

A MECHANOMYOGRAPHIC ANALYSIS OF CONTRACTION TIME IN LUMBAR SPINE MUSCULATURE; CONTROL DATA

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Mechanomyography (MMG) is an emerging diagnostic tool that investigates the contractile properties of human muscle tissues. This study investigated the contraction time (Tc) of localised muscle tissues within the lumbo-sacral spine in young, healthy participants (age: 20.92±2.02, BMI: 23.09±4.51, n=12). Analysis of 10 erector spinae muscle sites, as well as two over multifidus, found that muscle contraction time (Tc) was heterogeneous (p>0.05) and averaged 87.79ms. The data presented here represents control data for a future study into the diagnostic value of injury-related localised changes in Tc in chronic low back pain patients.

KEY WORDS: mechanomyography, lumbar, sacral, lower back pain.

INTRODUCTION: Lower back pain (LBP) is the cause of severe societal problems and disability to individuals. Approximately 67-84% of the population (van Kleef et al., 2010; Fournay et al., 2011) experience LBP during their lives with over 10% suffering from long-term disability (Walker et al., 2004). In addition, 10% to 15% of young athletes suffer from lower back pain (de Luigi, 2014), with back pain prevalence as high as 27% in football and 86% in gymnastics (de Luigi, 2014). Diagnosis of anatomical injury-site in those experiencing chronic low back pain (CLBP) has been problematic when utilising standard diagnostic techniques (e.g. X-rays, MRI, electromyography, ultrasound imaging, double and triple nerve blocks) (O'Sullivan, 2005). To improve diagnosis in CLBP patients, it is theorized that the site of anatomical injury in CLBP patients should be indicated by the extent of atrophy in the surrounding paraspinal muscles. Previous research has shown a direct link between joint injury and localised muscle inhibition and atrophy (Wallwork et al., 2009; Tsao et al., 2011). In order to test this hypothesis we utilised a mechanomyographic (MMG) technique which allows recording of localised muscle contraction times around potentially injured joints. The MMG technique records the lateral displacement of a muscle belly following maximal percutaneous neuromuscular stimulation (PNS) (Malek & Coburn, 2012). From that recording may be accurately determined the localised muscle's contraction time (Tc) which is directly related to its fibre type or state of atrophy/hypertrophy.

Therefore, the aim of this study was to provide control data regarding the contractile properties of localised muscle tissues that surrounds each of the lumbar zygapophyseal joints (LZJ), and over the sacrum, in a cohort of CLBP free subjects. Testing was undertaken with the localised lumbar musculature in a stretched (extended lumbar spine) prone position. It was hypothesized that no significance differences would be found in the contractile properties of lumbo-sacral muscle tissues in these subjects who do not experience CLBP. The study provides control data for a subsequent study of patients with CLBP.

METHODS: All procedures were approved by the University of Queensland Ethics committee. Young healthy participants (age: 20.92±2.02, BMI: 23.09±4.51, n=12) were asked to lie prone on a plinth exposing their lumbar spine (Figure 1). Bony markers were identified to facilitate identification of each of 10 LZJs and their surrounding Erector Spinae (ET) muscle tissues. Two additional sacral sites, for the left and right multifidus (MT) muscle, were also investigated.

Two MMG surface electrodes (TENS pads), connected to the muscle stimulator (Digitimer DS7A), were positioned over each recording site parallel to the muscle belly. In this way the

contractile properties of local muscle tissues were recorded at 12 sites over the lumbar spine and sacrum. At each recording site a current ramp (low to high) was utilised to determine the PNS needed to maximally stimulate the local muscle tissues. The muscle stimulator delivered a variable current (between 40mA to 280mA) for a constant duration (200 μ s) at a constant voltage (400V). The MMG signal was recorded using a laser measurement device (class 2 laser; model LG10A65PU, Banner Engineering Australia) that was positioned between the two electrodes, perpendicular to the muscle belly. Each brief PNS was followed by a 30 second rest period to minimise fatigue. The maximal PNS, following the current ramp, was determined when the muscle's contraction reached maximal amplitude with symmetrical contraction and relaxation phases.

Analysis of data was conducted using a two-way ANOVA, with two factors- segment (L1 to M2) and side (left to right), with significance accepted at $p \leq 0.05$. If significance was reached, a pair-wise multiple comparison procedure (Tukey Post-Hoc) would be performed to determine which segments attributed to the significant result. All statistical analysis was conducted in GraphPad PrismTM 6.



Figure 1- Experimental setup for stimulation MMG protocol. A pair of TENS surface electrodes deliver a brief PNS to maximally stimulate the local muscle tissues surrounding a LZJ. A laser, positioned between the two surface electrodes, records the lateral swelling of the local muscle tissues following the PNS. The resultant MMG waveform allowed characterisation of the contractile properties of local muscle tissues surrounding the 10 LZJ and the left and right multifidus over the sacrum.

RESULTS: There was no significant ($p > 0.05$) difference in the contraction time (T_c) of local muscle tissues (ES) surrounding the 10 LZJs nor the left and right MT. On average the local muscle tissues had a T_c of 87.79 ± 5.57 ms with a range of 78.03ms-99.76ms across all joints. The average T_c for muscles on the right side was 87.28 ± 5.66 ms compared to that on the left side being 88.31 ± 5.429 ms ($p > 0.05$).

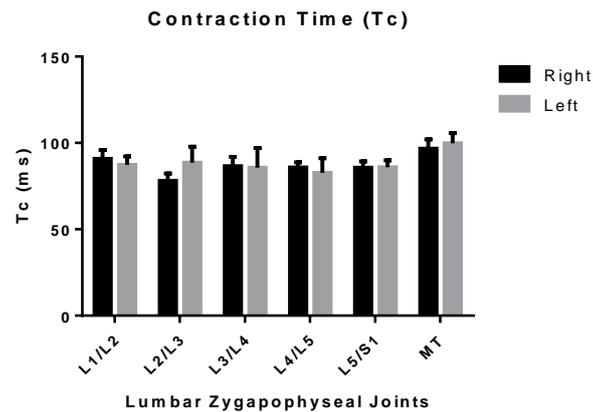


Figure 2 - Average Tc of muscles surrounding the 10 lumbar/sacral joint segments (ES) and over the sacrum (MT) following mechanomyographic analysis. Error bars represent standard error mean (\pm). Values are in units of ms. No significant differences were found ($p>0.05$) within or between segments from a two-way ANOVA.

DISCUSSION: The results of the study support the hypothesis that there would be no significant difference between the Tc of any muscle tissues within the lumbo-sacral spine. The recorded Tc's suggested that the local muscle tissues were moderately slow contracting (Figure 2). In healthy humans, the erector spinae muscles (spinalis, longissimus, and iliocostalis), and the multifidus, function as both postural and dynamic muscles as reflected by their relatively mixed (40%:60% fast vs slow fibres) fibre distribution (Mannion et al., 1997; Mannion et al., 2000). The results presented here support the contention that fibre type is relatively heterogenous throughout the lumbar erector spinae muscles and the multifidus (Mannion et al., 1997) in normal healthy individuals unaffected by CLBP.

For future studies the effect of joint positioning must be investigated as changes in muscle length may potentially cause variations in Tc. In a study conducted by Azami (2011), lumbo-sacral muscles around all LZJs and over the sacrum contracted (Tc) on average at 138.86 ± 7.05 ms, with a range of 127.39ms-150.43ms. This study, however, analysed a cohort who were positioned with a flexed lumbar spine to stretch the local muscle tissues. It is possible that the stretching of the local muscle tissues could have induced a longer (slower) contraction time (Tc) (Kim et al., 2014). Furthermore, the older cohort investigated by Azami (2011) may have exhibited slower muscle contractions due to the effects of age-related muscle atrophy (Gibala et al., 1995; Ivarsson et al., 2012; Santilli et al., 2014).

CONCLUSION: MMG has the capacity to characterise the contractile properties of localised muscle tissues within the lumbo-sacral spine. The heterogeneity of Tc in the lumbo-sacral spine of young healthy subjects reflects muscle tissues that balance postural control with the capacity to quickly rotated spinal segments. It is now an opportune time to determine whether MMG also has the capacity to identify localised changes in muscle Tc that might reflect localised atrophy of muscle tissues surrounding the anatomical sites of injury in CLBP. Accurate diagnosis and treatment of CLBP would hasten recovery and promote an earlier return to full functional capacity (de Luigi, 2014).

REFERENCES:

- Azami, Z. (2011). Non-invasive diagnosis of anatomical injury sites in Chronic Low Back Pain patients: A clinical application of mechanomyography. *The University of Queensland, Honours Thesis*.
- de Luigi, A.J. (2014). Low back pain in the adolescent athlete. *Physical Medicine & Rehabilitation Clinics of North America*, 25(4), 763-88.
- Fourney, D.R., Andersson, G., Arnold, P.M., Dettori, J., Cahana, A., Fehlings, M.G., Norvell, D., Samartzis, D. & Chapman, J.R. (2011). Chronic low back pain: a heterogeneous condition with challenges for an evidence-based approach. *Spine*, 36, 1-9.
- Gibala, M. J., MacDougall, J. D., Tarnopolsky, M. A., Stauber, W. T., & Elorriaga, A. (1995). Changes in human skeletal muscle ultrastructure and force production after acute resistance exercise. *Journal of Applied Physiology*, 78(2), 702-08.
- Ivarsson, N., Rundqvist, H. & Lanner, J. T. (2012). Endurance exercise increases force production in mouse fast-twitch muscles. *Biophysical Journal*, 102(3), 364.
- Kim, J., Kang, M., Kim, J. & Lee, D. (2014). Selective activation of lumbar paraspinal muscles during various exercises in the prone position as measured by EMG. *Journal of physical therapy science*, 26, 12-23.
- Malek, M. & Coburn, J. (2012). The utility of electromyography and mechanomyography for assessing neuromuscular function: A noninvasive approach. *Physical medicine and rehabilitation clinics of North America*, 23, 23-32.
- Mannion, A.F., Dumas, G.A., Cooper, R.G., Espinosa, F.J., Faris, M.W. & Stevenson, J.M. (1997). Muscle fibre size and type distribution in thoracic and lumbar regions of erector spinae in healthy subjects without low back pain: normal values and sex differences. *Journal of Anatomy*, 190(Pt 4), 505-13.
- Mannion, A.F., Käser, L., Weber, E., Rhyner, A., Dvorak, J. & Müntener, M. (2000). Influence of age and duration of symptoms on fibre type distribution and size of the back muscles in chronic low back pain patients. *European Spine Journal*, 9(4), 273-81.
- O'Sullivan, P. (2005). Diagnosis and classification of chronic lower back pain disorders: Maladaptive movement and motor control impairments as underlying mechanism. *Manual Therapy*, 10, 242-55.
- Santilli, V., Bernetti, A., Mangone, M. & Paoloni, M. (2014). Clinical definition of sarcopenia. *Clinical Cases in mineral and bone metabolism*, 11(3), 177-80.
- Tsao, H., Danneels, L. & Hodges, P. (2011). Individual fascicles of the paraspinal muscles are activated by discrete cortical networks in humans. *Clinical Neurophysiology*, 122(8), 1580-87.
- van Kleef, M., Vanelderen, P., Cohen, S.P., Lataster, A., van Zundert, J. & Mekhail, N. (2010). Pain originating from the lumbar facet joints. *Pain Practice*, 10, 459-69.
- Walker, B.F., Muller, R. & Grant, W.D. (2004.) Low back pain in Australian adults: prevalence and associated disability. *Journal of Manipulative and Physiological Therapeutics*, 27, 238-44.
- Wallwork, T.L., Stanton, W.R., Freke, M. & Hides, J.A. (2009). The effect of chronic low back pain on size and contraction of the lumbar multifidus muscle. *Journal of Manual Therapy*, 14, 496-500.

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