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# Are regions of the lumbar multifidus differentially activated during walking at varied speed and inclination?

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ABSTRACT

*Purpose:* Lumbar multifidus is a complex muscle with multi-fascicular morphology shown to be differentially controlled in healthy individuals during sagittal-plane motion. The normal behaviour of multifidus muscle regions during walking has only received modest attention in the literature. This study aimed to determine activation patterns for deep and superficial multifidus in young adults during walking at different speeds and inclination.
*Methods:* This observational cohort study evaluated ten healthy volunteers in their twenties (three women, seven men) as they walked on a treadmill in eight conditions; at 2 km/h and 4 km/h, each at 0, 1, 5, and 10% inclination. Intramuscular EMG was recorded from the deep and superficial multifidus unilaterally at L5. Activity was characterized by: amplitude of the peak of activation, position of peak within the gait cycle (0–100%), and duration relative to the full gait cycle.
*Results:* Across all conditions superficial multifidus showed higher normalised EMG amplitude ($p < 0.01$); superficial multifidus peak amplitude was 232 ± 115% higher when walking at 4 km/h/10%, versus only 172 ± 77% higher for deeper region ($p < 0.01$). The percentage of the gait cycle where peak EMG amplitude was detected did not differ between regions (49 ± 13%). Deep multifidus duration of activation was longer when walking at the faster vs slower speed at all inclinations ($p < 0.01$), which was not evident for superficial multifidus ($p < 0.05$). Thus, a significantly longer activation of deep multifidus was observed compared to superficial multifidus when walking at 4 km/h ($p < 0.05$).
*Conclusions:* Differential activation within lumbar multifidus was shown in young adults during walking. The prolonged, more tonic activation of deep relative to superficial regions of multifidus during gait supports a postural function of deeper fibres.



## 1. Introduction

Multifidus is a complex muscle in the thoracolumbar region, with differential activation shown in healthy individuals in the sagittal plane (Claus et al., 2009; MacDonald et al., 2009; O'Sullivan et al., 2006), which is likely due to its multi-fascicular morphology. Deepest fibres attaching to the innermost spinous process span one (thoracic) or two (lumbar) motion segments (Cornwall et al., 2011; Macintosh et al., 1986), are closest to the axis of rotation, and are purported to provide support of intervertebral motion (Macintosh and Bogduk, 1986; Macintosh et al., 1986). Relatively superficial fibres of the multifidus span four (lumbar) or more (thoracic) segments (Cornwall et al., 2011; Macintosh et al., 1986) and act as an agonist for trunk and lumbar extension (Macintosh and Bogduk, 1986). Multifidus increases in volume caudally in the lumbar spine and is largest at the level of the fifth lumbar vertebra, while the more lateral erector spinae (longissimus, and iliocostalis) diminish caudally to terminate at the ilium (Cornwall et al., 2011; Crawford et al., 2016). As such, the role of multifidus is crucial at the lowest spinal levels where degenerative change (Brinjikji et al., 2015; Crawford et al., 2016) and injury are most prevalent.

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With a parallel architecture and morphology that supports tonic activity (Cornwall et al., 2011), short/deep and long/superficial paravertebral muscle fascicles are differentially activated in healthy volunteers during tasks involving altered spinal posture (Claus et al., 2009; MacDonald et al., 2009; O'Sullivan et al., 2006). Specifically, activity involving an increased lumbar lordosis results in greater and earlier activity of multifidus (medial), with limited impact on iliocostalis (lateral) (Claus et al., 2009; O'Sullivan et al., 2006). Additionally, predictable trunk perturbations are associated with earlier activation of deep versus superficial fascicles of the multifidus (MacDonald et al., 2009; Moseley et al., 2002). Surprisingly, very few studies have investigated either the thoracolumbar spinal posture or paravertebral muscle activity during gait in asymptomatic adults (Lamoth et al., 2004; Lee et al., 2014; Saunders et al., 2004, 2005; Thorstensson et al., 1982), or in adults with back pain (Lamoth et al., 2004, 2006), despite walking being commonly promoted as beneficial in optimising low back health. An improved understanding of the neuromuscular mechanics of the lumbar spine appears necessary to better inform the use of walking as a therapeutic strategy.

In the only study that we are aware of that examines inclination and speed parameters together during walking, Lee et al. (2014) described differing activity within the lumbar paravertebral muscles of male healthy volunteers. Multifidus showed higher activation at L3 and L5 levels with increasing speed (erector spinae activity did not change), and higher activation of both muscles at L3 with increased inclination. However, their methods used surface EMG and the potential cross-talk from erector spinae at the higher lumbar level limits the confidence of their results in promoting variable inclination for differential activation of the paravertebral muscles. Based on a slightly older and predominantly male (six of seven) cohort to examine postural and respiratory trunk muscle activation during walking and running at variable speeds, Saunders et al. (2004) utilised intramuscular EMG to measure activity of the deep and superficial regions of multifidus at L4. Comparing their two walking speed conditions, biphasic activity was shown for both regions at their slow, and triphasic activity at their faster speed, with different timing noted according to foot strike between the multifidus regions. However, despite kinematic adaptations, the authors reported no differential activity within multifidus during walking, but a trend for increased duration of activation and period of activity with faster locomotion speeds progressing from walking to running. A concentrated evaluation of the influence of modifiable walking parameters on multifidus activity appears warranted.

We therefore aimed to determine the activation of deep and superficial multifidus in young adults when walking on a treadmill under various conditions. We first hypothesised that greater activation would occur in the superficial compared to the deeper region of multifidus secondary to their multi-level mechanical advantage as agonists for trunk mobility, and second, with relatively challenging walking conditions involving higher speed and/or inclination as a response to increasing demand. Third, we expected differential activity to be demonstrated between deep and superficial multifidus regions in relation to the gait cycle, and fourth, for trunk inclination to increase and lumbar lordosis to consequently accommodate the postural changes needed with increased inclination. Our final hypothesis expected lower limb kinematics to be influenced by walking condition, and in particular ankle, knee, and hip motion to increase with more demanding conditions (Saunders et al., 2005).

Normative differential activation of multifidus regions is important to establish as this may lead to future work examining the influence of various factors such as age or pain on the neuromuscular control of the lumbar paravertebral muscles during gait.

## 2. Materials and methods

### 2.1. Participants

Ten adult volunteers in their twenties (three women, seven men; aged 26.3 ± 2.5 years) participated after initial screening excluding history of low back pain requiring attention from a health care professional, musculoskeletal injury/disorder, cardiovascular or neurological disorders, diabetes, previous infection following clinical needle insertion, coagulation disorders, medications affecting such, or difficulty with treadmill walking. Recruitment was achieved through local advertisements. The study achieved institutional Ethics Committee approval and complied with the Declaration of Helsinki. All volunteers gave their written informed consent before participation.

### 2.2. Electromyography

With subjects in prone-lying, wire electrodes made of Teflon-coated stainless steel (diameter: 0.1 mm; A-M Systems, Carlsborg, WA) were inserted into the deep and superficial regions of the multifidus muscle via 27-gauge hypodermic needles using ultrasound guidance (Echo Blaster, Telemed; 10-MHz linear transducer) according to an established method (MacDonald et al., 2009). Approximately 3–4 mm of insulation was removed from the tip of the wires to obtain an interference EMG signal. Following skin disinfection (injection swabs: 70% isopropylalkohol, 30 × 30 mm, Selefatrade, Spånga, Sweden), the needles containing the wire were inserted into the muscle belly and removed immediately to leave the wires in the muscle for the duration of the experiment. Signals were acquired in monopolar mode. Reference electrodes were placed over the right iliac crest and posterior superior iliac spine (PSIS) following skin preparation. EMG data was band pass filtered (8th order zero lag band pass 10–500 Hz), sampled at 2048 samples/s, 12-bit A/D converted (EMG-USB2, OT Bioelettronica, Turin, Italy) and saved on a personal computer HDD (OTBiolab software V.2.05, OT Bioelettronica, Turin, Italy) for further analyses.

### 2.3. Motion capture

Tridimensional tracking of gait cycles was achieved using an 8 camera stereo-photogrammetry system (Oqus 300+, Qualisys Gothenburg, Sweden). Retro-reflective, ball-shaped markers were placed on each subject's skin overlying the following landmarks: seventh cervical spinous process (C7), thoracolumbar junction (~T11; TLJ), peak of the lumbar lordosis (~L3; LUM), sacrum (~S2; SACR), and bilateral PSISs, greater trochanters, fibula heads, lateral malleoli, and fifth metatarsals. Kinematic data was sampled at 256 frames/s (Qualysis Track Manager V. 2.8, Qualisys AB Gothenburg, Sweden) together with one analog channel for synchronization (described below), and stored on a hard disk drive for further analyses.

### 2.4. Procedure

Once the electrodes were in place, participants were given time to familiarise themselves with treadmill walking at a self-selected speed and at different inclinations. An investigator controlled the treadmill settings, explained the procedure, and remained in close proximity to the participant and treadmill. Participants were required to walk continuously for two minutes at 2 km/h and then 4 km/h, and at each of 0, 1, 5, and 10% inclination; all inclinations were undertaken in incremental order at 2 km/h before starting the 4 km/h set at zero inclination; 30–45 s rest was given (0 km/h-0%)