Musculoskeletal disorders, especially in the low back region, are very present and widely spread all over the world, impacting the societies in their productivity and straining their health care management systems. Ironically, this kind of discomfort is a direct consequence of life’s increased comfort. Sedentariness, increased body weight and prolonged life span make people more susceptible to developing all sorts of problems, among which of musculoskeletal origin. In addition, biomedical research is driven by more urgent goals: the defeat of molecular diseases such as cancer and AIDS, and advances in surgery techniques are indeed a question of life and death. This cannot be said of low back pain.

This work nobly addresses exactly such a neglected diagnostic issue, picking up the discourse where medicine drops it once exhausted all possible diagnoses. The underlying assumption of this research is that unexplained pain on the low back region is a consequence of abnormal mechanical properties of the sacroiliac joints, which connect the sacrum to the two innominate bones of the pelvis. Laxity is an often heard term in physiotherapy, and it designates the compliance of the joints between bones under the constant force that a practitioner applies. As such it is not measurable nor objective.

During this research the development of a diagnostic tool for a non-invasive objective measurement of the mechanical properties of the sacroiliac joints is investigated. The physical principle enabling such identification is borrowed from the dynamics field: a vibrating force is applied to the pelvis and provokes a vibrating displacement pattern all around the structure which depends on the mechanical properties of the structure (such a stiffness, mass and damping) and on the frequency of the applied force. The development of the apparatus for the introduction of the force and the measurement of the response by means of ultrasound technology (now existing in form of a prototype) has been investigated in a parallel track. In this work it is only briefly described.

To correctly interpret the measured response, and from it to extract the mechanical properties of interest, a model has been developed, comprising three rigid bodies representing the three bones of the pelvic girdle, a number of springs representing the ligaments of the girdle, and dashpots between the joints to implement damping. The anatomy of the pelvis, which has inspired the creation of the model, and the mathematics of the model derivation are presented and explained.

Based on this model several simulation studies were performed. Two algorithms for the identification of the mechanical properties of the model (especially stiffness) starting from the measured response have been devised and verified, one based on the first vibration mode shape of the model (thus in modal domain), and the other one based on the curve fitting of Frequency
Response Functions in frequency domain. Moreover the question about the constancy of the mechanical properties has been addressed: the response of a system showing frequency dependent stiffness and damping properties has been simulated and analysed with commercially available tools (all assuming constant stiffness and (viscous) damping properties), to investigate the magnitude of the error on the analysis outcome. Results showed that resonance frequencies and mode shapes were accurately identified, but not so much the damping.

Interweaved into these numerical efforts, experiments have been performed on embalmed and fresh-frozen human pelvises, mainly to obtain data for the model validation. The adventure in setting up such experiments and the results are presented in this work. A different set of experiments, with a different goal, has been performed on rabbit knee ligaments to determine whether the stiffness is dependent on the excitation frequency or not. As it resulted, there is not enough evidence to confirm it.

Finally the success and the difficulties in correlating the established model to the results from the experiments are discussed, which lead directly to the last chapter of this dissertation, where the conclusions and recommendations are presented.