Journal of
Physiotherapy & Physical Rehabilitation

Sawale et al.,Physiother Rehabil 2016, 1:1
DOI: 10.4172/2573-0312.1000101

Research Article Open Access

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

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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 (>95$^{th)}$ 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 a 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 in clinometric 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

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Received: November 02, 2015; **Accepted:** November 05, 2015; **Published:** November 09, 2015

Citation: Sawale S, Bisen R, Kumar ES (2016) Normative Values for Active Lumbar Range of Motion in Children and Confounding Factors That Affects the Active Lumbar Range of Motion. Physiother Rehabil 1: 101. doi: 10.4172/2573-0312.1000101

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

Figure 1: Measuring height on stadiometer.

Figure 2: Measuring weight on weighing scale.

Figure 3: Measuring limb length.

Figure 4: Measuring trunk length.

were carried out with the universal inclinometer based on guidelines provided in the *American Medical Association (AMA) Guides (1993).*

Figure 5: Measuring hamstring flexibility.

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

Figure 6: Measuring flexion.

Figure 7: Measuring extension.

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

Figure 8: Measuring lateral flexion.

	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
Hams 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.

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

	Male	Female	F	P value
Age	8 ± 2	8 ± 2	0.000	1.000
BMI	17.8 ± 3	17.47 ± 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 2: Independent F test - Difference between males and females. BMI: Body Mass Index; TL: Trunk Length; LL: Limb Length; HF: Hamstring Flexibility.

	5	7	9	11		
	X ± SD	X ± SD	X ± SD	X ± SD	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*

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.

length (r=0.553; p=0.0001),flexion and age(r=0.354; p=0.0001), flexion and trunk length(r=0.313; p=0.0001), flexion and limb length(r=0.361; p=0.0001), flexion and hamstring flexibility(r=0.235; p=0.0001) which is shown in Table 4. Mean, standard deviation, range and 25th, 75th and 95th percentile scores and were determined for four age categories and both genders for spinal flexibility of all participants. Flexibility levels were defined using percentiles as poor (<25th), moderate (between 25th and 75th), good (between 75th and 95th), and very good (>95th) respectively which is shown Table 5.

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

	Age	BMI	TL	LL	Hams
Age r-val	1				
p-val					
BMI r-val	0.108*	1			
p-val	0.03				
TL r-val	0.780**	0.182**	1		
p-val	0.0001	0.0001			
LL r-val	0.888**	0.181**	0.861**	1	
p-val	0.0001	0.0001	0.0001		
Hams r-val	0.586**	0.162**	0.414**	0.553*	1
p-val	0.0001	0.001	0.0001	0.0001	
Flex r-val	0.354**	-0.041	0.313**	0.361**	0.235**
p-val	0.0001	0.417	0.0001	0.0001	0.0001
Ext r-val	0.42	0.08	0.008	0.079	0.126
p-val	0.402	0.724	0.103	0.116	0.012
Rt.flex r-val	0.032	-0.086	0.009	0.018	0.024
p-val	0.519	0.087	0.861	0.717	0.635
Lt.flex r-val	-0.02	-0.077	-0.018	-0.022	-0.015
p-val	0.693	0.126	0.719	0.654	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; HF: Hamstring Flexibility.

extension was more in males than females in our study.

Reduced lumbar side bending was seen in both genders when comparing 11 year old children to five year old children, this correlates with two important skeletal maturation milestones that are achieved during the same time period. Primary ossification of the lumbar spine is completed between seven and nine years of age and mature lumbar facet orientation is achieved by approximately 11 years of age [7,9-11]. Side bending was greatest in the five-year-old group in this study, which coincides with a more frontal plane orientation of facets. The 11-year-old children had the least side bending, which correlates with achieving a relatively sagittal plane orientation. It has been reported that sagittal orientation of the lumbar facet joints may play a role in constraining and/or directing movement within the adult lumbar spine, specifically limiting a lesser degree side bending [8,9,11]. Conversely, a more frontal plane orientation may allow greater rotation and side bending [8,11]. It is possible that normal developmental changes in Lumbar facet orientation may play a role in the decline in side bending that is observed in this sample of children [1,9].

In our study there is significant relationship between flexion and age, trunk length, limb length and hamstring flexibility. Esola et al. found 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.

Acknowledgement

A Sincere thanks to all the subjects from Sinhgad Spring Dale School, Ambegaon, Pune for their cooperation during the study. A deep gratitude to the management of Sinhgad Spring Dale School, Pune for allowing data collection to be taken in the school premises. A special thanks to Dr. Ashok Patil and Dr. Kashibai Navale College of

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	40	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).

Physiotherapy, Pune and the teaching staff for their everlasting support during and after the course of the study.

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