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# MRI-based registration of pelvic alignment affected by altered pelvic floor muscle characteristics

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**Abstract**

*Background.* Pelvic floor muscles have potential to influence relative pelvic alignment. Side asymmetry in pelvic floor muscle tension is claimed to induce pelvic malalignment. However, its nature and amplitude are not clear. There is a need for non-invasive and reliable assessment method. An intervention experiment of unilateral pelvic floor muscle activation on healthy females was performed using image data for intra-subject comparison of normal and altered configuration of bony pelvis.

*Methods.* Sequent magnetic resonance imaging of 14 females in supine position was performed with 1.5 T static body coil in coronal orientation. The intervention, surface functional electrostimulation, was applied to activate pelvic floor muscles on the right side. Spatial coordinates of 23 pelvic landmarks were localized in each subject and registered by specially designed magnetic resonance image data processing tool (MPT2006), where individual error calculation; data registration, analysis and 3D visualization were interfaced.

*Findings.* The effect of intervention was large (Cohen's $d = 1.34$). We found significant differences in quantity ($P < 0.01$) and quality ($P = 0.02$) of normal and induced pelvic displacements. After pelvic floor muscle activation on the right side, pelvic structures shifted most frequently to the right side in ventro-caudal direction. The right femoral head, the right innominate and the coccyx showed the largest displacements.

*Interpretation.* The consequences arising from the capacity of pelvic floor muscles to displace pelvic bony structures are important to consider not only in management of malalignment syndrome but also in treatment of incontinence. The study has demonstrated benefits associated with processing of magnetic resonance image data within pelvic region with high localization and registration reliability.


*Keywords:* Pelvis; Magnetic resonance imaging; Image registration; Pelvic floor muscles; Malalignment; Sacroiliac joint; Electrostimulation; *in vivo*

## 1. Introduction

From a mechanical perspective, the pelvis is a closed linked structure. Motion of any link in the chain is dependent on motion of the other links. A primary function of the pelvis is to transfer loads generated by body weight and gravity during standing, walking and sitting (Snijders et al., 1993). Pelvis also represents a basis for the axial system, thus its alignment influences posture and stability of the spine.

At a balanced position, soft tissues of the pelvic system transmit external loads and keep the pelvic ring stable. When an extra load is applied onto the pelvic system, or the material properties of the soft tissues around the pelvic joints are altered, the relative positions of the pelvic bones change to adjust tension in ligaments and pressures in joint cartilage. If extra load exceeds the stabilizing capacity, the pelvic ring becomes unstable (Zheng et al., 1997). The tension in soft tissues becomes asymmetrical and regular load transfer through the lumbopelvic region is impaired. Failed

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load transfer through the lumbopelvic region can manifest either as low back pain (Al-Eisa et al., 2006; Lee and Lee, 2004; Schamberger, 2002; Snijders et al., 1993) or as loss of urethra closure, causing stress urinary incontinence (Lee and Lee, 2004).

Bø and Sherburn (2005) defined function of pelvic floor muscles (PFM) as ability to perform a correct contraction, meaning a squeeze around pelvic openings and an inward movement of the pelvic floor. Recent studies showed that PFM also have potential to influence relative pelvic alignment and pelvic joint function via attachments to the bony pelvis. Pool-Goudzwaard et al. (2004) registered a significant counternutation of the sacrum when tension of PFM was simulated *in vitro*. Snijders et al. (1993) proposed that PFM can generate a direct compressive force on the sacroiliac joint (SIJ) and change the position of the joint. Unilateral increase of PFM tension, seen in patients suffering from levator ani syndrome, is claimed to generate force imbalance throughout the pelvic ring, resulting in displacement of pelvic bony structures (pelvic malalignment) (Malbohan et al., 1989; Schamberger, 2002; Tichý et al., 1999; Tichý, 2003). However, there is no reliable evidence regarding the nature and amplitude of such displacement.

Complex anatomy and spatial relationships within the pelvis have led researchers to use invasive techniques for precise assessment of pelvic kinematics. There is a need for a practical and non-invasive method that is accurate and reliable for pelvic alignment and motion measurements. Imaging techniques seem to be relevant for this purpose (Al-Eisa et al., 2006; Bussey et al., 2004; Buyruk et al., 1995; Lalonde et al., 2006; van Wingerden et al., 2004).

Magnetic resonance imaging (MRI), processing of the detected changes in atom nuclear magnetic moment after application of radiofrequency pulse (Westbrook and Kaut Roth, 2005), offers high resolution and multiplanar capabilities in addition to its non-invasive nature.

Concerning the pelvic region, only a few MRI-based studies have focused on the relationship between soft tissue characteristics and pelvic alignment. Handa et al. (2003) reported an association of certain pelvic phenotype with occurrence of pelvic floor disorders in a sample of 64 females. Hoyte et al. (2005) observed on 22 women racially predefined bony-soft tissue pelvic floor parameters, which, if increased, may incite the development of incontinence-related problems. Gutman et al. (2005) evaluated anatomical distances between the vaginal apex and the pelvic bony structures of 11 nulliparous women, concluding that there exists a consistent relationship between soft and solid structures of the pelvis.

In the present study, we focused on the role of PFM tension asymmetry in relative spatial pelvic organisation. The aim was to register the nature and amplitude of the pelvic displacements induced by unilaterally altered PFM characteristics using MRI data. In addition, we tested the reliability of registration procedure for intra-subject comparison of image data and its suitability for the pelvic region.

## 2. Methods

The study was designed as an experimental intervention trial based on comparison of normal and altered conditions in individual subjects (the control subjects became experimental subjects after the intervention).

The sample consisted of 14 adult nulliparous subjects, who were healthy volunteers recruited prospectively. Based on published data (Handa et al., 2003), the sample size was adequate to detect differences in pelvic alignment between the control and experimental group ($n = 12.1$; $\alpha = 0.05$; $\beta = 0.05$). Subject parameters were mean age of 26.5 and body mass index of 22.3. Exclusion criteria were a history of chronic low back pain, dysmenorrhoea, incontinence, gynaecologic operations and apparent musculoskeletal abnormalities in the pelvic region or the lower extremities. All subjects signed a letter of informed consent.

### 2.1. Intervention

A single-shot intervention of unilateral functional electrostimulation (FES) was applied onto right side of PFM to alter their characteristics. Based on findings of Kodešová et al. (2005), the idea of the intervention was to induce contemporary poststimulative shortening and increase of tension in PFM; mainly the coccygeus, the levator ani and the caudal portion of the gluteus maximus pars coccygeofemoralis (Tichý and Grim, 1985). The Institutional Research Ethics Committee of the Faculty of Physical Education and Sports at Charles University in Prague approved the experiment.

We used mid-frequency current with rectangular characteristics (Neuroton Universal 926; Medizintechnik AG, Rimbach, Germany); 50 Hz modulated frequency; 100–300 μs impulse latitude; 3 s impulses duration, 6 s pause; individually adopted overthreshold motoric intensity of 16–30 mA and 5 min duration. The surface punctual cathode was placed in the paracoccygeal region, vertical to the muscle course. The surface square anode was attached to the lower part of the gluteal muscles.

### 2.2. MRI management

Each subject underwent three MRI investigations. To identify intra-subject variance in MRI data without any alteration, we performed two sequent MRI examinations of controls. The subjects stood up from the gantry bench, stepped once on each leg and laid back. The third MRI scanning was performed immediately after the intervention.

MR imaging of the pelvic region was performed with 1.5 T static body coil (Gyroscan ACS-NT; Philips Medizin System, Hamburg, Germany) in coronal orientation (3D TFE gradient sequence; 1 mm slice thickness; 2 mm gap; 9.3–9.7 ms repetition time; 4.6 ms echo time; 256 × 256 matrix; 400 mm field of view; 11 min duration). Supine subjects were scanned with controlled uniform position of