MUSCULAR CONTRIBUTION TO FORCE CLOSURE; SACROILIAC JOINT STABILIZATION IN VIVO

Wingerden JP van[a], Vleeming A[a], Buyruk HM.[b], Raissadat K.[c]
[a]Spine & Joint Centre, The Netherlands
[b]Institute of Rehabilitation
University Hospital Dijkzigt, Rotterdam
The Netherlands
[c]St. Antonius Hospital
Dept. Surgery
The Netherlands

Correspondence address:
Spine & Joint Centre
J.P. van Wingerden
Westerlaan 10
3016 CK ROTTERDAM, The Netherlands
E-mail : sjceco@wxs.nl

INTRODUCTION

The goal of his study is to demonstrate in vivo that muscles contribute to force closure of the sacroiliac joint (SIJ). In previous anatomical and biomechanical studies a model on SIJ stability was proposed, based on the principles of form and force closure.[13,17,18,19] The base of this model is that to effectively transfer load from the spine through the pelvis to the legs, muscles acting on the pelvis must be activated thus increasing force closure of the SIJ.[14,20,21]

Confirmation of this model in vivo was not feasible due to lacking of a reliable method to measure SIJ stability in living subjects. The development of a technique, combining Color Doppler Imaging (CDI) with excitation of the pelvis by means of an oscillation device made it possible to analyse forceclosure in vivo [1,2,3].

In several anatomical in vitro studies specific muscles that could contribute to SIJ stabilization were identified. Based on these findings, this study focuses on the effect of unilateral activation of the biceps femoris, gluteus maximus and erector spinae, and contralateral activation of the latissimus dorsi muscle. [11,15,16,20,21]

MATERIAL AND METHODS

Subjects

In 6 out of 15 subjects threshold values of the CDI were sufficient for inclusion in this study (Table 1). Preliminary tests showed the protocol to be fairly straining to the subjects. Because testing bilaterally may have led to unreliable results due to fatigue [10] during the experiment, tests were performed unilaterally (4 right, 2 left side).

Table 1. Demographic data of test subjects

	Mean	SD
Age	22	2.6
Length	170	4.1
Weight	62	4.9

Testing procedure

Volunteers were lying prone with the anterior superior iliac spine in contact with the oscillator plate (figure 1).

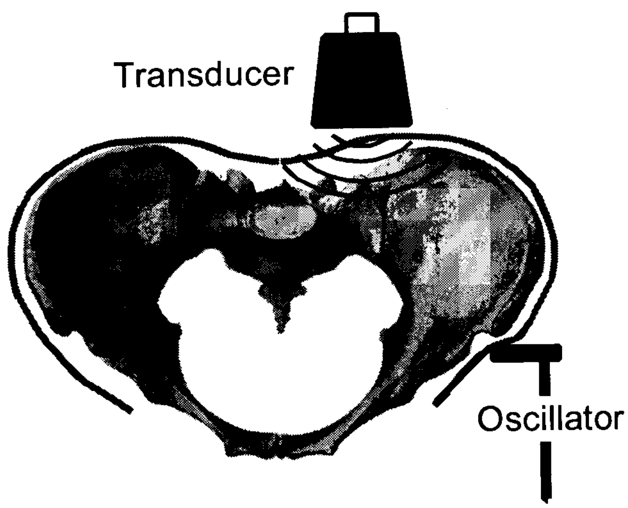

Figure 1. Outline of transducer and oscillator position for echo doppler measurements

Both before and after the measurements a maximal voluntary contraction (MVC) of each separate muscle was recorded, using isometric muscle test procedures with manual resistance as described by Kendall et al.[9]
Each measurement started with determination of SIJ stiffness without any muscle activation using CDI. Then the volunteers were asked to activate only one particular muscle as specific as possible for the period of the measurement using the technique as for the MVC test. However, in contrast to the MVC test, no maximal voluntary contraction but only slight effort of the tested muscle was pursued (>10% of MVC), with no or only minimal coactivation of other muscles (<10% of MVC) and minimal disturbance of the initial posture. Since only minimal exertion was required no manual resistance (in contrast with the MVC test) was applied during the tests.
During each test, EMGs of all four muscles were recorded simultaneously to test for cocontractions. Sustained muscle contractions with an average duration of 10 seconds were required to analyze SIJ stiffness by means of the CDI method.
The test sequence was repeated three times with biceps femoris, gluteus maximus, latissimus dorsi and erector muscles tested in randomized order for each subject.

EMG recording

Electrode location was determined as described by Delagi et al.[4,10] Volunteers were instrumented with surface EMG electrodes (Meditrace pallet electrodes) after the skin was scrubbed and cleaned with alcohol. EMG signals were amplified and 10 - 2 kHz filtered (bipolar EMG amplifier PS-800, Twente Medical System). The signals were rectified, low-pass filtered (10 Hz) and simultaneously fed to a computer with a sample frequency of 50 Hz. Preliminary studies showed no interference of the vibration device with the EMG recordings.

Color Echo Doppler imaging (CDI)

The application of CDI in combination with generated oscillation and the subsequent validation of this method, is described in detail in previous studies on SIJ stiffness.[1,2,3] Vibrations with a frequency of 200 Hz (using a Derritron VP3 oscillator) were unilaterally applied to the anterior superior iliac spine. The vibrations from ilium and sacrum were measured by a Philips Quantum AD1 CDI transducer covering both sides of one SIJ (Figure 1).
The threshold indicates the necessary signal power to display perceived vibration in color. The height of the threshold can freely be set by the operator by means of the threshold button on the control panel of the CDI apparatus. During a measurement the threshold is precisely set to the level were no vibrations are visible on the CDI screen. A large difference between the thresholds (threshold difference; THD) measured at the sacrum and ilium indicates little stiffness of the SIJ. A small or absent THD indicates a stiff joint.[1,2,3] In this study differences between THD in the relaxed position and the THD during a muscle test were used as a measure for change in SIJ stiffness. A decreased THD during the muscle test indicates that the joint has become more stiff.

Analysis

To determine changes in SIJ stiffness during muscle activity, THD's found during muscle tests were subtracted from THD's found during relaxed postures for each individual and analysed with a paired two sample t-test.
To quantify the activity level of each muscle during the tests the mean activity level was calculated from the three repetitions of each muscle test and presented as percentages of the MVC. For analysis of EMG activity during the tests a paired t-test was used. A muscle was considered active when the EMG signal exceeded 10% of MVC. P-values less then 0.05 were considered significant.

RESULTS

Mean results of all subjects are presented in figures 2 and 3. During the initial SIJ stiffness measurements (no muscle activation) the mean THD was 5.2 (sd 1.94). During each muscle test the THDs significantly diminished (figure 2). This effect is particularly strong during the erector, gluteus and biceps muscle test. The mean results show a significant increase in SIJ stiffness when muscles were activated.
With respect to muscle contribution in all tests the highest mean EMG level is especially found for the target muscle (figure 3). In some individual tests however erector EMG level is higher than the target muscle. In most individual tests there is more than 10% of MVC EMG activity of other muscles. However as figure 3 shows, this does not result in significant co-activation with exception of the gluteus test. Here the mean EMG activity of another muscle besides the gluteus (erector) is significantly more than 10% of MVC (42%).

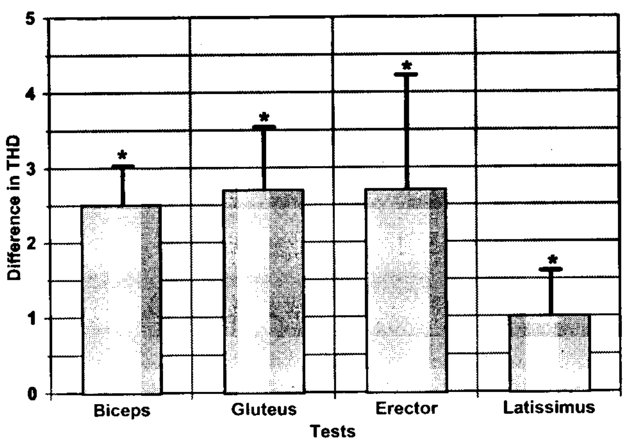

Figure 2. Increase in thresholddifferences (THD) during muscle tests. Positive values indicate that the sacroiliac joint has become more stiff. * $p<0.05$, P values are calculated with a paired t-test.

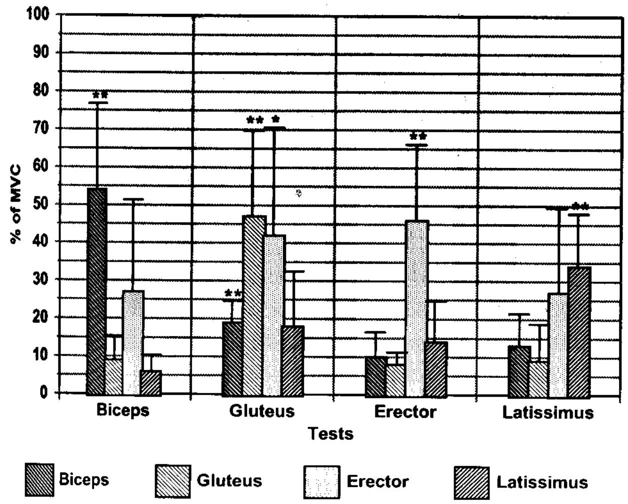

Figure 3. Mean muscle EMG values during muscle tests. * $p<0.05$, ** $p<0.01$, P values are calculated with a paired t-test, $H0:\mu=10$.

DISCUSSION

In this study, color Doppler imaging in combination with pelvic oscillation was used to analyze the influence of muscle activity on SIJ stiffness. It was demonstrated that SIJ stiffness increased when selected muscles were activated. The erector spinae, biceps femoris and gluteus maximus muscles showed the greatest effect on SIJ stiffness. The latissimus dorsi muscle only had a small effect on SIJ stiffness.

During all tests the activated muscle was electromyographically most active (figure 3). But coactivation of other muscles occurred. Coactivation of the erector muscle during the biceps, latissimus and gluteus maximus tests, could be expected. This is in agreement with the stabilizing function of the multifidus part of the muscle as described by Hides et al.[5] Their study shows that the multifidus is coactive with the transverse abdominals and possibly oblique abdominals as primary stabilizers of spine and pelvis. [5,6,7] Regrettably, since surface electrodes were used in this study, the abdominal muscles could not be included.

The results of this study have specific clinical consequences. Clinically, determination of joint stiffness usually takes place by means of the manual skills of the clinician. The intra- and inter- tester reliability of such manual tests is low.[12] Poor reproducibility of manual tests could be related to variance of muscle tension and hence joint stiffness between tests (in fact intra-joint or patient reliability). Until now this has not been demonstrated. This study showed that SIJ stiffness is influenced by muscle activity and thus by motor patterns. It can be expected that this also holds for joint stiffness in general. Small variations in the excitation pattern of muscles can lead to differences in joint stiffness. Consequently, during retesting of joints in patients, relatively small postural changes can result in altered muscle contraction patterns and subsequently influence the inter and intra tester reliability of manual joint play tests.

This study shows that besides structural quality and integrity of the joint, joint stiffness is also influenced by muscles. It can be assumed that joint stiffness is already influenced by basic muscle tone, when no muscle activity is detected on EMG. Emotional states are known to influence basic muscle tone and patterning.[8] Therefore the effect of emotional states on specific muscle patterns needs to be taken into account when analyzing SIJ stiffness. Presumably this assumption can be applied to joints in common.

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