Clinical Biomechanics 30 (2015) 827–831

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

The influence of simulated transversus abdominis muscle force on sacroiliac joint flexibility during asymmetric moment application to the pelvis

Rafael Gnat [a,b,c,*], Kees Spoor [a], Annelies Pool-Goudzwaard [a,d]

[a] Department of Neuroscience, Erasmus MC, University Medical Centre Rotterdam, P.O. Box 2040, 3000 CA Rotterdam, The Netherlands
[b] Motion Analysis Laboratory, Faculty of Physiotherapy, University of Physical Education, ul. Mikolowska 72, 40-065 Katowice, Poland
[c] Faculty of Physiotherapy, Academy of Business, ul. Cieplaka 1c, 41-300 DąbrowaGórnicza, Poland
[d] Research Institute MOVE, Faculty of Human Movement Sciences, VU University Amsterdam, Van der Boechorststraat, 9, 1081 BT Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 19 February 2015
Accepted 8 June 2015

Keywords:
Pelvis
Sacroiliac joint
Transversus abdominis
Flexibility

ABSTRACT

Background: The role of so-called local muscle system in motor control of the lower back and pelvis is a subject of ongoing debate. Prevailing beliefs in stabilizing function of this system were recently challenged. This study investigated the impact of in vitro simulated force of transversely oriented fibres of the transversus abdominis muscle (a part of the local system) on flexibility of the sacroiliac joint during asymmetric moment application to the pelvis.

Methods: In 8 embalmed specimens an incremental moment was applied in the sagittal plane to one innominate with respect to the fixed contralateral innominate. Ranges of motion of the sacroiliac joint were recorded using the Vicon Motion Capture System. Load–deformation curves were plotted and flexibility of the sacroiliac joint was calculated separately for anterior and posterior rotations of the innominate, with and without simulated muscle force.

Findings: Flexibility of the sacroiliac joint was significantly bigger during anterior rotation of the innominate, as compared to posterior rotation (Anova $P < 0.05$). After application of simulated force of transversus abdominis, flexibility of the joint did not change both during anterior and posterior rotations of the innominate.

Interpretation: A lack of a stiffening effect of simulated transversus abdominis force on the sacroiliac joint was demonstrated. Earlier hypotheses suggesting a stiffening influence of this muscle on the pelvis cannot be confirmed. Consistent with previous findings smaller flexibility of the joint recorded during posterior rotation of the innominate may be of clinical importance for physio- and manual therapists. However, major limitations of the study should be acknowledged: in vitro conditions and simulation of only solitary muscle force.

1. Introduction

The role of so-called local muscle system (Bergmark, 1989) in motor control of the lower back and pelvis is a subject of ongoing debate. Prevailing beliefs in an exclusive stabilizing function of this system as well as studies leading to the formulation of such ideas (e.g. Hodges and Richardson, 1997a, 1997b, 1998; Hodges and Gandevia, 2000; Sapsford and Hodges, 2001b, 2001a; Ferreira et al., 2006, 2007; Tsao and Hodges, 2007) were recently challenged (Allison and Morris, 2008; Burns et al., 2011; Cleland et al., 2002; Hodges et al., 2013; Koumantakis et al., 2005; Lederman, 2010; Mannion et al., 2008; Mills et al., 2005; Reeves et al., 2011). Indeed, earlier evidence suggested that local (deep) muscles of this region, inserting on or deriving from the lower lumbar spine and pelvis (e.g. transversus abdominis (TrA), lumbar multifidus, pelvic floor), have the potential to decrease flexibility and thus stabilize the articular junctions. In case of the pelvis, Richardson et al. (2002) reported that after voluntary contraction of the TrA, "laxity" of the sacroiliac joint decreases. Pool-Goudzwaard et al. (2004) provided partial confirmation of this finding demonstrating decreased flexibility of the sacroiliac joint during in vitro simulation of pelvic floor activity. However, such an effect was limited to female specimens and occurred after mimicking multiple pelvic floor muscles. In line with these studies, Pel et al. (2008) created a biomechanical simulation model showing an increase in compression of the sacroiliac joint linked to activation of transversely oriented TrA fibres as suggested earlier by Snijders et al. (1995). In contrast with these studies, recently Gnat et al. (2013) demonstrated lack of a stiffening effect of simulated TrA muscle force on the pubic symphysis in vitro. In line with their results, also the claim of a stiffening effect of TrA on the sacroiliac joint (SIJ) seems questionable, although the anatomy and hence

* Corresponding author at: University of Physical Education, Faculty of Physiotherapy, ul. Mikolowska 72, 40-065 Katowice, Poland.
E-mail address: rafal.gnat@interial.pl (R. Gnat).

http://dx.doi.org/10.1016/j.clinbiomech.2015.06.006
0268-0033/

biomechanical action of this muscle (Askar, 1977; Rizk, 1980) suggests a compressive effect on the SIJ, as partly demonstrated by previous studies (Pel et al., 2008; Pool-Goudzwaard et al., 2004; Richardson et al., 2002; Snijders et al., 1995).To our knowledge no in vitro study has proven the stiffening effect of simulated TrA activity on the SIJ.

The present study investigated the impact of in vitro simulated force of transversely oriented fibres of the TrA on flexibility of the SIJ during asymmetric loading of the pelvis. Flexion (linked to SIJ counternutation) and extension (linked to SIJ nutation) rotations in the sagittal plane of one innominate with respect to the other were used to mimic the natural behaviour of the pelvis during e.g. locomotion. Our secondary objective was to compare SIJ flexibility for flexion and extension rotations of the innominate. Such objective was formulated since previous studies using similar methodology (e.g. Jacob and Kissling, 1995; Smidt et al., 1995; Sturesson et al., 2000a, 2000b; Agarwal et al., 2014) did not address this issue. Moreover, for quite a long time extension of the innominate (SIJ nutation) has been regarded as the ‘position of stability’ (or close-packed position) protected by larger ligamentous guard, as opposed to flexion of the innominate (SIJ counternutation) limited only by the thin anterior ligamentous complex and long dorsal sacroiliac ligament (Vleeming et al., 1989a, 1989b, 1996).

Findings of this study can be of importance in the debate whether local muscles indeed have a stabilizing function in contrast to other muscles of the trunk. Outcome of this debate can interfere with current treatment modalities employed in e.g. management of patients with postpartum pelvic girdle pain (Stuge et al., 2004) or demonstrating difficulties in transferring load across the pelvic ring (Beales et al., 2010; Mens et al., 2006). Analysis of SIJ flexibility for flexion and extension of the innominate relative to the sacrum may also add to our understanding of SIJ function in human gait.

2. Methods

2.1. Material

Eight embalmed specimens (6 females, mean age at time of death 70.3 ($\pm$5) years, embalming time 3–6 months) consisting of the pelvis and L5 vertebrae with all ligaments and capsules intact were available.

2.2. Experimental setup

In our specimens, an incremental torque was applied to one innominate in the sagittal plane while the other innominate was fixed to a custom-made frame (Fig. 1). To enable both torque application to one innominate and fixation of the opposite innominate, a rigid metal plate was screwed to each innominate through the compact bone at the height of the iliac crest, above the acetabulum and through the ischial tuberosity. One plate was attached to the frame to fix the bone, while the second was connected to a steel bar and axle to allow application of an incremental force resulting in a moment in the sagittal plane. To allow three-dimensional movements of the innominate on the non-fixed side and the sacrum, the axle was equipped with two universal joints and one prismatic sliding joint (Fig. 1). Torque was exerted on the axle by a custom-made pneumatic traction system installed on the frame. The force was transmitted by non-elastic cord to a steel disk (diameter 300 mm) and then to the axle and innominate. To calculate the real moment applied to the bone a torque transducer was placed between the steel disk and the bar with two universal joints (Fig. 1). Throughout the whole measurement its signals were registered with a sampling frequency of 10 Hz.

Prior to flexibility analysis, it was necessary to record ranges of motion of the SIJ in the sagittal plane during the specimen loading. To achieve this the Vicon MX Motion Capture System (Vicon Motion Systems, Oxford, UK) was used. A total of 11 reflective markers (diameter 9.5 mm) were screwed to the specimen (4 per each innominate, 3 per sacrum). To minimize interference by bone deformations (especially

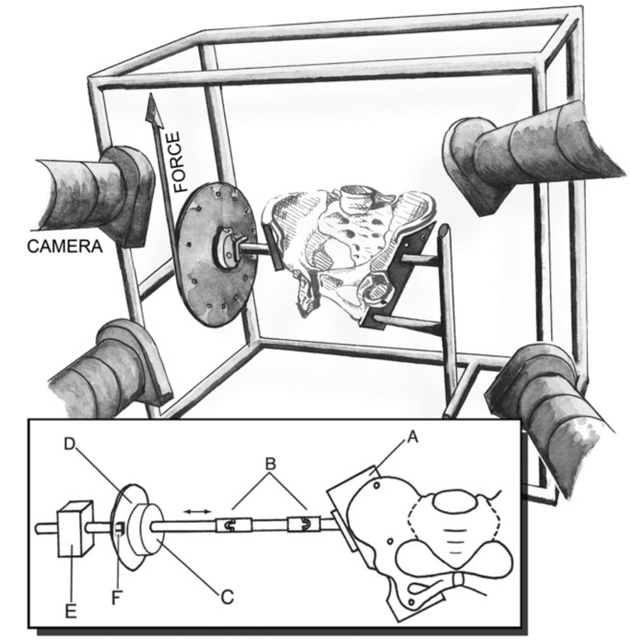

Fig. 1. Experimental setup with metal plates (A) screwed to both innominates, one fixed to the frame, the other connected to a steel bar with two universal joints (B), a torque transducer (C), a pulley (D) and a prismatic sliding joint (E). Electronic goniometer (F) was used to control range of motion during the procedure. To maintain clarity, pneumatic cylinders generating the necessary forces are not shown.

in the lower part of the innominate), in the current analysis only the 9 markers located close to the SIJs (Fig. 2) were used and the remaining two markers in the pubic symphysis area (not shown in the Fig. 2) were omitted. Markers were illuminated by an infrared light source mounted on each of four video cameras equipped with a 20 mm lens (Sigma, Tokyo, Japan). A sampling frequency of 100 Hz was used which was fairly enough for the employed, semi-static mode of load application. The precision of the measurement estimated on a mechanical model was equal to 0.1 deg for angular and 0.1 mm for linear measurements.

During each test an incremental torque was first applied to either the left or right innominate bone (randomly chosen) in a semi-static, step-wise manner. The opposite innominate was properly fixed and remained immovable throughout the trial. During consecutive stages of the procedure (see below) the torque increased/decreased in load-steps ranging from 3 to 7 Nm applied with 20 s intervals. Starting from the unloaded state, we used larger load-steps (7 Nm) and approaching maximal torques they were gradually becoming smaller (minimally 3 Nm). This prevented specimen destruction when maximal loads were in use. The torque during each load-step increased/decreased

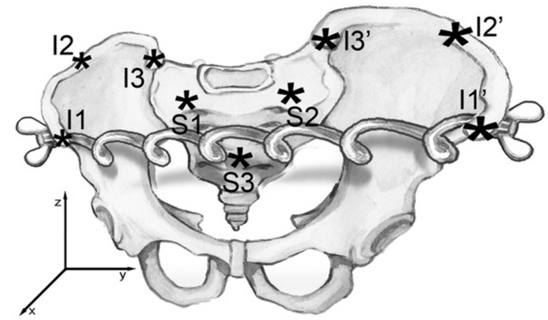

Fig. 2. The coordinate system and position of the sacral (S 1, 2, 3) and innominate (I 1(1′), 2(2′), 3(3′)) markers. The spring represents an elastic rubber band imitating the force exerted by the transversus abdominis muscle on the two innominates.