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## Motor Control and Lumbopelvic Stability in Young Healthy Women

Many people, especially women during or after pregnancy, suffer from Pelvic Girdle Pain (PGP), which has remained a puzzling problem for a long time. With clinical relevance in mind, the present thesis limited itself to research on young healthy women, reasoning that the understanding of pathophysiology requires the understanding of normal physiology first. Chapter 1 presents a general introduction, focusing on the relationship between motor control and lumbopelvic stability.

Chapter 2 takes its starting point in Snijders' assertion that the sacroiliac joints are intrinsically unstable, and that concerted activity of the lateral abdominal muscles is needed to press the ilia against the sacrum, i.e., *force closure*. This mechanism may be disturbed in PGP. Electromyographic (EMG) activities during the Active Straight Leg Raise (ASLR), and during treadmill walking, were studied without or with a pelvic belt, which is supposed to substitute part of force closure. All muscles measured were active during the ASLR. In both tasks, the lateral abdominal muscles were less active in conditions with the belt, which result confirms Snijders' theory of force closure. Increased activity of contralateral hip extensors was found, i.e., the m. biceps femoris during the ASLR, and the m gluteus maximus in treadmill walking. It is important to note that hip flexors exert a forward rotating torque on the ilium. As long as the lateral abdominal muscles press the ilia against the sacrum (Snijders' "force closure"), the pelvis moves as one unit in the sagittal plane, and contralateral hip extensor activity will contribute to preventing forward rotation of the ipsilateral ilium.

Psoas function is a topic of considerable relevance in sports and clinical science, but the literature on psoas function is insufficiently consistent. Chapter 3 focuses on the question if the m. psoas is mainly a hip flexor, like the m. iliacus, or more involved in stabilization of the lumbar spine, which would require bilateral rather than unilateral activity. EMG activity was measured of right-sided psoas, iliacus, rectus femoris, and adductor longus, all during left or right ASLR. The four muscles measured started to contract before movement onset. The iliacus, rectus femoris, adductor longus, and psoas were active ipsilaterally, but psoas was also active contralaterally. There was no significant difference between the amplitudes or onset times of ipsilateral and contralateral psoas EMG activity. Nor was there a significant

interaction between Side (left or right ASLR) and Condition (without or with weight added above the ankle) for the psoas. Although ipsilateral psoas activity is consistent with the psoas being involved in hip flexion, contralateral activity is not. The most plausible explanation of the pattern found is that the psoas is recruited to stabilize the lumbar spine in the frontal plane.

Chapter 4 focuses on multitasking of the lateral abdominal muscles during walking, and on the question how the control system deals with conflicting constraints. Transversus abdominis (TA), obliquus internus (OI), and obliquus externus (OE) are involved in multiple functions: breathing, control of trunk orientation, and stabilization of the pelvis and spine. We studied EMG activity of these muscles, and 3-dimensional moments during treadmill walking at six different speeds (1.4-5.4 km/h) in healthy young women. PCA revealed that the time series of trunk moments were consistent across speeds and subjects, though somewhat less in the sagittal plane. All three muscles were active during  $\geq 75\%$  of the stride cycle, which is indicative of a stabilizing function. Clear phasic modulations were observed, with TA more active during ipsilateral, and OE during contralateral swing, while OI activity was largely symmetrical. Fourier analysis revealed four main frequencies in muscle activity: respiration, stride frequency, step frequency, and a triphasic pattern (probably a summation of stride and step frequency). With increasing speed, the absolute power of all frequencies remained constant or increased; the relative power of respiration and stride-related activities decreased, while that of step-related activity and of the triphasic pattern increased. Effects of speed were gradual, and EMG linear envelopes had considerable common variance ( $> 70\%$ ) across speeds within subjects, suggesting that the same functions were performed at all speeds. Further analyses in the time domain revealed both simultaneous and consecutive task execution. To deal with conflicting constraints, the activity of the three muscles was clearly coordinated, with co-contraction of antagonists offsetting unwanted mechanical side-effects of each individual muscle.

Chapter 5 presents a more detailed understanding of muscle activity during the ASLR. In the literature, it is often assumed that stabilizing activity reveals itself as bilateral symmetry. Detailed analysis of the ASLR suggests that this is incorrect, and that actual muscle activity results from the summation of symmetrical and asymmetrical components. In Chapter 2, contralateral activity of a hip extensor was found, i.e., the m. biceps femoris. Such activity will press the contralateral heel

downwards, and the contralateral pelvis upwards, which implies ipsilateral rotation of the pelvis. This ipsilateral rotation of the pelvis was mainly prevented by ipsilateral activity of the transversus abdominis, which offers another, more complex, example of the control system dealing with conflicting constraints by co-contraction, with unwanted effects of one muscle being offset by the activity of another muscle.

Chapter 6 presents a general discussion of motor control during the ASLR and during walking, in terms of lumbopelvic stability. By now, we know that bilateral activity of the lateral abdominal muscles may contribute to lumbopelvic stabilization; multitasking is important; no single muscle is limited to a single task; muscle coordination deals with conflicting constraints; and motor performance is variable. The most important conclusion of this thesis is that further biomechanical research into pelvic girdle pain needs to include the three dimensional kinematics and kinetics of (most of) the body. In and of itself, this conclusion may not be surprising, but so far, there is hardly any literature that takes the 3 dimensions involved sufficiently into account.