Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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MSc (University of Saskatchewan, 2011)
BSc (University of Saskatchewan, 2008)

“Effects of cutaneous input and resistance training on motor output”

Department of Exercise Science, Physical and Health Education

Tuesday, June 28, 2016
10:00 am
McKinnon Building
Room 0025

Supervisory Committee:
Dr. Paul Zehr, Department of Exercise Science, Physical & Health Education, University of Victoria (Supervisor)
Dr. Marc Klimstra, Department of Exercise Science, Physical & Health Education, UVic (Member)
Dr. Craig Brown, Division of Medical Sciences, UVic (Outside Member)

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Dr. Tim Inglis, Department of Kinesiology, University of British Columbia

Chair of Oral Examination:
Dr. Rodney Herring, Department of Mechanical Engineering, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies
Abstract

An entire field of research was born when a paper entitled ‘On the education of muscular control and power’ first discussed a “psychical rather than a physical” bilateral adaptation to a unilateral training program. Although the true relevance of this paper would not be recognized for over a century, its novel findings, describing adaptations resulting from physical and skilled training, continue to influence scientific literature to this day. Most notably, Scripture coined the term ‘cross-education’ to describe the improvement in strength or functional performance of not only the trained limb but also in the untrained contralateral limb. Recently, unilateral training or ‘cross-education’ has been highlighted as a possible rehabilitation strategy during recovery from unilateral injuries. However, a number of limitations must be addressed within the scientific literature in order to properly apply unilateral resistance training as an effective rehabilitation strategy. Therefore, the primary goal of this dissertation was to address a number of fundamental issues related to optimizing unilateral resistance training.

One such issue is knowledge on the time course of strength increase during unilateral resistance training. The primary purpose of Chapter 2 was to characterize the time-course of strength changes in both the trained and untrained limbs during unilateral handgrip training. Experiment 1 assessed the time-course with a ‘traditional’ training protocol (3x/week for 6 weeks: 18 total sessions) while Experiment 2 assessed a “compressed” protocol in which the number of sessions and contractions were matched but participants trained for eighteen consecutive days. An anticipated outcome was the determination of the minimum number of sessions required to induce contralateral strength gains in the upper limb. A secondary purpose of this study was to examine whether spinally-mediated adaptations in muscle afferent reflex pathways occur after unilateral handgrip training.

Experiment 1 indicated six weeks of handgrip training significantly increased force output in both trained and untrained limbs. This strength increase was accompanied by changes in the maximal muscle activation in the trained limb only. Time course data indicated the trained limb was significantly stronger than baseline after the 3rd week of training (session 9) while the untrained limb was stronger after 5 weeks (15 sessions) of unilateral handgrip training. Interestingly, the rate at which strength increased in the untrained limb was similar to the trained side. These strength increases were also accompanied by significant changes in the current needed to produce H@50 in the trained, and Hmax in both the trained and untrained limb indicating alterations in spinal cord excitability. Experiment 2 showed a similar number of sessions was needed to induce significant strength gains in the untrained limb. This indicates training without rest days may be the most efficient protocol within a clinical population when the trained limb is not the focus of recovery.

It remains necessary to determine if specific strategies can be employed to optimize unilateral resistance training interventions to increase strength gains. To date, no study has directly assessed the relative contribution of afferent pathways to cross-education. Cutaneous feedback from the skin provides perceptual information about joint position and movement. Unilateral training involves forceful contractions that activate cutaneous receptors in the skin, producing widespread and powerful effects between limbs. Providing “enhanced” cutaneous stimulation during unilateral contractions may alter excitability of interlimb reflex pathways, modifying the contralateral increase in strength. Therefore, the purpose of Chapter 3 was to determine the relative contribution of cutaneous afferent pathways as a mechanism of cross-education by directly assessing if unilateral cutaneous stimulation alters ipsilateral and contralateral strength gains.

Participants were randomly assigned to either a voluntary contraction (TRAIN), cutaneous stimulation (STIM), or cutaneous stimulation during voluntary contraction (TRAIN+STIM) group. Each participant completed 6 sets of 8 reps 3x/week for 5 weeks. TRAIN included unilateral maximal voluntary isometric contractions (MVCs) of the wrist extensors. STIM training included cutaneous stimulation (2xRT for 3sec @ 50Hz) of the superficial radial (SR) nerve at the wrist only. TRAIN+STIM included MVCs of the wrist extensors with SR stimulation provided for the duration of the contraction. Two pre-training and 1 post-training session assessed the relative increase in force output during MVCs for wrist flexion, wrist extension and handgrip strength. Results indicated unilateral wrist extension training alone (TRAIN) increased force output in both trained and untrained wrist extensors. Providing ‘enhanced’ sensory feedback via electrical stimulation during training (TRAIN+STIM) led to similar increases in strength in the trained limb compared to TRAIN. However, the major finding revealed that ‘enhanced’ feedback in the TRAIN+STIM group completely blocked interlimb strength transfer to the
untrained wrist extensors. It appears the large mismatched sensory volley which was provided may have interfered with the integration of the appropriate sensory cues to the untrained cortex and impaired the ability to induce “cross-education”.

It may be possible to enhance effects of training by altering excitability via apparel such as compression garments. Currently, it is unknown whether tactile input to the skin induced via compression apparel may alter transmission of muscle afferent feedback within a limb. Thus, the purpose of Chapter 4 was to examine if sustained input to the skin via compression garment modulates sensory feedback transmission in the upper limb using the Hoffmann (H-) reflex as a probe. The purpose of these experiments was to: 1) explore the effects of compression gear on sensory feedback transmission in the upper limb during a static task, and 2) if the task (locomotor vs. reaching) or phase of a movement differentially modulated this transmission of sensory information. Furthermore, differences in performance of the discrete reaching task were assessed to provide data on whether a compression garment leads to alteration in motor task performance. Combined results from both parts of the study suggest that tactile input provided to the skin via compression garments modulates the excitability of afferent connections independent of descending input. The alteration in excitability occurs across multiple sensory pathways and across multiple movement tasks. Interestingly, there was a significant reduction in the number of errors made during the reaching task, which provides preliminary evidence of an improved performance while wearing a compression garment. Therefore, the compression sleeve appears to increase precision and sensitivity at the joint where it is applied.

Overall, these results address many fundamental questions which have previously limited effective translation for rehabilitative interventions. These results provide preliminary guidelines for subsequent strength training interventions to prescribe the optimal ‘dose’ of unilateral strength training to maximize benefits while minimizing intervention burden. These studies also help refine a unifying model of unilateral strength training to include contributions from central motor output as well as afferent feedback. These studies highlight the importance of appropriate sensory feedback during maximal force production and the impact that sensory information from the skin can have on motor output in the nervous system.