An Investigative Study on Spine Shape by Gender and Age in Teenagers 10-13 Years Old

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Purpose This study sought to investigate the shape of spine in students aged 10-13 according to gender and age in order to obtain basic data for early detection and prevention of spine curvature disorders. ***Methods*** 10 to 13-year-old primary school students. The pelvic tilt, trunk imbalance, thoracic kyphosis and lumber lordosis were investigated using the Formetric 4D system, which is a device developed to evaluate the spine position. ***Results*** More subjects showed normal pelvic tilt, imbalanced trunk towards the left and decreased thoracic kyphosis and lumbar lordosis. The results of this study stressed the importance of regular check-ups to evaluate the spinal position among adolescents who are in their growing period. ***Conclusion*** Further studies should be conducted to educate the public about preventing spinal deformity and carry out a primary screening program regularly for the early detection of spinal disorders.

Key words Pain, Spine shape, Teenagers

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I. Introduction

The spine supports the head and is connected to pelvic to deliver the weight to the lower limbs. It also serves as a pillar of the body trunk. The biomechanical function of the spine is related to the physiological exercise between the trunk and the pelvic. The normal curvature of the spine acts as a cushion to relieve the weight and impacts loaded on the spine and activates the spine segmental muscles of the back effectively.[1)]

The ideal posture maintains the normal curvature of the spine in line with the biomechanical alignment and is related to performance of daily activities. The coordination of the spine, pelvic and muscles of lower extremities helps us maintain an ideal posture. However, the use of public transport and poor posture at work, school and even at home negatively influence the normal curvature in the cervical and lumbar vertebrae.[2)] In particular, when a person looks at the computer monitor horizontally, the posture makes the neck straight and shortens the muscles at the back of the neck. This leads to decreased lumbar curvature and a post tilt of the pelvic. It was reported that this poor posture during daily activities affects the segments of the spine and increases the load in the segmental muscles of the back.[3)] Sitting in front of the computer for a long time causes a different shoulder height in each side and forwarded head location in teenagers. This posture causes abnormal segmental alignments of the body.[4)] Since teenagers have a great range of motion of the joints, good alignment of the segments and curvature of the spine are important. The normal spine shape, in particular, greatly affects primary school students who are in their active growing period.[5)] Spine curvature disorder among teenagers may remain or progress in their adulthood. If left untreated, it can cause physical problems in appearance, pain, functional problems of the heart and lungs or neurological complications. Spine curvature disorders in teenagers include lordosis, kyphosis and scoliosis. About 70-80% of structural scoliosis is idiopathic, appearing most commonly during adolescence when the growth of the musculoskeletal system is fast. Early de-

tection of spine curvature disorders can prevent further spine deformities and allow effective treatment using conventional treatment. As such, early detection is important to prevent the progression of spine deformity.[6)]

Regular check-up is required to maintain the normal spine curvature among primary school students. The early detection of spine deformity can avoid surgical treatment for severe misshaped spine curvature and improve the outcome of conventional treatment. As such, this study aimed to investigate the spine shape among primary school students to obtain basic data for further study to prevent spine curvature disorders. The subjects of this study were primary school students aged 10-13. The pelvic tilt, tilt imbalance, thoracic kyphosis and lumbar lordosis were obtained using Formetric 4D equipment to investigate spine curvatures.

II. Materials and Methods

1. Subjects

The subjects in this study were 301 students aged 10-13. There were 152 boys and 149 girls. 98 students were 10 years old; 79, 11 years old; 59, 12 years old; and 65, 13 years old (Table 1).

2. Methods

1) Measurement tool

Formetric 4D (DIERS, International GmbH of Schlangenbad, Germany, 2010) was used to analyze the spine shape of the subjects in the study.

2) Measurement method

(1) Formetric 4D

The formetric 4D system is a device used to analyze the spine structure as an alternative to radiology tests. It provides accurate images of the spine curvature as well as objective data with high measurement reproducibility. The system analyzes in 3D the back surface and the back side of the trunk. It is a fast, radiation-free method to evaluate the spine position using surface topography.

Table 1. Subject characteristics

Age	10 (N=98)	11(N=79)	12(N=59)	13(N=65)	Total
Boys	51	40	29	32	152
Girls	47	39	30	33	149

The measurement principle is as follows: a light projector creates a raster line grid on the back of the subjects and is then recorded by a camera; a computer software spots the location of the spinosus from the center of the spine and measures the location of the curvature using the spinosus and other anatomical markers. The central line of the spine is reconstructed. Using the obtained images, the parameters including central line deviation to the left and right, left and right rotation angle of the spinosus (frontal images), the angles of thoracic kyphosis and lumbar lordosis (lateral images), the deviation degree of spinal curve and pelvic tilt to the right and left and anteversion are determined.

(2) Posture for measurement

The subjects were made to stand comfortably facing the wall at a point 2m away from the camera. They were asked to take off their top and lower their bottoms to the middle of the pelvic. They were asked to stand at a point marked on the floor by placing their arms comfortably and looking at the mark in front. Different examiners were selected by gender.

(3) Comparison of measurements

The normal range of the system was determined in German adolescents aged 11-19. To compare the normal range in Korean students, Korean adolescents aged 11-19 were assessed using the Formetric 4D system. The measurement was conducted at the Raonjena Posture Analysis Center located in Bundang, Sungnam-si, Republic of Korea. The angle and length of the normal range was presented (−) left and (+) right (Table 2).

① Pelvic tilt

Pelvic tilt is presented as the difference (mm) of the pelvic height between left and right based on the frontal line from the left posterior superior iliac

Table 2. Comparison of normal range in German and Korean teenagers aged 11-19

Label	Germany a	Korea b
Pelvic tilt (mm)	−4~4	−3.1~3.1
Trunk imbalance(mm)	−7~7	−5~5
Thoracic Kyphosis (°)	47~50	45~50
Lumbar Lordosis (°)	38~42	35.2~43

a. Harzmann, 1999, no. of subjects: 428
b. Raonjena Posture Analysis Center, 2012, no. of subjects: 1200

spine to the right posterior superior iliac spine. The normal range was −4−4 mm and the measurement lower than the −4 mm was presented as left tilt and those over the 4mm, as right tilt.

② Trunk imbalance

Trunk imbalance is presented as the distance of the tilted spine to the right or left as observed from the front of the trunk. The distance between the left and the right was presented in mm where the vertical line drawn from the cervical 7 vertebra meets the midpoint of the both posterior superior iliac spine. The normal range was −7−7 mm and the measurement lower than the −7 mm was presented as left imbalance and those over the 7mm, as right imbalance

③ Thoracic kyphosis

Thoracic kyphosis is measured laterally and represented the maximal value of the kyphosis angle from the thoracic 1 to 12 vertebra. The normal range was 47°~50° and the value below 47° was presented as 'decreased' and those over 50° as 'increased'.

④ Lumbar lordosis

Lumbar lordosis is measured laterally. The maximum value of the lordosis angle is from the lumbar 1 to sacral 1 vertebra. The normal range was 38°−42° while the value below 38° was presented as 'decreased' and those over 42°, as 'increased'.

3) Data management method

The SPSS (Ver. 18.0) program was used to analyze the data in this study. χ^2 test was performed to compare the spine shape according to gender and age. The level of significance was determined at α<.05.

III. Results

1. Comparison of pelvic tilt by gender and age

Most of the subjects showed normal pelvic tilt while more girls showed normal pelvic tilt than boys. There was no significant difference in the pelvic tilt according to gender (p>.05). In terms of age, the younger students showed more normal pelvic tilt than the older students. The difference was significant (p<.05) (Table 3).

2. Comparison of trunk imbalance by gender and age

Many of the subjects showed trunk imbalance to the left. The difference between genders was not large, which concluded there was no significant difference in terms of gender (p>.05).

The 10-year-old subjects accounted for the greatest percentage among those with imbalance to the left

Table 3. Comparison of pelvic tilt by gender and age

Unit: no. of subjects (%)

		Pelvic tilt			Total	χ^2-value
		Left	Normal	Right		
Gender	Boy	17(44.7)	101(48.1)	34(64.2)	152(50.5)	4.942
	Girl	21(55.3)	109(51.9)	19(35.8)	149(49.5)	
Age (years)	10	15(39.5)	70(33.3)	13(24.5)	98(32.6)	14.395 *
	11	9(23.7)	53(25.2)	17(32.1)	79(26.2)	
	12	6(15.8)	49(23.3)	4(7.5)	59(19.6)	
	13	8(21.1)	38(18.1)	19(35.8)	65(21.6)	
Total		38(100)	210(100)	53(100)	301(100)	

*p<.05

Table 4. Comparison of trunk imbalance by gender and age

Unit: no. of subjects (%)

		Trunk imbalance			Total	χ^2-value
		Left	Normal	Right		
Gender	Boy	69(50.4)	65(49.2)	17(54.8)	151(50.3)	0.315
	Girl	68(49.6)	67(50.8)	14(45.2)	149(49.7)	
Age (years)	10	41(29.9)	44(33.3)	13(41.9)	98(32.7)	2.982
	11	37(27.0)	32(24.2)	9(29.0)	78(26.0)	
	12	27(19.7)	28(21.2)	4(12.9)	59(19.7)	
	13	32(23.4)	28(21.2)	5(16.1)	65(21.7)	
Total		137(100)	132(100)	31(100)	300(100)	

*p<.05

Table 5. Comparison of thoracic kyphosis by gender and age

Unit: no. of subjects (%)

		Thoracic kyphosis			Total	χ^2-value
		Decreased	Normal	Increased		
Gender	Boy	87(70.2)	14(35.0)	42(36.2)	143(51.1)	32.475*
	Girl	37(29.8)	26(65.0)	74(63.8)	137(48.9)	
Age (years)	10	44(35.5)	11(27.5)	36(31.0)	91(32.5)	5.617
	11	35(28.2)	12(30.0)	24(20.7)	71(25.4)	
	12	22(17.7)	10(25.0)	25(21.6)	57(20.4)	
	13	23(18.5)	7(17.5)	31(26.7)	61(21.8)	
Total		124(100)	40(100)	116(100)	280(100)	

*p<.05

but there was no significant difference in results according to age (p>.05)(Table 4)

3. Comparison of thoracic kyphosis by gender and age

The decreased thoracic kyphosis accounted for the greatest percentage. There were more boys than girls among those who showed decreased thoracic kyphosis, while the thoracic kyphosis was significantly different in terms of gender (p<.05).

The 10-year-old subjects accounted for the greatest percentage among those with decreased thoracic kyphosis but there was no significant difference in results according to age (p>.05)(Table 5).

4. Comparison of lumbar lordosis by gender and age

The decreased lumbar lordosis accounted for the greatest percentage. There were more boys than girls among those who showed decreased lumbar lordosis. The result was significantly different by gender (p<.05).

The 10-year-old subjects accounted for the greatest percentage among those with decreased lumbar lordosis but there was no significant difference in results according to age (p>.05)(Table 6).

IV. Discussion

Adolescents these days spend more time sitting while studying and using the computer, resulting in relatively reduced physical activities. Sitting for a long time affects the activation of segmental muscles in the back depending on the spine shape. A study that investigated muscle activation while sitting according to the spine curvatures in males in their 20s reported that posture with spinal kyphyosis decreased activa-

Table 6. Comparison of lumbar lordosis by gender and age

Unit: no. of subjects (%)

		Lumbar lordosis			Total	χ^2-value
		Decreased	Normal	Increased		
Gender	Boy	101(56.1)	17(34.0)	25(49.0)	143(50.9)	7.742*
	Girl	79(43.9)	33(66.0)	26(51.0)	138(49.1)	
Age (years)	10	60(33.3)	21(42.0)	14(27.5)	95(33.8)	6.307
	11	53(29.4)	8(16.0)	15(29.4)	76(27.0)	
	12	34(18.9)	10(20.0)	8(15.7)	52(18.5)	
	13	33(18.3)	11(22.0)	14(27.5)	58(20.6)	
Total		180(100)	50(100)	51(100)	281(100)	

*p<.05

tion of the abdominal and back muscles. Posture with lumbar lordosis and thoracic kyphosis in the sitting position increased the activation of the lumbar paraspinals and lumbar multifidus. As such, maintaining a neutral spine without kyphosis at thoracolumbar region is important for spine alignment.[7] The spinal alignment influences the trunk muscle activities. Moreover, the location of the pelvis affects spinal alignment. For example, the ant tilt of the pelvis result spinal lordosis and the post tilt of the pelvis results in spinal kyphosis. As such, the direction of the spine and pelvis movement affects each other's movement.[8] The movement of the pelvis affects the movement of the hip and spine. The movable range of the pelvic tilt is required to maintain spinal mobility.[9] Pelvic adjustment stabilized and enhanced the trunk and positively influenced posture correction and balance.[10] A study that investigated spinal alignment in 7- and 8-year-old students according to gender and age reported no difference in pelvic tilt by gender and age but spine curvature was higher than the normal range.[11] Most of scoliosis patients aged 14-17 showed a rotated pelvis toward thoracic curvature as a compensation of the scoliosis.[12] Results of this study showed normal pelvic tilt in more subjects. There were more girls with normal pelvic tilt than boys, while younger subjects showed more normal pelvic tilt, which differed from findings of previous studies. Even if the present study did not investigate the pelvic tilt based on spinal deformity, the high percentage of normal pelvic tilt was quite different from results of the previous studies that revealed changed pelvic tilt affected by the spinal deformity.

The spine curvature is not fixed and is more dynamic. The shape of the spine is changed by movements and various postures, while the changed spine position causes non-alignment muscles of the trunk[2]. The abnormal spine curvature also affects the relationship between spinal segments and their biomechanical characteristics, leading to the inefficient activities of the muscles.[13] Sitting for a long time creates imbalance of muscles in the trunk among adolescents. The difference between the left and right side of the trunk was reported among 12-year-old students who use backpacks.[14]

The current study evaluated trunk imbalance by measuring the tilt distance of the spine left or right from the front of the trunk. More subjects showed imbalance towards the left. There was no difference in result by gender while the younger subjects showed more trunk imbalance to the left.

Trunk imbalance is caused by poor posture during daily activities and causes musculoskeletal pains.[15] Sitting for a long time causes imbalanced trunk muscles, back pain as well as spine curvature disorders among adolescents.[16] Sitting position changes the spine curvature by redistributing the weight in the biodynamical point of view based on the locations of the lower and upper limbs.[17]

The trunk imbalance observed in the current study was attributed to poor posture due to lifestyle as reported in previous studies. Good sitting posture dur-

ing the adolescent years is important in preventing spine curvature disorders or pain. Further studies should be conducted to investigate the environmental factors that cause spine deformities.

Korean teenagers with scoliosis increased 1.66% in 2000, 2.41% in 2001, 3.53% in 2004, 4.95% in 2007 and 6.17% in 2008 out of 10,000 teenagers.[18] A study that investigated spine alignment in children aged 7 and 8 according to age and gender reported that the incidence of lumbar lordosis and thoracic kyphosis was higher among 7-year-olds than 8-year-olds.[11] Another study that investigated spine curvature disorder in 14- and 15-year-old children according to gender reported that kyphosis was more observed among boys while lordosis was more notable among girls.[19]

Teenagers aged 7, 11 and 15 who use the computer for 14 hours a week exhibited 32% with lordosis and 31% with kyphosis.[20] A study that investigated the sagittal alignment of the thoracic and lumbar vertebra and pelvis in standing position among 13 or 15-year-old adolescents reported that 32% of the subjects exhibited ideal posture; 25.6%, swayback posture - decreased lumbar lordosis with increased thoracic kyphosis; 22.5%, flat back posture - decreased lumbar lordosis and thoracic kyphosis and 21.8%, hyperlordotic posture - increased lumbar lordosis. The results also showed that structural spinal deformity can occur more often in abnormal postures by giving loads to the tissues of the spinal joints than when there is ideal posture.[21]

The results of this present study showed that more subjects had decreased thoracic kyphosis within the normal range and more male, younger subjects showed decreased thoracic kyphosis. Lumbar lordosis also showed the same result, with more subjects, particularly boys and younger subjects, exhibiting decreased lumbar lordosis. Results pertaining to spinal deformity including thoracic kyphosis and lumbar lordosis obtained in this study were in line with those of a study that reported flat back posture - decreased lordosis and kyphosis. When comparing between genders, more boys and younger subjects showed decreased lordosis and kyphosis, which was in contrast to results of the previous study.

More subjects showed normal pelvic tilt, imbalanced trunk towards the left and decreased thoracic kyphosis and lumbar lordosis. The results of this study stressed the importance of regular check-ups to evaluate the spinal shape in adolescents who are in their growing period. Further studies should be conducted to educate the public about the prevention of spinal deformity and carry out a primary screening program regularly for the early detection of spinal disorders.

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