The effect of the length, angle, height, and depth of lumbar lordosis on selected features of thoracic spine

MROZKOWIAK Mirosław

Physiotherapy Clinic AKTON, Poznań, Poland

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Summary

The purpose of this study was to demonstrate the significant effect of the values of the angle, depth, height, and length of lumbar lordosis on selected features of the thoracic spine.

Material and Methods. The study was carried out in a group of 2,361 children aged 7 to 15 years, in 6 semiannual consecutive editions. This allowed to record 16,608 observations of 31 features describing posture by photogrammetric method.

Results. The following influential features like angle, depth, heights, and lengths of lumbar lordosis were selected for multiple regression analysis with selection of a subset of the optimal set of variables.

Conclusions

The presented statistical analysis shows the mutual influence of the values of the selected characteristics. The study showed no independent feature, however, the degree of influence varied. This demonstrates the interrelatedness of the different spinal segments.
Corrective actions that change the value of one postural trait force the change of others in a positive or negative way.

**Keywords: projection moiré, features of spine and pelvis**

1. Introduction

Body posture during the developmental period undergoes constant changes. The greatest dynamics of these changes are observed in the first year of a child's life. It is determined, to a large extent, by successive (alternating) flexion and extension stages. Following, thoracic kyphosis, cervical lordosis, lumbar lordosis are gradually modulated. The latter appears the latest around 12th month of age and is an obvious expression of the spatial adaptation of the human body system to the upright position [1, 2]. Its appearance has a modifying effect on the shape of the thoracic kyphosis. There is a significant lability of physiological curvatures throughout early childhood. A full stabilization of cervical lordosis occurs around age of 7. The lumbar lordosis begins to deepen gradually from about 3-8 years of age, and it gets its final shape at about 10-12 years of age. The individually variable development of posture is influenced by phylogenetic and genetic factors as well as epigenetic factors. Nowadays, because of visible changes in the quality of life, they seem to have an increasing negative impact. The development of posturogenesis may also be determined by certain dimorphic variations in skeletal structure [3]. Studies [4] on the angles of physiological curvatures of the adult spine have determined their values (according to Humphrey) as cervical lordosis is 18 degrees, thoracic kyphosis is 42 degrees, lumbar lordosis is 80 degrees, and sacral kyphosis is 125 degrees. Our own research made it possible to determine the angular and linear values of lumbar lordosis specific for age and gender by photogrammetric method. In individuals of both sexes, the average values of the angle of lordosis, the depth, length and height of thoracic kyphosis and lumbar lordosis are parallel to one another in the age of 7 - 15 years, and the angle of kyphosis up to 13 years. At the same time, the values of the angle of lordosis are higher than those of kyphosis, and the depths, lengths and heights are lower. In the case of kyphosis, in girls and boys up to age 13, the angle increases and then decreases its value. The angle of lordosis, in girls and boys until the age of
10, decreases its value, and further successively increases. The depth of both curvatures successively decreases until the age of 14 and increases in the following year. The length and height decrease until 10 years of age, in 10 and 12 years of age it stabilizes and further increases. The most intense changes in the values of all features occur in the period from 8 to 10 and from 12 to 14 years of age. Only features like DCK%, Wc, Mc in the period from 10 to 12 years show high dynamics of changes. The periods of the most intensive increases in the values of the studied traits in individuals of both sexes coincide, with different values [3].

The purpose of the study was to demonstrate the significant effect of the values of the length, angle, height, and depth of lumbar lordosis on selected features of the thoracic spine.

2. Research material and methods

The study of posture was conducted in randomly selected kindergartens and schools of Warmian-Masurian and Pomeranian regions. There were 46.84% of boys (1,106 subjects) and 53.15% of girls (1,255 subjects) participated in the study. The preponderance of girls was 149 people, which makes 6.31%. The respondents were recruited 69.97% (1,652 people) from urban environment, 52.11% girls (861 people) and 47.88% boys (791 people), and from rural environment 55.57% girls (394 people), and 44.42% boys (315 people), tab 1. In total, the study was conducted in a population of 2,361 children aged 7 to 15 years, in 6 semiannual consecutive editions allowed to record 16,608 observations.

Tab. 1. The number of observations in the age and sex categories

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Sex</th>
<th>Total (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K</td>
<td>M</td>
</tr>
<tr>
<td>7</td>
<td>610</td>
<td>597</td>
</tr>
<tr>
<td>8</td>
<td>1341</td>
<td>1255</td>
</tr>
<tr>
<td>9</td>
<td>1839</td>
<td>1677</td>
</tr>
<tr>
<td>10</td>
<td>1752</td>
<td>1542</td>
</tr>
<tr>
<td>11</td>
<td>1047</td>
<td>901</td>
</tr>
<tr>
<td>12</td>
<td>670</td>
<td>549</td>
</tr>
<tr>
<td>13</td>
<td>569</td>
<td>462</td>
</tr>
<tr>
<td>14</td>
<td>582</td>
<td>436</td>
</tr>
<tr>
<td>15</td>
<td>424</td>
<td>355</td>
</tr>
<tr>
<td>total</td>
<td>8834</td>
<td>7774</td>
</tr>
</tbody>
</table>

Source: own research

The legend
K – girls
M – boys
The measurement site for the value of selected body posture features consists of a computer, card, program, monitor, printer, projection and receiving device with a camera for measuring selected parameters of the spine-pelvis complex. The place of the examined person and the camera were spatially oriented according to the contour lines on the camera and in relation to the line of the child's toes. Obtaining a spatial image was possible by displaying lines with strictly defined parameters on the child's back, pic. 1. Lines falling on a body are distorted depending on the configuration of its surface. The image of the subject was received by a special optical system with a camera using a lens, and then transferred to a computer monitor. Distortions of the line image recorded in the computer's memory are processed by a numerical algorithm into a contour map of the examined surface [3, 6]. The research was carried out by a physiotherapist with 20 years of experience in diagnosing body posture using the photogrammetric method.

3. Subject of the study

Sixteen features describing the sagittal curvatures of the axial organ were selected to study the relationships of selected spinal traits, tab. 2.

Table. 2. List of registered spine features in the sagittal plane

<table>
<thead>
<tr>
<th>No</th>
<th>Symbol</th>
<th>Parametres</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alfa</td>
<td>degrees</td>
<td>Sacrifolumbar tilt, fig. 1.</td>
</tr>
<tr>
<td>2</td>
<td>Beta</td>
<td>degrees</td>
<td>Thoracolumbar tilt, fig. 1.</td>
</tr>
<tr>
<td>3</td>
<td>Gamma</td>
<td>degrees</td>
<td>Upper thoracic tilt, fig. 1.</td>
</tr>
<tr>
<td>4</td>
<td>Delta</td>
<td>degrees</td>
<td>The sum of the angular values Delta = Alfa+Beta+Gamma.</td>
</tr>
<tr>
<td>5</td>
<td>DKP</td>
<td>mm</td>
<td>Length of thoracic kyphosis The distance between LL a C7 points, fig. 2.</td>
</tr>
<tr>
<td>6</td>
<td>DKP</td>
<td>%</td>
<td>DKP value as a percentage of total spine length C7-S1.</td>
</tr>
<tr>
<td>7</td>
<td>KKP</td>
<td>degrees</td>
<td>Angle of thoracic kyphosis KKP = 180 – (Beta+Gamma), fig. 1.</td>
</tr>
<tr>
<td>8</td>
<td>RKP</td>
<td>mm</td>
<td>The height of thoracic kyphosis The distance between C7 a PL points, fig. 2.</td>
</tr>
<tr>
<td>9</td>
<td>RKP</td>
<td>%</td>
<td>RKP value as a percentage of total spine length C7-S1.</td>
</tr>
<tr>
<td>10</td>
<td>GKP</td>
<td>mm</td>
<td>The depth of thoracic kyphosis Distance measured horizontally between vertical lines passing through the PL a KP points, fig. 2.</td>
</tr>
<tr>
<td>11</td>
<td>DLL</td>
<td>mm</td>
<td>The length of lumbar lordosis The distance between S1 a KP points, fig. 2.</td>
</tr>
<tr>
<td>12</td>
<td>DLL</td>
<td>%</td>
<td>DLL value as a percentage of total spine length C7-S1.</td>
</tr>
<tr>
<td>13</td>
<td>KLL</td>
<td>degrees</td>
<td>Angle of lumbar lordosis KLL = 180 – (Alfa + Beta), fig. 1.</td>
</tr>
<tr>
<td>14</td>
<td>RLL</td>
<td>mm</td>
<td>The heigth of lumbar lordosis The distance between S1 a PL points, fig. 2.</td>
</tr>
<tr>
<td>15</td>
<td>RLL</td>
<td>%</td>
<td>RLL as a percentage of total spine length C7-S1.</td>
</tr>
<tr>
<td>16</td>
<td>GLL</td>
<td>mm</td>
<td>The depth of lumbar lordosis Distance measured horizontally between vertical lines passing through the PL i LL points, fig. 2.</td>
</tr>
</tbody>
</table>

Source: own research
Fig. 1. Selected angular features of the spine in the sagittal plane
Fig. 2. Selected linear features in the sagittal plane
4 Statistical methods used

Statistical analysis was carried out on the results of measurements of individuals from 4 to 18 years of age in 6 semiannual editions. Empirical data were quantitative and qualitative characteristics (gender, place of residence, etc.). There were values of positional statistics (arithmetic mean, quartiles), dispersion parameter (standard deviation) and symmetry indices (asymmetry coefficient, clustering coefficient) calculated, which gave a complete view of the distribution of the studied traits considering age groups and gender. There was the significance of changes in the values of the averages in subsequent years within one sex analyzed for selected traits (Student's t-test was used). The obtained results allow to draw conclusions about the quality and dynamics of changes in the studied features. In addition, within age groups, there were comparative analyses of average values between gender groups (Student's t-test).

5 Results obtained

For multiple regression analysis with selection of a subset of the optimal set of variables one influential feature was selected like the length of lumbar lordosis (DLL). The set of variable features included the studied spine features: 1 - 16, table 2, 3. From the regression of the registered traits, it is noticeable that (DKP) length of thoracic kyphosis is significantly and positively influenced by length of lumbar lordosis (DLL), (KKP) thoracic kyphosis angle is significantly and negatively influenced by length of lumbar lordosis (DLL), (RKP) thoracic kyphosis height is significantly and positively influenced by length of lumbar lordosis (DLL), (GKP) depth of thoracic kyphosis is significantly and positively influenced by length of lumbar lordosis (DLL), (KLL) angle of lumbar lordosis is significantly and negatively influenced by length of lumbar lordosis (DLL), (RLL) height of lumbar lordosis is significantly and positively affected by length of lumbar lordosis (DLL), and (GLL) depth of lumbar lordosis is significantly and positively affected by length of lumbar lordosis (DLL), Tab. 7.
Tab. 3. Multiple regression analysis with selection of a subset of optimal explanatory variables like city, age, gender, weight and body height, length of lumbar lordosis, and characteristics of the 1 - 16 N = 16608

<table>
<thead>
<tr>
<th>Variables</th>
<th>Influences</th>
<th>R2%</th>
<th>I. r.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Name</td>
<td>Xo</td>
<td>City</td>
</tr>
<tr>
<td>5</td>
<td>DKP</td>
<td>59.85</td>
<td>-3.49</td>
</tr>
<tr>
<td>6</td>
<td>DKP%</td>
<td>88.56</td>
<td>-0.79</td>
</tr>
<tr>
<td>7</td>
<td>KKP</td>
<td>165.98</td>
<td>0.02</td>
</tr>
<tr>
<td>8</td>
<td>RKP</td>
<td>65.96</td>
<td>-3.73</td>
</tr>
<tr>
<td>9</td>
<td>RKP%</td>
<td>65.98</td>
<td>-0.98</td>
</tr>
<tr>
<td>10</td>
<td>GKP</td>
<td>-3.26</td>
<td>-0.6</td>
</tr>
<tr>
<td>12</td>
<td>DLL%</td>
<td>63.14</td>
<td>0.17</td>
</tr>
<tr>
<td>13</td>
<td>KLL</td>
<td>170.03</td>
<td>-0.61</td>
</tr>
<tr>
<td>14</td>
<td>RLL</td>
<td>-8.09</td>
<td>2.69</td>
</tr>
<tr>
<td>11</td>
<td>RLL%</td>
<td>33.3</td>
<td>1.07</td>
</tr>
<tr>
<td>16</td>
<td>GLL-</td>
<td>-4.91</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Source: own research

For multiple regression analysis with selection of a subset of the optimal set of variables one influential trait was selected like the angle of lumbar lordosis (KLL). The variable feature set included spine features 1-16, table 2, 4. The regression shows that (DKP) the length of thoracic kyphosis is significantly and negatively affected by angle of lumbar lordosis (KLL), (KKP) angle of thoracic kyphosis is significantly and positively affected by the angle of lumbar lordosis (KLL), (RKP) height of thoracic kyphosis is significantly and positively affected by the angle of lumbar lordosis (KLL), (GKP) depth of thoracic kyphosis is significantly and negatively affected by the angle of lumbar lordosis (KLL), (RLL) height of lumbar lordosis is significantly and negatively affected by the angle of lumbar lordosis (KLL), and (GLL-) depth of lumbar lordosis is significantly and negatively affected by the angle lumbar lordosis (KLL), Tab. 7.
Tab. 4. Multiple regression analysis with selection of a subset of optimal explanatory variables like city, age, gender, weight and body height, angle of lumbar lordosis, and characteristics 1 – 16 N = 16608

<table>
<thead>
<tr>
<th>Variables</th>
<th>Influences</th>
<th>Name of parameters of variables in the model</th>
<th>R²%</th>
<th>I. r.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Name</td>
<td>Xo City Age Sex W.C. M.C. KLL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>DKP</td>
<td>233,08 -6,16 3,28 0,79 -0,15 16,42 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DKP%</td>
<td>72,48 -0,77 0,01 0,82 0,03 -0,03 0,1 4,11 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>KKP</td>
<td>112,22 0,2 0,01 -0,84 -0,04 0,04 0,29 18,05 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>RKP</td>
<td>70,67 -4,63 1,47 0,59 0,29 0,35 19,92 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>RKP%</td>
<td>23,49 -0,71 0,32 0,06 0,2 11,16 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>GKP</td>
<td>105,11 -1,37 0,02 0,99 -0,06 -0,08 -0,46 20,05 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>DLL%</td>
<td>355,59 -3,97 0,05 0,39 -0,15 -0,88 14,28 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>RLL%</td>
<td>110,16 -0,3 0,02 -0,11 -0,07 -0,13 10,02 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>RLL%</td>
<td>76,41 0,8 -0,31 -0,06 -0,2 11,45 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>GLL -</td>
<td>106,35 -0,34 0,88 -0,11 -0,52 23,96 ***</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: own research

For multiple regression analysis with selection of a subset of the optimal set of variables one influential trait was selected like height of lumbar lordosis (RLL). The set of variable features included spine features: 1 - 16, Table 2, 5. The regression shows that (DKP) length of thoracic kyphosis is significantly and positively influenced by height of lumbar lordosis (RLL), (KKP) angle of thoracic kyphosis is significantly and negatively influenced by height of lumbar lordosis (RLL), (RKP) height of thoracic kyphosis is significantly and negatively influenced by height of lumbar lordosis (RLL), (GKP ) depth of thoracic kyphosis is significantly and positively influenced by height of lumbar lordosis (RLL), (DLL) length of lumbar lordosis is significantly and positively influenced by height of lumbar lordosis (RLL), (KLL) angle of lumbar lordosis is significantly and negatively affected by height of lumbar lordosis (RLL), and (GLL-) depth of lumbar lordosis is significantly and positively affected by height of lumbar lordosis (RLL), Tab. 7.
Tab. 5. Multiple regression analysis with selection of a subset of optimal explanatory variables like city, age, gender, weight and body height, height of lumbar lordosis, and characteristics 1 - 16 N = 16680

<table>
<thead>
<tr>
<th>Variables</th>
<th>Name of parameters of variables in the model</th>
<th>R²%</th>
<th>I. r.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Name</td>
<td>Xo</td>
<td>City</td>
</tr>
<tr>
<td>5</td>
<td>DKP</td>
<td>166,52</td>
<td>-6,53</td>
</tr>
<tr>
<td>6</td>
<td>DKP%</td>
<td>101,67</td>
<td>-0,7</td>
</tr>
<tr>
<td>7</td>
<td>KKP</td>
<td>162,22</td>
<td>-0,61</td>
</tr>
<tr>
<td>8</td>
<td>RKP</td>
<td>138,09</td>
<td>-4,72</td>
</tr>
<tr>
<td>9</td>
<td>RKP%</td>
<td>73,92</td>
<td>-0,65</td>
</tr>
<tr>
<td>10</td>
<td>GKP</td>
<td>22,57</td>
<td>-1,25</td>
</tr>
<tr>
<td>11</td>
<td>DLL</td>
<td>102,26</td>
<td>-4,59</td>
</tr>
<tr>
<td>12</td>
<td>DLL%</td>
<td>74,4</td>
<td>-0,35</td>
</tr>
<tr>
<td>13</td>
<td>KLL</td>
<td>-171,39</td>
<td>-0,32</td>
</tr>
<tr>
<td>15</td>
<td>RLL%</td>
<td>25,27</td>
<td>0,73</td>
</tr>
<tr>
<td>16</td>
<td>GLL</td>
<td>9,97</td>
<td>0,63</td>
</tr>
</tbody>
</table>

Source: own research

For multiple regression analysis with selection of a subset of the optimal set of variables one influential trait was selected like the depth of lumbar lordosis (GLL-). The set of variable features included the studied spine traits: 1 - 16, table 2, 6. The regression shows that (DKP) length of thoracic kyphosis is significantly and positively influenced by depth of lumbar lordosis (GLL-), (KKP) angle of thoracic kyphosis is significantly and negatively influenced by depth of lumbar lordosis (GLL-), (RKP) height of thoracic kyphosis is significantly and positively affected by depth of lumbar lordosis (GLL-), (GKP) depth of thoracic kyphosis is significantly and positively affected by depth of lumbar lordosis (GLL-), and (DLL) length of lumbar lordosis is significantly and positively affected by depth of lumbar lordosis (GLL-), Tab. 7.
Tab. 6. Multiple regression analysis with selection of a subset of optimal explanatory variables like city, age, gender, weight and body height, and depth of lumbar lordosis, and characteristics 1 – 15  N = 16608

<table>
<thead>
<tr>
<th>Variables of parameters of variables in the model</th>
<th>Influences</th>
<th>R2%</th>
<th>I. r.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Name</td>
<td>Xo</td>
<td>City</td>
</tr>
<tr>
<td>5</td>
<td>DKP</td>
<td>162.33</td>
<td>-5.7</td>
</tr>
<tr>
<td>6</td>
<td>DKP%</td>
<td>85.09</td>
<td>-0.77</td>
</tr>
<tr>
<td>7</td>
<td>KKP</td>
<td>169.73</td>
<td>0.01</td>
</tr>
<tr>
<td>8</td>
<td>RKP</td>
<td>110.27</td>
<td>-4.78</td>
</tr>
<tr>
<td>9</td>
<td>RKP%</td>
<td>57.8</td>
<td>-0.8</td>
</tr>
<tr>
<td>10</td>
<td>GKP</td>
<td>12.79</td>
<td>-1.07</td>
</tr>
<tr>
<td>11</td>
<td>DLL</td>
<td>170.64</td>
<td>-3.41</td>
</tr>
<tr>
<td>12</td>
<td>DLL%</td>
<td>83.78</td>
<td>-0.21</td>
</tr>
<tr>
<td>13</td>
<td>KLL</td>
<td>169.41</td>
<td>-0.47</td>
</tr>
<tr>
<td>14</td>
<td>RLL</td>
<td>84.74</td>
<td>1.02</td>
</tr>
<tr>
<td>15</td>
<td>RLL%</td>
<td>41.86</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Source: own research

Tab. 7. Multiple regression of variable parameters with selection of the optimal subset  
N = 16608

Source: own research

The Legend:

Explanation of features numbers, tab. 2.

Features listed vertically affect those ranked horizontally

Red – significant positive influence

Yellow – significant negative influence

White – irrelevant influence
6 Discussion

Due to editorial limitations and the very large number of obtained test results, the author deliberately limited himself to describe lumbar lordosis and thoracic kyphosis features.

From Lewandowski's electro goniometric measurements [4], the angular values of the physiological curvatures of the spine present that their development shows a convergent course in both sexes, but the total increase in the angular values of individual curvatures is greater in male individuals. A study by Drzal-Grabiec et al [5] conducted using the photogrammetric method in a group of 480 students of the first third graders of elementary school showed that the parameters characterizing posture are mutually influencing parameters. They also showed that the angle of torso tilt is the most dependent parameter on the others and the least dependent parameter is the length of thoracic kyphosis. The author's research also proved the mutual influence of the various parameters describing posture on each other. They did not show a parameter that was independent on the others, which indicates that posture as a whole changes even if one of the describing characteristics is changed.

7. Summary

The presented statistical analysis shows the mutual influence of the values of the selected features. The study showed no independent trait, however, the degree of influence varied. This demonstrates the interrelatedness of the different spinal segments. Corrective actions that change the value of one postural trait force the change of others in a positive or negative way.

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