarities. First, spinal mobility varied in this sample of children, as well as in other studies of children [14] and adults [3,4,13-16] which suggests that variability may be the norm. Flexion was more variable than any other spinal motion in both boys and girls, a pattern that was also observed in other studies of both children [9] and adults [4,16]. Flexion was found to be less in the subjects 11 years of age as compared with the five-year-old subjects in this sample of children. This finding was greater in girls than boys [8]. Normal developmental changes in ligament and muscle fiber elasticity across these age groups 11 may contribute to greater “stiffness” of the soft tissues and increased resistance to lumbar flexion. Our findings of normative data are in similar with the previous study that was done in 2007 in Michigan [11].

**Conclusion**

Normative values of lumbar spine mobility of children five, seven, nine, and 11 years of age can be used as a baseline for comparing spinal mobility that may be in question and for monitoring progress during periods of physical therapy intervention. This study established a set of normal values for lumbar spinal ranges in children between 5-11 years of age. Increasing age was associated with decreasing spinal flexibility without gender bias. These values can be used in clinical practice. This study also established confounding factors that are age, trunk length, limb length and hamstring flexibility affect active lumbar flexion range of motion.

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| Age r-val | BMI r-val | TL r-val | LL r-val | Hams r-val | Flex r-val | Ext r-val | Lt.flex r-val | Rt.flex r-val | p-val |
|-----------|-----------|---------|---------|-----------|-----------|---------|-------------|-------------|-------|
| 1         | 1         | 1       |         |           | 0.354**  | 0.42    | -0.02       | -0.077      | 0.693    |
| 0.108*    | 0.03      | 0.780** | 0.888** | 0.586**   | 0.354**  | 0.42    | -0.02       | -0.077      | 0.693    |
| p-val     | p-val     | p-val   | p-val   | p-val     | p-val     | p-val   | p-val       | p-val       | p-val   |
|           |           | 0.0001  | 0.0001  | 0.0001    | 0.0001    | 0.0001  | 0.0001      | 0.0001      | 0.0001  |
|           |           | 0.182** | 0.181** | 0.861**   | 0.313**   | 0.08    | 0.861       | 0.816       | 0.724   |
|           |           |         |         |           | 0.361**   |         |             |             |         |
|           |           |         |         |           | 0.235**   |         |             |             |         |
|           |           |         |         |           | 0.012     |         |             |             |         |
|           |           |         |         |           | 0.024     |         |             |             |         |
|           |           |         |         |           | 0.635     |         |             |             |         |
|           |           |         |         |           | 0.015     |         |             |             |         |
|           |           |         |         |           | 0.767     |         |             |             |         |

*Table 4: Pearson correlation analysis - to determine the relationship between spinal flexibility and each of age, BMI, TL, LL and hamstring flexibility. BMI: Body Mass Index; TL: Trunk Length; LL: Limb Length; Hams: Hamstring Flexibility.*

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Variables | Age | Sex/No. | X ± SD | Min | Median | 25th | 75th | 95th | Max |
|---|---|---|---|---|---|---|---|---|---|
| **Forward flexion** | 5 | F-50 | 32.2 ± 7.8 | 20 | 30 | 28.75 | 40 | 45 | 45 |
| | | M-50 | 34 ± 7.8 | 20 | 30 | 30 | 40 | 47.2 | 50 |
| | 7 | F-50 | 68 ± 13.7 | 40 | 70 | 60 | 76.2 | 92.2 | 100 |
| | | M-50 | 68.9 ± 13.6 | 40 | 62.5 | 60 | 80 | 100 | 100 |
| | 9 | F-50 | 63.5 ± 13.9 | 30 | 62.5 | 58.7 | 75 | 84.5 | 90 |
| | | M-50 | 58.7 ± 13.7 | 35 | 60 | 50 | 70 | 80 | 90 |
| | 11 | F-50 | 56.5 ± 11.4 | 40 | 57.5 | 48.7 | 65 | 77.2 | 80 |
| | | M-50 | 58.1 ± 11 | 40 | 60 | 50 | 66.2 | 77.2 | 80 |
| **Extension** | 5 | F-50 | 19.4 ± 4.1 | 10 | 20 | 20 | 20 | 30 | 30 |
| | | M-50 | 18.7 ± 5.5 | 10 | 20 | 15 | 20 | 30 | 30 |
| | 7 | F-50 | 23.9 ± 6.4 | 15 | 25 | 20 | 30 | 35 | 40 |
| | | M-50 | 25.3 ± 6 | 10 | 30 | 20 | 30 | 35 | 35 |
| | 9 | F-50 | 23.3 ± 4.9 | 10 | 20 | 20 | 30 | 30 | 30 |
| | | M-50 | 24.5 ± 7.1 | 10 | 20 | 20 | 30 | 30 | 40 |
| | 11 | F-50 | 19.3 ± 5.1 | 10 | 20 | 15 | 20 | 30 | 30 |
| | | M-50 | 20.4 ± 4.4 | 10 | 20 | 20 | 20 | 30 | 30 |
| **Rt. Flexion** | 5 | F-50 | 12.2 ± 2.8 | 10 | 10 | 10 | 15 | 17.2 | 20 |
| | | M-50 | 13.1 ± 3.3 | 10 | 15 | 10 | 15 | 20 | 20 |
| | 7 | F-50 | 18.7 ± 5 | 10 | 20 | 15 | 25 | 25 | 25 |
| | | M-50 | 18.3 ± 4.8 | 10 | 20 | 18.7 | 20 | 27.2 | 30 |
| | 9 | F-50 | 14.5 ± 4.8 | 10 | 15 | 10 | 20 | 25 | 25 |
| | | M-50 | 14.7 ± 5 | 10 | 15 | 10 | 15 | 25 | 25 |
| | 11 | F-50 | 13.1 ± 4 | 10 | 10 | 10 | 15 | 20 | 25 |
| | | M-50 | 16.4 ± 6 | 10 | 15 | 10 | 15 | 27.2 | 35 |
| **Lt. Flexion** | 5 | F-50 | 12.2 ± 2.8 | 10 | 10 | 10 | 15 | 17.2 | 20 |
| | | M-50 | 13.1 ± 3.3 | 10 | 15 | 10 | 15 | 20 | 20 |
| | 7 | F-50 | 18.5 ± 4.9 | 10 | 20 | 15 | 20 | 25 | 25 |
| | | M-50 | 18.3 ± 4.8 | 10 | 20 | 30 | 20 | 27.2 | 30 |
| | 9 | F-50 | 14.4 ± 4.9 | 10 | 15 | 10 | 20 | 25 | 25 |
| | | M-50 | 14.3 ± 5.1 | 10 | 10 | 10 | 20 | 25 | 25 |
| | 11 | F-50 | 12.9 ± 4 | 10 | 10 | 10 | 15 | 20 | 25 |
| | | M-50 | 15.1 ± 5.9 | 10 | 15 | 10 | 15 | 25 | 35 |

Table 5: Mean score and percentile data of spinal flexibility (values are in degree).

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