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Biomechanical analysis and modeling of lumbar belt: preliminary study.

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1. Introduction

Low back pain is a major public health problem in European Countries. In France, about 50% of population is suffering of this pathology every year (Fassier 2011). Because of health care cost and sick leave (Fassier 2011; Leclerc et al. 2009), low back pain has both societal and economic adverse consequences. Many treatments are proposed. However no guideline is provided to physician. Treatment depends on patient, on low back pain type and evolution and also on physician knowledge and believes. Medical devices, as lumbar belt might be proposed to treat low back pain. Several clinical trials have shown their efficacy (Calmels et al. 2009). Nevertheless, both mechanical and physiological effects of lumbar belts remain unclear.

In this study, the application of a lumbar belt on the trunk is simulated by a finite element model. It is often assumed that the pain comes from the toe of the intervertebral discs and is related only to the intradiscal pressure and the thoracolumbar posture. Beside, abdominal pressure is used by belt manufacturers as a marker of the lumbar belt efficiency, because a change in the abdominal pressure could bring a change in the thoracolumbar posture and consequently on the intradiscal pressure. That's why the goal of this study is to determine the mechanical effect of wearing lumbar belt: i) on abdominal pressure; ii) on thoracolumbar posture; iii) on intervertebral disc pressure.

2. Methods

The 3D geometry of the trunk was acquired by parameters measurement in lateral radiography (vertebral length, width and endplate slope) and in patients (bust, waist, hips and stature measurement). Thanks to these parameters, a generic model with three components (vertebras, intervertebral discs and soft tissues) has been built. All components are represented by tetrahedral elements.

Mechanical properties of all the components of the model were taken from published data (Goel et al. 1993; Sylvestre, 2007; Clin, 2011). They are summarized in table 1. Materials behaviour was considered as linear elastic.

Components	Young's modulus (MPa)	Poisson's ratio
Vertebras	12 000	0.3
Intervertebral discs	8	0.49
Soft Tissue	1	0.2

Table 1 Mechanical properties of the component of the model

Pressure was applied onto the trunk to simulate lumbar belt wearing. Surface of applied pressure in the model was the same as the area applied on the patient. Two possibilities were simulated for this surface, depending on the height of the lumbar belt back side. Pressure was calculated by the Laplace's law (Dubuis et al. 2012):

$$P = T/R \qquad (1)$$

with P the pressure, T the line tension and R the radius of curvature. Line tension varies with lumbar belt type. As a consequence, mean pressure was between 4 and 13 kPa.

The following boundary conditions were applied on the model: upper surface of the trunk was blocked to just allow translation in longitudinal direction and in lower surface, translation to longitudinal direction was blocked.

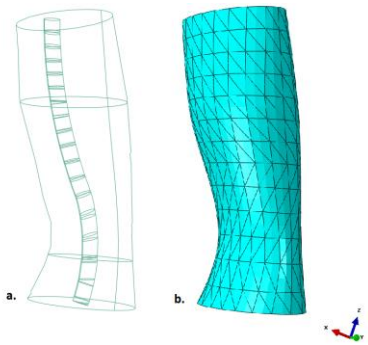

Figure 1 Finite element model of the trunk, a. Entire model, b. Meshing model

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Sensibility of the model to mechanical properties was evaluated by modifying Young's modulus for all components of the model. Young's modulus variation was chosen from publishing data (Clin et al. 2011; Périé et al. 2004; Goel et al. 1993). Convergence test was carried out to assess the effect of the mesh resolution.

3. Results and Discussion

Figure 1 shows the finite elements model of the trunk. According to the convergence test, optimal model contains more than 1 200 000 elements with more than 1 600 000 nodes.

Modification of the spine posture is characterized by the existence of a displacement gradient (up to 3mm for the trunk and 2.5mm for the spine). The mean abdominal pressure variation is 10 kPa when the stiffer lumbar belt is used (mean applied pressure of 13 kPa).

In this model, different geometries can be easily modelled using only one radiography per patients. This geometry doesn't take into account the presence of the rib cage and the pelvis, because the first modeled lumbar belts almost no cover these areas. In addition, muscles are not precisely represented, while they are related to the intradiscal pressure. This is explained by the fact that for the first study, only changes in intradiscal pressure from the wearing or not of the lumbar belt was studied. Proprioception effects are not taken into account in this model.

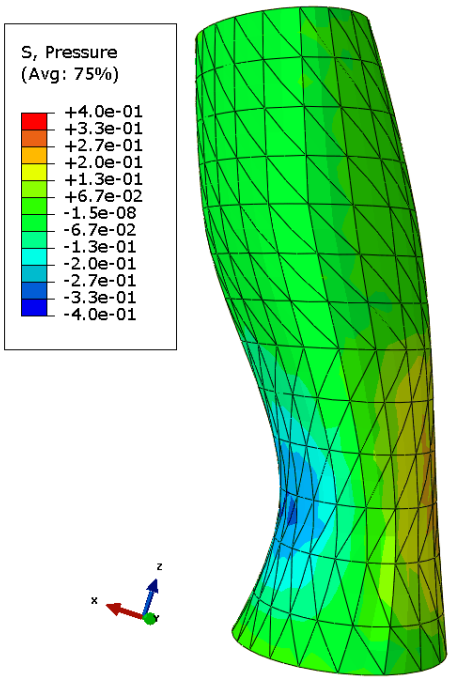

Figure 2 Example of simulation's results: Pressure applied on the trunk by the lumbar belt

4. Conclusion and future works

Finite elements model developed in this study is a first model to simulate the impact of a lumbar belt wearing. Interface pressure applied to the model according to the Laplace's law is equivalent to pressure applied by the lumbar belt to a patient according to a preliminary experimental study.

By modifying the generic geometry, other components of the trunk could be modelled like the distinction between annulus and nucleus in the intervertebral disc or between the skin and other soft tissue. To improve the accuracy of this model and to simulate bigger lumbar belt, a partition of the soft tissue can be considered to represent abdominal cavity, thoracic cage, muscles or the presence of the pelvis. A sensibility study will be done to determine influence of detailled geometry.

Next steps of this study are the comparison of numerical results to experimental data (interface pressure and displacement measurement) and the numerical simulation of different kind of lumbar belts.

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