Biomechanical Aspects Of Lumbar Hyperlordosis And Low Back Pain During Pregnancy.
G Sulima, O Bryekhov, E Kosobokova, O Poliakov, M Kalinin, O Kovalenko, V Volkov

Citation

Abstract
Low back pain (LBP) during pregnancy is polyfactorial and occurs in the second trimester of pregnancy. In this report we investigate the biomechanical component of lumbalgia during pregnancy and the mechanism of its origin\textsuperscript{2,5,6,7,9}. The goal of this paper is to investigate the biomechanical component of lumbalgia during pregnancy and the mechanism of its origin. Sixty two pregnant women, aged 26±2.2, were examined by us in the last term of pregnancy (37-40 weeks). 48 patients (77.4%) suffered from the low back pain. The results of the clinical examination displayed the size of lumbar lordosis between 19-30 mm. The 3D-model of lumbar spine during the 37-40 weeks of pregnancy was developed in a three-dimensional system - compas - 3D. The deflected mode analysis was carried out by the finite element method in COSMOS DesignSTAR environment\textsuperscript{1,4}. From the biomechanical point of view, LBP pathogenesis is a consequence of dorsal decentration of gravity that realizes in the fixed hyperlordosis with the following series of morpho-functional disorders, which are accompanied with the decrease of stress and the deformation in the structural elements of vertebral-motor segments.

INTRODUCTION
Pregnancy-related low back pain (LBP) is a frequent clinical problem even during the early stages of pregnancy\textsuperscript{2,6,7}. Recent studies have shown that about 33-50% of pregnant women report LBP before 20 weeks of gestation, and that the prevalence may reach 60-70% in late pregnancy\textsuperscript{5,7,9}. Back pain and the causes of it among pregnant patients are not entirely understood. There is no consensus among orthopedists and obstetricians on the relationship of back pain with structural and functional elements of the vertebral-motor segment in spite of its prevailing during pregnancy\textsuperscript{2,5,6,9}. The goal of this investigation was to investigate the biomechanical component of lumbalgia during pregnancy and the mechanism of its origin.

MATERIALS AND METHODS
Sixty two pregnant women, with the average age of 26±2.2 years, were examined by us. Forty eight patients (77.4%) suffered from the low back pain. The results of the clinical examination displayed the size of the lumbar lordosis ranging between 16 and 35 mm. Functional changes of the lumbar spine elements with lordotic deformation were studied on the 3D-models developed in the laboratory of biomechanics of SevNTU. The 3D-model of lumbar spine was developed in a three-dimensional system - COMPAS - 3D. The deflected mode analysis was carried out by the finite element method in the COSMOS DesignSTAR environment\textsuperscript{1,3}. Linear elastic models of the materials of the vertebral-motor segments’ elements with the characteristics presented in Table 1 were used in the models\textsuperscript{4}. The deformation of the models under the load was considered to be small.
Table 1. Mechanical properties of the material elements of the vertebral-motor segment

<table>
<thead>
<tr>
<th></th>
<th>Cortical bone</th>
<th>Spongy bone</th>
<th>Intervertebral disc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young's modulus, Pa</td>
<td>1.56×10^6</td>
<td>1.0×10^3</td>
<td>5.0×10^7</td>
</tr>
<tr>
<td>Poisson's ratio</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4 - 0.45</td>
</tr>
<tr>
<td>Shear modulus, Pa</td>
<td>5.77×10^5</td>
<td>3.84×10^5</td>
<td>19.23×10^5</td>
</tr>
<tr>
<td>Ultimate strength, Pa</td>
<td>1.0×10^2</td>
<td>4.0×10^3</td>
<td>1.0×10^2</td>
</tr>
</tbody>
</table>

DISCUSSION

The 3D-model of the spine with lordosis ranging between 10 and 12 mm was originally studied, which corresponds to the normal state of a spine (Figure 1).

Pattern of behavior of the model was investigated by giving the external load applied to the surface elements of the upper vertebrae and rigid clamping of the lower vertebra. Herewith, 80% of the load was applied to the end plate surface, and 20% to the surface of the vertebra in the area of the facet joints.

The pattern of the equivalent stresses distribution in the form of the von Mises (Von Mises Stresses) on the model elements' surfaces under the above-mentioned conditions is
presented in Figure 2.

**Figure 3**
Figure 2: A pattern of the equivalent stresses’ distribution in the form of the von Mises on the model elements’ surfaces

It is vivid that the maximal stress arises at level L3-L5 in the posterior supporting complex, and reaches 4.5 MPa; it can be compared with the breaking point of a spongy tissue (see Table 1). Thus, the maximal deformations reach 0.8 mm in the intervertebral discs between L3-L4 and L4-L5.

**Figure 4**
Figure 3: A pattern of the equivalent deformations’ distribution on the model elements’ surfaces

At the next stage the deflected mode of lumbar spine model with hyperlordosis with the size of 34 mm was studied, as an average value of the observed range of values that were between 30 and 40 mm, and which corresponds to 36-39 weeks of pregnancy (Figure 1b).

The applied loading of 400 N was taken (half of patient’s weight) for the pregnant woman of this term of pregnancy and also the total weight of the uterus, placenta, amniotic fluid, fetal membranes and fetus was considered to be equal to 100 N. We consider that the center of this weight is at level L3-L4 in front of a spine axis at the distance of 0.1 m.
A pattern of the equivalent stresses distribution in the form of the von Mises on the model elements’ surfaces is presented in Figure 4 in different planes. A pattern of the equivalent deformations’ distribution on the surface of the model with hyperlordosis size of 34 mm is presented in Figure 5.

**Figure 5**  
Figure 4: The patterns of the equivalent stresses’ distribution in the form of the von Mises on the model elements’ surfaces with hyperlordosis of 34 mm

The deflected mode ultimate analysis showed that the maximum stress, as in the first case, is on the vertebrae surfaces at the level of L3-L5. However, the value of maximum stress increased to 30 MPa in this case, which is almost 6.5 times higher than in the first case, the lordosis 10-12 mm. At the same time the model elements’ deformations increase, the maximal values of which is within 1.5-2 mm.

Conceptual model of lumbar spine’s functional condition in the late pregnancy was developed by us on the basis of the clinical examinations and the results of the studied deflected mode of lumbar lordosis. Decreasing of fetus mass and his center of gravity location ahead lead to the displacement of total power load-line in dorsal direction. At the same time the arc of lumbar spine becomes shorter and spinous processes of the adjoining vertebrae approach each other. The clinical display of these biomechanical changes is the apparent lordosis and hyperlordosis (over 18 mm). In the present state of affairs, the power load-line doesn’t pass through the disc centers and vertebral bodies, but displaces posteriorly into the posterior area of the disc semiring and zygapophyseal joints, that morpho-functional state is not programmed to carry vertical load. This realizes into the joints’ overload and decreasing stress and deformation into them. And clinically it manifests itself in the inclination of the superior articular processes, a malfunction of articular congruence pairs, stretching the joints capsule and irritation of branches of spinal nerves.

The results that we received after the modeling of such system’s state are presented in Figure 6. As opposed to the models studied above, in this case a loading of the posterior supporting complex was allowed.

**Figure 6**  
Figure 5: The patterns of the equivalent deformations’ distribution on the model elements’ surfaces with hyperlordosis of 34 mm

**Figure 7**  
Figure 6: The patterns of the equivalent stresses’ distribution in the form of the von Mises on the model elements’ surfaces considering the interaction between the vertebrae in the posterior supporting complex

**CONCLUSIONS**

From the biomechanical point of view, the pathogenesis of low back pain is a consequence of dorsal decentration of gravity that realizes in the fixed hyperlordosis with the following series of morpho-functional disorders, which are accompanied by the decrease of stress and the deformation in the structural elements of vertebral-motor segments.

It can be assumed that hyperlordosis observed in pregnant women is the result of adaptive reactions to the appearance
of additional loads from the direction of the fetus. In this case, the muscles generate additional bending moment, counter-torque of the fetus weight. As a result, the whole biomechanical system converges to the most optimal shape in each case. Side effect of this optimality is the redistribution of stresses in the elements of vertebral-motor segments, which may increase significantly in the local areas. Finally, as this process occurs within a short period of time (several months) the adaptability process remains incomplete and many women suffer from pain, its intensity is determined, among other things, and the state of their spine in the postpartum period.

References
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