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Original article

Understanding the Active Straight Leg Raise (ASLR): An electromyographic study in healthy subjects

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A B S T R A C T

The Active Straight Leg Raise (ASLR) is an important test in diagnosing pelvic girdle pain (PGP). It is difficult to understand what happens normally during the ASLR, let alone why it would be impaired in PGP. In the present study, healthy subjects performed the ASLR under normal conditions, with weight added above the ankle, and while wearing a pelvic belt. Activity of the abdominal muscles, rectus femoris (RF), and biceps femoris (BF) was recorded with surface electromyography (EMG), and transversus abdominis (TA) with fine wire EMG. RF was ipsilaterally active, BF contralaterally, and the abdominal muscles bilaterally. All muscle activity was higher with weight, and abdominal muscle activity was lower with the pelvic belt. In both these conditions, TA and obliquus abdominis internus (OI) were more asymmetrically active than obliquus externus. The abdominal muscles engage in multitasking, combining symmetric and asymmetric task components. Hip flexion causes an unwanted forward pull on the ipsilateral ilium, which is counteracted by contralateral BF activity. To transfer this contralateral force toward ipsilateral, the lateral abdominal muscles press the ilia against the sacrum ("force closure"). Thus, problems with the ASLR may derive from problems with force closure. Also abdominal wall activity counteracts forward rotation of the ilium. Moreover, contralateral BF activity causes transverse plane rotation of the pelvis, often visible as an upward movement of the contralateral anterior superior iliac spine. Such transverse plane rotation is countered by ipsilateral TA and OI. The present study facilitates the understanding of what normally happens during the ASLR.

1. Introduction

Pelvic Girdle Pain (PGP) affects over 20% of pregnant women (Wu et al., 2004; Mulholland, 2005; Vleeming et al., 2008; Robinson et al., 2010; Gutke et al., 2010; Vermani et al., 2010), and may also occur in athletes with groin pain (Verrall et al., 2001), or after trauma (cf. Kanakaris et al., 2011). Several diagnostic examinations are commonly used, especially the Active Straight Leg Raise (ASLR) (Mens et al., 1999, 2001, 2002), during which the subjects are supine and attempt to raise their leg by hip flexion, with the knee in extension. In subjects with PGP, the test maybe painful or limited (Mens et al., 2002). The ASLR was reported to have good reliability, sensitivity, and specificity (Mens et al., 2001).

The ASLR assesses the ability to transfer load between the spine and the legs via the pelvis (Mens et al., 1999, 2001; cf. Beales et al., 2009a,b; Beales et al., 2010a,b; Hu at al., 2010a,b; Jansen et al., 2010), and can be used to differentiate PGP from hip or lumbar pain (Cowan et al., 2004; Mens et al., 2006; Roussel et al., 2007).

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During the test, subjects with PGP sometimes reported that they felt "as if the leg is paralyzed" (Mens et al., 1999). Relatedly, a "catching" sensation during walking was reported (Sturesson et al., 1997). These phenomena remain poorly understood.

The ASLR appears to consist of raising one leg, requiring ipsilateral hip flexor activity. Nevertheless, bilateral activity of muscles in the lumbopelvic region has been reported (Hu et al., 2010a). Snijders and his colleagues proposed that the transversus abdominis (TA), obliquus abdominis internus (OI), and obliquus abdominis externus (OE) stabilize the pelvis by pressing the iliac bones against the sacrum, i.e., sacroiliac "force closure" (Vleeming et al., 1990a,b; Snijders et al., 1993a,b). A pelvic belt maybe used to substitute, or partially substitute, the force required, which could be helpful when the ASLR is painful or limited (Mens et al., 1999). Still, it is not immediately obvious why raising one leg from a supine position would require pelvic stability (cf. Mens et al., 1999; Hu et al., 2010a). Moreover, Liebenson et al. (2009) reported on ipsilateral transverse plane rotation of the pelvis during the ASLR, which was interpreted in terms of lumbar spine stability. However, it remains unclear why the pelvis would rotate during the ASLR, or how this would relate to stability.

Clearly, we need to improve our basic understanding of the ASLR. Several studies have attempted to disentangle symmetric, stabilizing muscle activity from the asymmetric activity that is needed to raise a leg. Some studies assumed that activity is symmetric if no asymmetry is observed (e.g., Beales et al., 2009b; cf. Teyhen et al., 2009), but this may be a moot point (cf. Hodges, 2008 vs. Allison et al., 2008). Abdominal muscles engage in multitasking (Saunders et al., 2004; Hu et al., 2011), and muscle activity contains both symmetric and asymmetric components. Hence, we need to disentangle the various mechanisms that are involved in performing the ASLR. The present study analyzed the ASLR in healthy subjects. Our aim was to improve understanding the mechanisms involved, and thereby facilitate the clinical interpretation of the ASLR.

2. Methods

2.1. Subjects

Sixteen healthy nulliparous females were enrolled, mean $\pm$ SD age 27.5 $\pm$ 2.7 years, weight 61.2 $\pm$ 9.8 kg, height 167.9 $\pm$ 7.6 cm, and BMI 21.6 $\pm$ 2.4 kg/m^2. Exclusion criteria were: previous orthopedic surgery, walking-related disorders such as low back pain (LBP) or PGP, or a history of low blood pressure. Participants signed a written informed consent. The protocol was approved by the local Medical Ethical Committee.

2.2. Electromyography (EMG)

To reduce the subjects' burden, EMG was measured on one side only. We arbitrarily selected the right side. TA was recorded with CE-marked intramuscular fine-wire electrodes of 40 gauge insulated stainless steel (VIASYS Healthcare, Madison WI, USA). The electrodes were threaded into sterile 50 mm hypodermic needles, and trimmed, with 2–3 mm long "hooks" extending from the tip. After disinfection, the needle was inserted under semi-sterile conditions with ultrasound guidance. Insertion for the transversus abdominis was 2 cm medial to the midpoint of the vertical from the spina iliaca anterior superior (SIAS) to the rib cage (Hodges and Richardson, 1997; cf. Hodges and Richardson, 1999). Some subjects felt anxious when the needle entered the muscle, but no lasting pain was reported. For OI, OE, rectus abdominis (RA), rectus femoris (RF), and biceps femoris (BF), EMG was recorded with pairs of surface electrodes, consisting of 24 mm diameter Ag/AgCl discs, with an inter-electrode distance of 20 mm (Kendall ARBO, Neustadt am Dom, Germany). For OI, electrode placement was 1 cm medial to the anterior superior iliac spine (ASIS), 0.5 cm below the line joining both ASISs (Ng et al., 1998; Beales et al., 2009a,b); for OE, 1 cm above the horizontal line through the umbilicus, 1 cm lateral to the border of RA (McGill and Norman, 1986), and for RA, 1 cm above and 2 cm lateral to the umbilicus. For RF and BF, SENIAM recommendations were used (Hermens et al., 1999). Data was recorded at a sample rate of 2000 samples/s with a multichannel Porti5 EMG system (TMS-international, Enschede, The Netherlands; Hu et al., 2010a).

2.3. Kinematics

Four clusters of three LED Markers each were fixed onto small lightweight custom-made triangular frames, and attached halfway along the upper and lower legs for registration with a 2 $\times$ 3 camera system (OPTOTRAK 3020, Northern Digital, Waterloo, Ontario, Canada), connected via a synchronization cable to the Porti5 EMG system. To determine leg movements, the heights of the centers of the clusters were calculated. The kinematic sampling frequency was 50 samples/s.

2.4. Conditions

The ASLR was performed in supine position with the feet 20 cm apart (Mens et al., 2001). Subjects were instructed to raise one leg until the heel was 20 cm above the table, without bending the knees, and keeping the leg elevated for about 10 s ("Normal"). To increase statistical precision, this was done three times per leg per condition. After every ASLR, subjects were asked to relax for approximately 10 s. The whole procedure was repeated with a weight added just above the ankle ("Weight"), so that the static moment of the leg with respect to the hip was increased by 50%. To calculate the required amount of weight (Zatsiorsky, 2002; p. 605), manually measured lower extremity anthropometry was used. Finally, the ASLR was repeated with a non-elastic pelvic belt ("Belt"; 3221/3300, Rafys, Hengelo, The Netherlands), just below the ASIS (Damen et al., 2002; Mens et al., 2006), with a tension of 50 N (Vleeming et al., 1992; Mens et al., 1999), fine-tuned with an inbuilt gauge.

2.5. Data analysis

Data was analyzed with MATLAB 7.4 (The Mathworks, Natick, MA, USA). Kinematic data were filtered with a 4th order bi-directional low pass Butterworth filter with a cutoff frequency of 5 Hz. We determined the onset and the peak of leg raise, i.e., the first point with zero velocity before/after a peak in velocity. Leg raise velocity was calculated as the height of peak position divided by the time to reach peak position.

Due to technical problems with the amplifier, TA EMG was not usable in four subjects, which left twelve valid datasets for TA. EMG data were high-pass filtered at 250 Hz (1st order Butterworth; Hu et al., 2010a), then full-wave rectified, and low-pass filtered at 5 Hz (2nd order Butterworth). The median amplitude during ASLR plateau (5 through 10 s after movement onset) was calculated.

To quantify the asymmetry of activity of TA, OI, and OE, an Asymmetry Index was calculated as: (ipsilateral $-$ contralateral) activity/(ipsilateral $+$ contralateral) activity $\times$ 100%, "ipsilateral" and "contralateral" referring to the leg being raised. Positive values indicate more ipsilateral, negative values more contralateral muscle activity.