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Does insertion of intramuscular electromyographic electrodes alter motor behavior during locomotion?

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ABSTRACT

Intramuscular electromyography (EMG) is commonly used to quantify activity in the trunk musculature. However, it is unclear if the discomfort or fear of pain associated with insertion of intramuscular EMG electrodes results in altered motor behavior. This study examined whether intramuscular EMG affects locomotor speed and trunk motion, and examined the anticipated and actual pain associated with electrode insertion in healthy individuals and individuals with a history of low back pain (LBP). Before and after insertion of intramuscular electrodes into the lumbar and thoracic paraspinals, participants performed multiple repetitions of a walking turn at self-selected and controlled average speed. Low levels of anticipated and actual pain were reported in both groups. Self-selected locomotor speed was significantly increased following insertion of the electrodes. At the controlled speed, the amplitude of sagittal plane lumbo-pelvic motion decreased significantly post-insertion, but the extent of this change was the same in both groups. Lumbo-pelvic motion in the frontal and axial planes and thoraco-lumbar motion in all planes were not affected by the insertions. This study demonstrates that intramuscular EMG is an appropriate methodology to selectively quantify the activation patterns of the individual muscles in the paraspinal group, both in healthy individuals and individuals with a history of LBP.

1. Introduction

Intramuscular or fine-wire electromyography (EMG) is commonly used to quantify the activity of the trunk musculature during static or dynamic motor tasks. In particular, intramuscular EMG methodology is often employed in research investigating alterations in postural control of the trunk in individuals with low back pain (LBP) (MacDonald et al., 2009; Tsao et al., 2011; Hall et al., 2009). Intramuscular EMG electrodes enable the measurement of activity in the deep muscles of the trunk that are not accessible to surface EMG electrodes. These include the internal oblique, transversus abdominis and the deep fibers of the lumbar multifidus (Beneck et al., 2013; MacDonald et al., 2009). In the paraspinal muscle group, the use of intramuscular EMG also minimizes potentially confounding cross-talk from adjacent musculature that may have a different functional role (Lee et al., 2009).

However, a potential disadvantage of intramuscular EMG is that the pain associated with the insertion of the electrodes may alter motor behavior (MacDonald et al., 2009). For example, Young et al., (Young et al., 2004) demonstrated that in children with cerebral palsy, self-selected locomotor speed, cadence, and step length significantly decreased following insertion of intramuscular electrodes into the lower extremities. Similarly, Jacobson et al., (Jacobson and Gabel, 1995) reported that after intramuscular electrode insertions into the vastus medialis and biceps femoris, two of their healthy adult subjects had an antalgic gait pattern during walking and running and two others required a break in testing due to anxiety. Despite the large number of studies utilizing this methodology, to date it has not been established whether inserting intramuscular EMG electrodes into the paraspinal muscles alters trunk control or locomotor kinematics.

It is clear however that in healthy individuals, experimentally induced pain in the paraspinals alters postural control of the trunk during standing and walking (Moseley et al., 2004; Lamoth et al., 2004; Arendt-Nielsen et al., 1995; Moe-Nilssen et al., 1999). These changes in postural control during experimental pain are on the whole suggestive of a "guarding' or splinting strategy to reduce motion in the painful area (Moe-Nilssen et al., 1999; Lamoth et al., 2004). Trunk control is also affected by the anticipation of pain in the low back, even in the absence of actual pain itself (Moseley et al., 2004). However, as studies that utilize intramuscular EMG in the trunk do not routinely quantify the level of pain associated with this methodology, it is unclear whether discomfort following insertion is of sufficient intensity or duration to elicit

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changes in motion in the trunk during motor activities after the electrode insertions. Individuals with a history of LBP may have a more pronounced response to the insertion of intramuscular electrodes than healthy individuals due to elevated fear avoidance behaviors or lowered pain thresholds (Imamura et al., 2013; Wand et al., 2011). Therefore, it is also important to determine if the magnitude of any change in motion in response to electrode insertion is the same in healthy individuals and individuals with a history of LBP.

Turning during walking is a common locomotor perturbation. Walking turns can be performed in the direction either ipsilateral to or contralateral to the stance limb. In comparison with steady-state locomotion, ipsilateral walking turns are associated with greater postural demand (Taylor et al., 2005) and increased paraspinal muscle activation (Armour Smith & Kulig, unpublished data). As a result, analysis of walking turns may provide greater insight into changes in locomotor kinematics in response to intramuscular EMG insertion than steady-state locomotion. Therefore, the primary purpose of this study was to investigate if insertion of intramuscular EMG electrodes into the paraspinal musculature in healthy individuals and individuals with a history of recurrent low back pain resulted in reduced locomotor speed and reduced amplitude of trunk motion during ipsilateral walking turns. We hypothesized that there would be no difference in locomotor kinematics following electrode insertion. The secondary purpose of this study was to quantify the anticipated and actual amount of pain associated with insertion of intramuscular electrodes into the paraspinal muscles.

2. Methods

2.1. Participants

Twenty-nine young adults between the ages of 22 and 31 years participated in the study (17 women, 12 men). Participants were recruited via word of mouth and study flyers. Control participants (CTRL) were individually matched to participants with recurrent LBP (RLBP) by age (±five years), height in m (±10%) weight in kg (±10%) and activity level in metabolic equivalents (METS, ±15%; Table 1). Physical activity level was quantified using the Physical Activity Scale (Aadahl and Jorgensen, 2003). One participant with a history of recurrent LBP did not complete the data collection due to a transient episode of vasovagal syncope in response to the intramuscular EMG insertion. Therefore only the remaining fourteen participants with a history of recurrent LBP were matched to control participants. The Institutional Review Board of the University of Southern California approved the procedures in the study. Participants gave written informed consent after a full explanation of the study procedures and the potential benefits and risks of participating.

Participants were included in the RLBP group if they were between 18 and 40 years of age, had a history of more than one year of recurrent episodes of primarily unilateral LBP, reported at least two functionally limiting pain episodes of at least 24 hours' duration in the preceding year (Stanton et al., 2009), and were in symptom remission at the time of the data collection (defined as a score of less than 0.5/10 cm on a visual analogue scale (VAS) for current pain at the start of the data collection). Participants were eligible for inclusion in the control group if they could be individually matched to a participant in the RLBP group as previously described and did not have any history of LBP requiring modification of activity or medical care. Participants in both groups were excluded if they had a history of diabetes mellitus, rheumatic joint disease, any blood-clotting disorder or current anti-coagulant therapy, polyneuropathy, history of low back surgery, history of bilateral leg pain, spinal stenosis or scoliosis, spinal malignancy or infection, lumbar radiculopathy, current or previous musculoskeletal injury or surgery affecting locomotion, or were currently pregnant.

Table 1
Participant demographics (median ± inter-quartile range).

	CTRL[a]	RLBP[a]	*p*
Age (years)	24.5 ± 1.75	26.5 ± 4.75	.068
Height (m)	1.73 ± 0.05	1.73 ± 0.09	.664
Mass (kg)	66.68 ± 14.97	67.70 ± 23.42	.152
PAS score (MET-time)	47.60 ± 5.00	48.20 ± 7.55	.470

[a] $n = 14$.

2.2. Assessment of symptoms

In the RLBP group, fear avoidance beliefs were quantified using the physical activity sub-scale of the Fear Avoidance Beliefs Questionnaire (FABQ) (George et al., 2010). All participants completed a baseline VAS for current pain, anchored at 0 with "no pain" and at 10 with "worst possible pain" (Carlsson, 1983). At baseline, participants also completed a VAS for the amount of pain they anticipated feeling during the electrode insertions and the amount of pain that they anticipated feeling during the locomotor trials following the insertions (Al-Obaidi et al., 2003). Immediately after the electrode insertions they completed a further VAS for the actual amount of pain they felt during the insertions, and at the end of the data collection they completed a VAS for the actual amount of pain they felt during the locomotor trials that followed the insertions.

2.3. Experimental task

Each locomotor trial consisted of three laps of a walking circuit. The circuit required both straight locomotion and a series of walking turns (Fig. 1). Participants performed the circuit both at a relaxed, self-selected speed (SELF) and at a controlled average speed of 1.5 m/s ± 5% (FAST). Average speed was measured from the time taken to complete the standardized length of the circuit and was measured using photo-electric triggers. Participants executed an ipsilateral pivot turn in the same location in each repetition of the circuit. They stepped into an outlined 70 cm by 70 cm area with the foot ipsilateral to the turn direction and turned briskly 90° to the ipsilateral side (Fig. 1a). The strategy used to perform the other walking turns in the circuit was not specified. Each participant practiced the circuit until they were consistently able to achieve the correct foot placement for the turn without looking down or breaking stride. At least seven successful trials of the circuit at each speed were collected for each participant, resulting in a total of at least 21 ipsilateral pivot turns in the defined turning area for analysis for each condition (Fig. 1b). All participants walked the circuit in the direction contralateral to the side of their EMG instrumentation.

2.4. Instrumentation

Participants were first instrumented with motion-capture markers. Retro-reflective markers were attached to anatomical landmarks to define body segments and joint axes. Rigid kinematic models of the pelvis and the lumbar and thoracic regions of the spine were defined using individual markers bilaterally on the anterior superior iliac spines, iliac crests, greater trochanters and on the L5/S1 disc space (pelvis), a rigid triad of markers affixed over the spinous process of L1 (lumbar spine) and a rigid triad of