

Study advance copy with selected results

Experimental, computer-based examination of the impact of orthoses on the sacroiliac joint and its ligaments

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Abstract

Lower back pain (SI joint syndrome) is a common clinically-diagnosed condition involving a high level of suffering for affected patients and high socio-economic significance. One possible cause of pain syndromes affecting the sacroiliac joint (SIJ) can be found in the interaction between the ligaments and the movement of the posterior pelvic ring. However, there has been inadequate research carried out so far into the interaction between the SI joint's shape or morphology and its function in SI joint syndrome. Pelvic orthoses are already widely used in the treatment of SI joint syndrome. However, any clinical explanation for their impact has only been inadequate, thereby making them of experimental biomechanical interest.

The objective of this study was to examine the impact of pelvic orthoses on the osteoligamentous pelvic ring using a computer model based on the application of the finite element method (FEM). Geometric and mechanical data of the bones, cartilage and pelvic ligaments were used to create the FEM pelvic model (Fig. 1). Furthermore, Bauerfeind's SacroLoc® orthosis was integrated into the FEM computer model. Finally, the mobility of the SI joint, as well as the strain on the SI joint ligaments with and without the orthosis (Fig. 2) were investigated.

Study design

Experimental biomechanical in silico study

Methods

Sample:	Computer model of a healthy male volunteer: 29 years old, height of 185 cm, weight of 69 kg; based on computer tomography data (Somatom Volume Zoom Scanner, Siemens AG, Erlangen, Germany)
Test orthosis:	Pelvic orthosis (SacroLoc, Bauerfeind)
Data analysis:	AMIRA 3.1.1 (VSG, Burlington, MA, USA), semi-automated segmentation of the bone image data; Geomagic software solution, (Geomagic, Morrisville, USA), ANSYS Workbench (ANSYS Inc., Canonsburg, USA, graphics program, [Fig. 1])
Results:	SPSS Version 20 (Armonk, USA); R Software (The R Foundation for Statistical Computing, Vienna, Austria); Shapiro-Wilk test for independent samples; Mann-Whitney U test; univariate analysis of variance (ANOVA); analysis of variance at a significance level of 5 percent
Test method:	MRI (Magnetom Trio, Siemens AG, Erlangen, Germany), Electromyography (Bagnoli-8, Delsys Inc., Boston, USA), gait analysis

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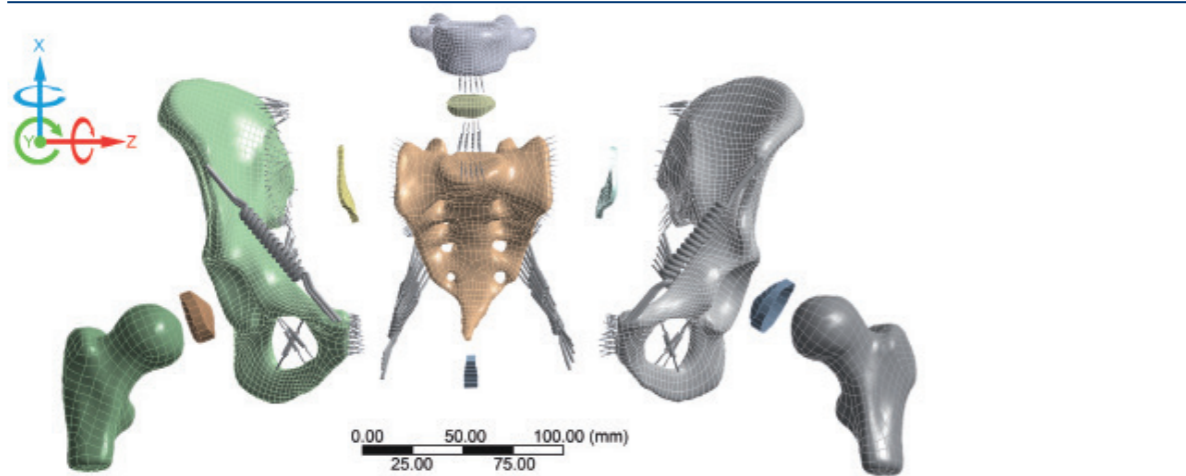


Fig. 1: Graphical representation of the front view of the pelvic model created using the Finite Element Method. The geometric data for bones and cartilage come from the CT data for a healthy 29-year-old man. Both hip bones, the sacrum and coccyx, the 5th lumbar vertebra, the proximal sections of the femora, and the connecting articular surfaces were integrated into the model. The geometric and mechanical data for the ligaments comes from studies carried out by the group comprising Hammer et al., also involved in researching the SI joint.

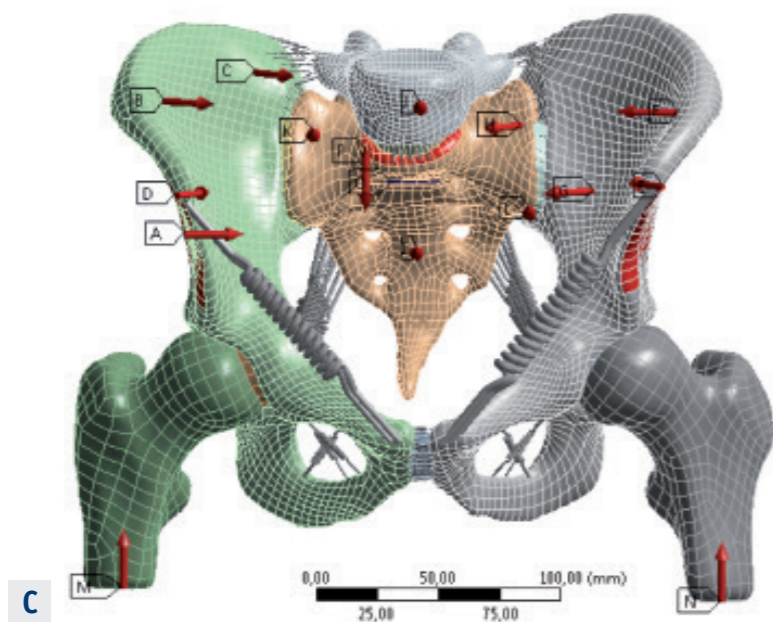
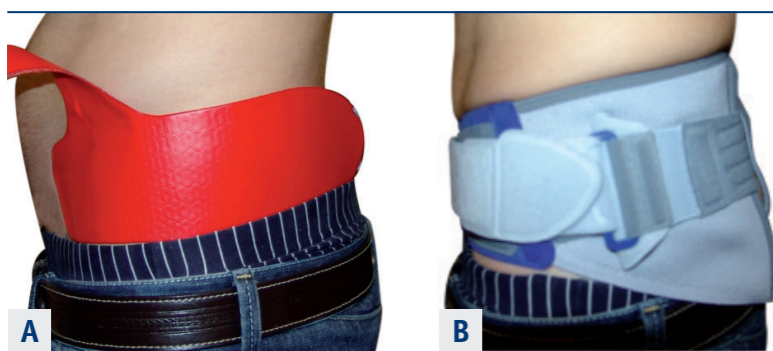


Fig. 2: Data was collected on the compressive effect of the SacroLoc orthosis on a 26-year-old man using a Pedar pressure measuring system. Fig. 2A and 2B show the in-vivo measurement device. Fig. 2C shows the resulting measured forces in the Finite Element pelvic model (red arrows correspond to the force vectors).

Results (selection)

Use of the computer model made it possible to display in 3D the nutation movement of the SI joint that is typical for the SI joint and controlled by ligament structures (Fig.3). The SI joint's movements are minimal. A rotation of the SI joint around the transverse (x) and sagittal (z) axes was observed. The compressive force exerted by the pelvic orthosis resulted in a movement opposing nutation (counternutation), which restricted the scope of the SI joint's movement (Fig. 3). The compressive force exerted by the SacroLoc results in a 42% reduction in the rotation around the transverse (x) axis. Movement around the sagittal (z) axis increases by 65%. At the same time, using the pelvic orthosis reinforces the transverse tilt of the hip bones by 62%. The change in kinematics brought about by the SacroLoc also indicates a measurable reduction in the strain on the SI joint's ligaments, primarily the sacrospinal and sacrotuberal ligaments (18% and 14% reduction respectively in the stretching observed; data table not shown).

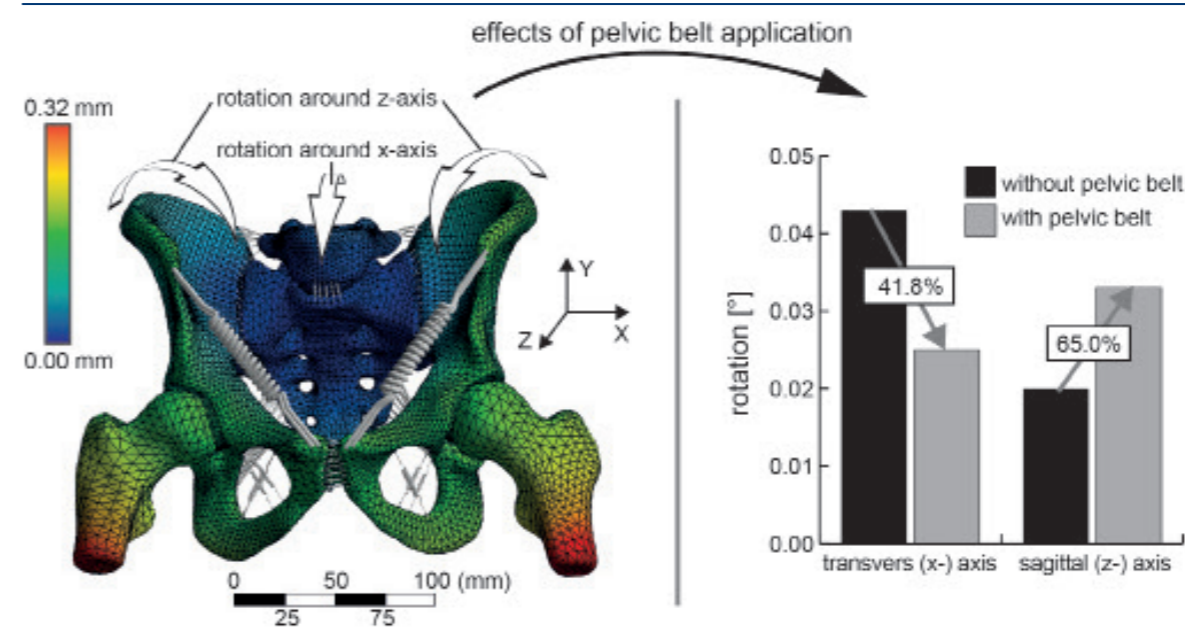


Fig. 3: The computer simulation demonstrates the movement of the SI joint when the pelvic orthosis is applied. In a weight-bearing position standing on both legs, a movement of the SI joint in the sagittal (z) axis and transverse (x) axis was observed. When the pelvic orthosis is fitted, this reduces the SI joint's movement in the transverse axis and increases it in the sagittal axis. The SI joint's total scope of rotation is reduced. The majority of the SI joint's ligaments are relaxed.

Discussion

Thanks to use of the computer model, it has been shown that the compressive force exerted by the pelvic orthosis causes a counternutation in the SI joint, thereby restricting the scope of physiological movement. This effect is also reflected in the stress applied to the ligaments involved in this movement. The stretching of the ligaments in the posterior pelvic ring was overwhelmingly reduced as a potential site for nociceptive input. The results highlight that pelvic orthoses such as the SacroLoc® can reduce the pain affecting the SI joint as a result of excessive mobility or strain and, therefore, provide a successful form of treatment. This data corroborates the theory that the ligament structures in the pelvis are not only involved in the mechanical stabilization but also in the neuromuscular stabilization of the pelvic ring. This data is consistent with existing studies on the mobility of the SI joint and the strain on the ligament structures involved.