WHY PREGNANT WOMEN SHOW INCREASED LORDOSIS – A MODEL BASED EXPLANATION

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SUMMARY
Based on a simplified biomechanical model, the concept of altered acting torques during pregnancy was explored by varying geometrical arrangements. The comparison of the non pregnant to the pregnant situation with normal lordosis demonstrates a considerable increase of acting counter torques. These acting counter torques in the lumbar segments could be substantially reduced by introducing a hyperlordosis in the sagittal plane.

INTRODUCTION
During pregnancy about 50% of the women suffer on low back pain (LBP) [2, 4, 8-10], while the aetiology of the low back problems remains unclear. It has been shown, that the sagittal moments and forces on the back increases due to an enlarged uterus, an increased total weight and hormonal changes [2, 6, 8, 12]. Furthermore, mechanical strain, the lumbar hyperlordosis, pelvic anteverision or dysfunction of sacroiliac joints, pubic symphysis or hip joints may cause back pain [2, 10]. Moreover functional changes in back muscle activity during pregnancy were shown [9].

The mechanical and physiological changes of the lumbar antagonistic system during pregnancy appear to influence considerable the acting forces of the lumbar spine. It results in an alteration of the effective moments on each centre of rotation (COR) whereby the demands on the lumbar back muscles increase. Although, the hyperlordosis during pregnancy is not contentious, their cause and benefits are critically discussed [2, 10, 12]. A self-selected increase of lordosis permit gravid females to maintain a stable anteroposterior position of the centre of mass as gestation progresses [12]. The question remains whether the increased lordosis during pregnancy is functional and appropriate. Therefore we proposed the hypothesis, that an increased lordosis decreases the counter torques (CTs).

METHODS
We used a biomechanical model of the lumbar spine in the sagittal plane consisting of five lumbar vertebrae (L1 – L5). It includes five CORs each having one rotational degree of freedom. The pelvis was fixed during simulations, and a point mass m [kg] represented the female upper part of the body. It includes the highly asymmetric, dorsally shifted location of the spinal column, realistic moment arms and physiological cross-sectional areas of the muscles as well as realistic force-length and force-velocity relationships. Three antagonistic pairs of global muscles were included as shown in Table 1. Each muscle consists of five separate muscle fibres. Finally, the equation of motion of this antagonistic model could be derived as follows:

\[ \ddot{\alpha} = \omega \]

\[ \omega = \left( \sum_{i=1}^{n} M_{wi} + mg \cdot (st + sg) \sin(\alpha) + CT_k \right) / \Theta \]

With \( \alpha \) flexion angle, \( \omega \) angular-velocity, \( g \) gravitational acceleration, \( st \) distance between k'th COR and the point mass m, \( sg \) height of rotation axis and \( \Theta \) moment of inertia of the upper body with respect to a COR. Corresponding to the theory of Ljapunov [5], the system is stable for negative real parts of both eigenvalues \( \lambda_{1,2} \):

\[ \lambda_{1,2} = \frac{1}{2} \frac{\partial \omega}{\partial \alpha} \pm \frac{1}{4} \left( \frac{\partial \omega}{\partial \omega} \right)^2 + \frac{\partial \omega}{\partial \alpha} \]

This was done for every CORk respectively, while the others were fixed, i.e. five Jacobian matrices \( J_k \) and ten eigenvalues were calculated. The minimum physiological cross sectional area (PCSA) needed to sustain stability was calculated numerically as the sum of each PCSA of the muscle fibres. To guarantee equilibrium at the k'th COR the counter torques \( CT_k \) were calculated, representing the effect of local muscles, to counteract the sum of the torques generated by global muscles and the external torque due to the point mass m.

The situations non pregnant and pregnant are modelled by varying the geometric arrangements of dorsal shift, lordosis and total weight (see in Table 1). To quantify the stability of the equation of motion the Jacobian was calculated for three simulations (A, B, C see Table 1). Situation A (Table 1) illustrates the non pregnant position of the lumbar spine. In case B and C (Table 1) we simulated the gravid situation at the end of pregnancy with a different lordosis [2, 8, 12].

RESULTS AND DISCUSSION
We found that an increased lordosis during pregnancy had a negative influence on the stability of the lumbar spine, but it substantially decreases the local CTs. Three different situations (A, B, C) were analysed to show how the geometrical changes during pregnancy influence the self-stability and the local counter torques in the lumbar spine (Figure 1). The minimum PCSA stabilising all CORs was 45 cm² for all 30 muscle fibres, i.e. 22.5 cm² each side. For this activation of the global muscles it is possible to assure equilibrium at every lumbar spinal segment. This PCSA is within the previously published values for lumbar
muscles [1, 7, 11]. Figure 1 shows the Euclidian norm of all five local CTs in dependence of dorsal shift and lordosis of the lumbar spine. For the normal physiological arrangement (see A in Figure 1) the CTs are within ±5.4 Nm. Case B displays the pregnant situation with an enlarged uterus whereby the dorsal shift extend by a factor of three hence the CTs rise substantially. In spite of the increased CTs all CORs are self-stabile for this geometrical arrangement. Case C shows that an increase of the lordosis decreases the CTs. Several studies indicated that hyperlordosis of gravid females are a result of the enlarged uterus [2, 3, 12]. Whitcome et al. showed that pregnant women self-selected choose an enlarged curvature of the lumbar spine [12]. Further they measured an increase of the body’s torque around the hip roughly eightfold if gravid females are constrained from exaggerating their lumbar lordosis [12].

Our results approve the rise of the acting torques by missing lordosis (Figure 1, B). The simulations are indicating an increased demand on the local muscles.

CONCLUSIONS
Hyperlordosis seems to be a physiological adaptation on the dramatically anthropometrical changes during pregnancy, i.e. it is a mechanical consequence due to the dorsal shift of the spine in the sagittal plane to reduce the local counter torques at the spinal segments. We conclude that not the hyperlordosis itself is the cause for back problems during pregnancy but the excessive demand on the local muscles. Therefore we suggest training of the local muscle fibres to reduce the activation level of the global lumbar muscles.

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REFERENCES

Table 1: The three simulated situations of the lumbar spine with the values for dorsal shift and lordosis as well as total weight of the women. A – normal physiological situation, B – pregnant situation, C – pregnant hyperlordosis situation

<table>
<thead>
<tr>
<th>situation</th>
<th>A - normal</th>
<th>B – pregnant – normal lordosis</th>
<th>C – pregnant – Hyperlordosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>dorsal shift</td>
<td>2 cm</td>
<td>6 cm</td>
<td>6 cm</td>
</tr>
<tr>
<td>lordosis</td>
<td>3 cm</td>
<td>3 cm</td>
<td>7 cm</td>
</tr>
<tr>
<td>total weight</td>
<td>60 kg</td>
<td>75 kg</td>
<td>75 kg</td>
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