Journal of Electromyography and Kinesiology 34 (2017) 65–71

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

The relationship of corticospinal excitability with pain, motor performance and disability in subjects with chronic wrist/hand pain

René Pelletier [a,*], Johanne Higgins [b,c], Daniel Bourbonnais [b,c]

[a] Sciences de la réadaptation, École de réadaptation, Faculté de Médecine, Université de Montréal, Montréal, Québec H3C 3J7, Canada
[b] École de réadaptation, Faculté de médecine, Université de Montréal, C.P. 6128, succursale Centre-ville, Montréal, Québec H3C 3J7, Canada
[c] Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal (CRIR), Canada

ARTICLE INFO

Article history:
Received 28 June 2016
Received in revised form 25 March 2017
Accepted 5 April 2017

Keywords:
Musculoskeletal
Input-output curve
Transcranial Magnetic Stimulation
Motor Evoked Potentials
Motor function
Disability
Strength

ABSTRACT

There is a growing body of evidence of changes in corticospinal excitability associated with musculoskeletal disorders, however there is a lack of knowledge of how these changes relate to measures of pain, motor performance and disability. An exploratory study was performed utilizing Transcranial Magnetic Stimulation to investigate differences in corticospinal excitability in the Abductor Pollicis Brevis (APB) between 15 pain-free subjects and 15 subjects with chronic wrist/hand pain and to determine how corticospinal excitability was associated with measures of pain (visual analog scale, AUSCAN™), hand motor performance (isometric and key pinch strength, Purdue Pegboard Test), disability (AUSCAN™), and spinal motoneuronal excitability. Input–output curves demonstrated increased corticospinal excitability of the APB in the affected hand of subjects with chronic pain ($p < 0.01$). Changes in corticospinal excitability were significantly correlated with pain intensity ($r = 0.77$), disability ($r = 0.58$), and negatively correlated with motoneuronal excitability ($r = -0.57$). Corticospinal excitability in subjects with heterogeneous injuries of the wrist/hand was associated with disability and pain.

1. Introduction

Changes in the properties and organisation of the primary motor (M1) cortex have been found in clinical conditions involving the hand such as complex regional pain syndrome, focal hand dystonia and carpal tunnel syndrome (McKenzie et al., 2003; Krause et al., 2006). There is a growing interest in determining if similar neurophysiological changes may also be associated with Musculoskeletal Disorders (MSD) as these may provide a target for rehabilitative interventions (Snodgrass et al., 2014; Pelletier et al., 2015).

The evaluation of properties and organisation of corticospinal outputs from M1 have been investigated in subjects with MSD. Tsao and colleagues found changes in map representation of corticospinal neurons innervating the multifidus and longissimus muscles in subjects with back pain (Tsao et al., 2008, 2010, 2011). In subjects with lateral epicondylitis, there were increased Motor Evoked Potential (MEP) amplitudes and an increase in the number of active sites eliciting MEP with Transcranial Magnetic Stimulation (TMS), indicative of increased corticospinal excitability (Schabrun et al., 2014). Changes in motor thresholds elicited by TMS of the quadriceps motor area have also been found in subjects with anterior cruciate ligament injury (Héroux and Tremblay, 2006), and increased MEP amplitude values of the quadriceps muscles have been found in subjects with patellofemoral pain (On et al., 2004). Increased neuronal activity was also demonstrated in brain areas, including M1, in persons with MSD such as knee osteoarthritis (Shanahan et al., 2015). Although study results of measures of corticospinal excitability are variable in subjects with MSD, studies tend to suggest that altered M1 properties and organisation are associated with increased corticospinal excitability and this for diverse MSD affecting different joints.

Since M1 is implicated in both motor control and motor learning, one would expect changes in corticospinal properties to

Abbreviations: AH, Affected Hand; APB, Abductor Pollicis Brevis; AUSCAN™, Australian Canadian Osteoarthritis Hand Index; CMSD, Chronic Musculoskeletal Disorders; CNS, Central Nervous System; EMG, Electromyography; I-O, Input-Output curve; M1, Primary Motor Cortex; MEP, Motor Evoked Potential; Mmax, Maximum Compound Motor Action Potential; NAH, Non-Affected Hand; PPG, Purdue Pegboard Test; RH, Right Hand; rMT, Resting Motor Threshold; S1, Primary Somatosensory Cortex; TMS, Transcranial Magnetic Stimulation; VAS, Visual Analog Scale.

* Corresponding author.
E-mail addresses: rene.pelletier@umontreal.ca (R. Pelletier), johanne.higgins@umontreal.ca (J. Higgins), daniel.bourbonnais@umontreal.ca (D. Bourbonnais).

http://dx.doi.org/10.1016/j.jelekin.2017.04.002
1050-6411/

impact motor function. Although corticospinal changes have been associated with measures of pain (Schabrun et al., 2014; Bradnam et al., 2015; Shanahan et al., 2015; Elgueta-Cancino et al., 2015) and symptom duration (Ngomo et al., 2015), few studies have investigated changes in corticospinal properties and their relationship with measures of motor performance, disability and pain (Tsao et al., 2008).

The aim of this study was to determine if subjects with pain associated with varied MSD of the wrist and hand demonstrate increased corticospinal excitability compared to pain-free individuals, and if so, how these changes relate to measures of motor function, disability and pain. The importance of the information arising from this exploratory study is to provide a clearer understanding of the relationship between pain, altered motor function, disability and corticospinal changes which may prove important in rehabilitation of MSD.

2. Methods

2.1. Subjects

Fifteen pain-free subjects (10F, 14 RH dominant) and fifteen subjects with wrist/hand pain (7F, 14 RH dominant) participated in the experiment. Subjects with wrist/hand pain were recruited from advertising and social media and had to be 18 years of age or older, experiencing unilateral pain in the wrist/hand for greater than 3 months that impacted activities of daily living. Pain-free participants were a convenience sample from the community, free of previous injury to the wrist and hand.

Subjects were excluded if presenting with any contraindications for TMS procedures, neurological conditions known to affect corticospinal or wrist/hand function, symptoms of radiculopathy or neuropathic pain, or previous injury to the hand (Rossi et al., 2009; Rossi et al., 2011). Dominance was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971). The study received ethics approval from the institutional review board and experiments were performed at the Institut de réadaptation Gingras-Lindsay of the CIUSSS Centre-Sud-de-l'Île-de-Montréal (CRIR-793-1113). All subjects provided written informed consent and the study was performed in accordance with the Declaration of Helsinki.

2.2. Measures of pain intensity, hand motor performance and disability

2.2.1. Pain intensity

Pain was assessed with a Visual Analog Pain Scale (VAS) (Jensen et al., 1989) and part 1 of the Australian Canadian Osteoarthritis Hand Index (AUSCAN™) questionnaire for pain levels during the performance of daily functional activities (Bellamy et al., 2002a). Date of pain onset was recorded to determine symptom duration.

2.2.2. Hand motor performance

Pinch strength was assessed using a U-shaped aluminum structure equipped with strain gauges. Isometric maximal abduction force of the thumb was measured utilizing a force transducer (Bourbonnais and Duval, 1991; Bourbonnais et al., 1993). Subjects were provided with 30-s rest periods between trials and a visual display indicating direction and force displacement. The maximum force produced over three trials was retained. Motor performance was also assessed with the Purdue Pegboard Test (PPG) comprising sub scores for the *Individual* hands and *Both* hands tasks, total (sum of each *Individual* hand and *Both* hands), and *Assemblies* score (Tiffin and Asher, 1948; Buddenberg and Davis, 2000).

2.2.3. Hand disability

Subjects answered the AUSCAN™ questionnaire (Bellamy et al., 2002a, 2002b; Moe et al., 2010) that is comprised of three subsegments for pain, stiffness, and disability. Higher scores indicate more severe impairment.

2.3. Measures of cortical excitability and Fwaves

2.3.1. Subject preparation

Skin preparation was performed following standard procedures. Ag/Ag Cl Electrodes (Ambu® Blue Sensor M-00-S) were applied in a belly tendon montage of the Abductor Pollicis Brevis (APB) muscle. Subjects were seated with their forearms and hands uncrossed for measures at rest.

2.3.2. Data acquisition

Electromyography (EMG) signals were amplified (x1000), band pass filtered (1 Hz–1 KHz) using a second order Butterworth filter, sampled (10 kHz) with a laboratory A/D conversion system (PCI-MIO-16E-4, National Instruments, Texas, USA), displayed, and recorded. Electrophysiological analysis of EMG responses was performed off-line.

2.3.3. Transcranial Magnetic Stimulation

Single pulse monophasic magnetic stimulations (Magstim®200, UK) were delivered by an angled TMS figure of eight focal coil to the contralateral hemisphere to elicit MEP responses in the APB. The coil orientation was tangential to the scalp resulting in a posterior to anterior direction of current flow (Brasil-Neto et al., 1992; Werhahn et al., 1994).

2.3.4. Hotspot and Resting Motor Threshold (rMT)

The location of the hotspot was recorded utilizing neuronavigation equipment (Brainsite™, Rogue Research, Montreal Canada). The site producing 5/10 visibly discernable MEPs of at least 50 μV with the lowest stimulator intensity was determined as the "hotspot" and the % of maximum stimulator output was recorded as the rMT (Rossini et al., 1994; Groppa et al., 2012). Trials with excessive EMG background activity in the 50 ms prior to TMS were discarded (Rossini et al., 1994; Groppa et al., 2012).

2.3.5. Input-output (I-O) curves and MEP amplitudes during active contractions

The I-O curves were constructed with blocks of ten stimuli at seven randomized stimulation intensities (95, 100, 110, 120, 130, 140, and 150% of rMT) (Boroojerdi et al., 2001). The median peak to peak amplitude values of the 10 MEP responses at each of the stimulus intensities in each subject were utilized for further analysis (Awiszus, 2005). Ten TMS stimuli were also applied in both groups at 1.2 rMT while the subjects performed an isometric contraction of the APB at 50% (±3%) of the maximum voluntary contraction force guided with a visible display of force direction and output.

2.3.6. Maximum Compound Muscle Action Potential (Mmax) and F wave evaluation

Mmax and F-waves were recorded in 11 pain-free and 12 subjects with wrist/hand pain (the intensity of stimulation was too painful for some subjects) from 32 supra-maximal consecutive stimuli to the median nerve, approximately 3 cm proximal to the distal wrist crease with a square wave pulse of 0.2 ms (Digitimer DS7A, UK) at a frequency of 0.5 Hz and a stimulation intensity of 1.3xMmax (Fischer, 1992; Panayiotopoulos and Chroni, 1996). F-wave parameters collected included latency, number of detectable F wave responses (persistence), mean amplitude of F-waves, and