©Journal of Sports Science and Medicine (2008) **7**, 520-524
http://www.jssm.org

Research article

The effect of stimulus anticipation on the interpolated twitch technique

Duane C. Button and David G. Behm ✉
School of Human Kinetics and Recreation , Memorial University of Newfoundland, St. John's, Newfoundland, Canada

Abstract
The objective of this study was to investigate the effect of expected and unexpected interpolated stimuli (IT) during a maximum voluntary contraction on quadriceps force output and activation. Two groups of male subjects who were either inexperienced (MI: no prior experience with IT tests) or experienced (ME: previously experienced 10 or more series of IT tests) received an expected or unexpected IT while performing quadriceps isometric maximal voluntary contractions (MVCs). Measurements included MVC force, quadriceps and hamstrings electromyographic (EMG) activity, and quadriceps inactivation as measured by the interpolated twitch technique (ITT). When performing MVCs with the expectation of an IT, the knowledge or lack of knowledge of an impending IT occurring during a contraction did not result in significant overall differences in force, ITT inactivation, quadriceps or hamstrings EMG activity. However, the expectation of an IT significantly ($p < 0.0001$) reduced MVC force (9.5%) and quadriceps EMG activity (14.9%) when compared to performing MVCs with prior knowledge that stimulation would not occur. While ME exhibited non-significant decreases when expecting an IT during a MVC, MI force and EMG activity significantly decreased 12.4% and 20.9% respectively. Overall, ME had significantly ($p < 0.0001$) higher force (14.5%) and less ITT inactivation (10.4%) than MI. The expectation of the noxious stimuli may account for the significant decrements in force and activation during the ITT.

Key words: Muscle activation, electromyography, evoked stimulation.

Introduction

A number of studies purport to show that humans can fully activate their quadriceps (Chapman et al. 1985; Phillips et al. 1992; Rice et al. 1992; Rutherford and White 1991), while others have reported a lack of full quadriceps activation (Behm and St-Pierre 1997; 1998; Belanger and McComas 1981; Kalmar and Cafarelli 1999; Strojnik 1995; Urbach and Awiszus 2000). Conflicting evidence regarding muscle activation as measured by the interpolated twitch technique (ITT) may not be a consequence of solely physiological performance, but methodological inadequacies as well. Observations from our laboratory have illustrated that decreases in force, and electromyographic (EMG) activity can occur prior to an evoked stimulus when performing a maximum voluntary contraction (MVC). Hortobagyi et al. (1992) suggested that evoked stimulation may interfere with the ability to produce a MVC due to the pain associated with the noxious evoked stimuli. Perhaps the anticipation of discomfort associated with the ITT may also affect the outcome. Since the ITT purports to estimate the extent of activation, it would be important to know whether the interpolated stimuli (IT) or its anticipation negatively impacts force and activation.

The objective of this research was to determine whether the prior knowledge or expectation and imposition of an electrical stimulus upon a voluntary contraction would affect force and activation measures with subjects who were experienced and inexperienced with the ITT. Based on the observations of Hortobagyi et al. (1992) and our laboratory, it was hypothesized that decreases in force and activation (ITT and EMG) would be expected with inexperienced, but not experienced individuals when 1) subjected to an interpolated stimulus and 2) expecting a stimulus during a voluntary contraction.

Methods

Subjects

Sixteen physically active (defined as regularly participating in 3 or more exercise or activity sessions per week) male (age: 25.5 ± 5.1 years, ht: 1.78 ± 0.07 m, wt: 85.3 ± 12.3 kg) subjects from the Memorial University of Newfoundland population volunteered for the experiment. There were 2 groups of 8 subjects: an experienced group (ME: received 10 or more series of ITT tests prior to the experiment) and an inexperienced group (MI: have not received the ITT previously). Subjects were verbally informed of the procedures, read and signed a consent form prior to participation. The Ethics Committee of Memorial University of Newfoundland sanctioned the study.

All subjects completed an Activity Inventory Questionnaire (adapted from The Canadian Physical Activity, Fitness and Lifestyle Appraisal manual from the Canadian Society for Exercise Physiology) to identify the physical activity profiles between the groups and a Likert Pain Analog Scale to measure perceived pain of stimulation.

Exercise protocol

Subjects came to the laboratory on 3 occasions but were tested on two occasions (Table 1). A preliminary practice session was administered to orient the subjects and allow them to experience the ITT. For all sessions, subjects performed a 5-minute warm-up on a stationary cycle ergometer to increase core body temperature, as well as 5 submaximal isometric leg extensions. In the orientation session, subjects performed 4 MVCs without a stimulus, followed by 3 MVCs with the IT. The subsequent two testing sessions were randomized. In one session, subjects were informed as to which contractions and at what time within the contraction they would receive the interpolated

Received: 16 July 2008 / Accepted: 17 October 2008 / Published (online): 01 December 2008

Table 1. Experimental design.

Orientation Session
4 MVCs
3 MVCs with IT
5 min rest periods

Randomized Testing Sessions

Testing Session A	Testing Session B
4 MVCs	4 MVCs
3 MVCs with IT	3 MVCs with IT
7 contractions randomized	7 contractions randomized
5 min rest periods between contractions	5 min rest periods between contractions
Subjects informed of impending ITT.	**Subjects not informed of impending ITT.**

stimuli (3 of 7 contractions). In the alternate session, subjects received interpolated stimuli during the MVCs, but were not cognizant of which contractions (3 of 7 contractions) would involve superimposed stimulation. Superimposed stimuli were randomly administered between 2 - 4 s of the 4 s MVCs to further prevent anticipation of the stimulus in the non-cognizant condition. Subjects were not informed that the onset of stimulation would be altered. The instructions for the MVC were to contract as fast and as hard as possible. All testing session contractions were randomized. Subjects performed the orientation and testing sessions over three different days with a minimum of 48 hours rest between the tests. Since diurnal rhythms have been shown to affect force output (Martin et al. 1999), experiments were performed at approximately the same time each day. Subjects received 5 minute rest periods between the MVCs in the orientation and testing sessions to avoid fatigue. Between testing day MVCs demonstrated excellent reliability with r values of 0.99. Measurements analyzed from 3 MVCs each with the expectation of an IT and no expectation of an IT were compared to the average force output of the 3 highest force MVCs with prior knowledge of no IT. MVC forces were determined from the maximum peak to peak amplitude of MVCs with no stimulation or the maximum amplitude prior to the IT.

Testing

Isometric knee extension: Subjects sat on a bench with their knees and hips flexed at 90^{o} and their upper leg, hips, and upper body (backrest) supported by straps. The dominant ankle was inserted into a padded strap attached by a high-tension wire to a Wheatstone bridge configuration strain gauge (Omega Engineering Inc. LCCA 250, Don Mills, Ontario). All voluntary and evoked torque's were detected by the strain gauge, amplified (BioPac Systems Inc. DA 100 and analog to digital converter MP100WSW; Hilliston, MA) and monitored on computer (Sona Phoenix, St. John's, Newfoundland). All data were stored on a computer at a sampling rate of 2000 Hz. Data were recorded and analyzed with a commercially designed software program (AcqKnowledge III, BioPac Systems Inc., Hilliston, MA).

Electromyography (EMG): Surface EMG recording electrodes were placed approximately 3 cm apart over the middle segment of the vastus lateralis and biceps femoris. A ground electrode was secured on the fibular and tibial heads. Thorough skin preparation for all electrodes included removal of dead epithelial cells with an abrasive (sand) paper around the designated areas followed by cleansing with an isopropyl alcohol swab. EMG activity was sampled at 2000 Hz, with a Blackman -61 dB band-pass filter between 10-1000Hz, amplified (bi-polar differential amplifier, common mode rejection ratio > 110 dB min (50/60 Hz), gain x 1000, noise > 5 µV), analog-to-digitally converted (12 bit) and stored on personal computer for further analysis. The quadriceps and hamstrings integrated EMG (iEMG) activity were measured over a one second period, prior to the superimposed twitch, in order to allow generation of peak forces.

In order to compare changes in EMG, the iEMG of each contraction with the expectation or anticipation of an IT was normalized as a percentage of the average iEMG activity of the 3 highest MVCs with no expectation of an IT.

Interpolated Twitch Technique (ITT): Bipolar surface stimulating electrodes were secured to the proximal (inguinal space, superficial to the femoral nerve) and distal (superior to the patella) portion of the quadriceps. Stimulating electrodes, 2-3 cm in width, were constructed in the laboratory from aluminum foil, and paper coated with conduction gel (Aquasonic) and immersed in an aqueous solution. The electrode length was sufficient to wrap the width of the muscle belly.

In order to determine the appropriate stimulation intensity for the ITT, peak twitch torques were evoked with electrodes connected to a high-voltage stimulator (Digitimer Stimulator; Model DS7H+, Welwyn Garden City, Hertfordshire, UK). The amperage (10 mA-1A) and voltage (100-150) of a 50 µs square wave pulse was progressively increased until a maximum twitch torque was achieved.

The ITT was administered as a measure of the extent of muscle inactivation. The ITT involved superimposing an electrically stimulated doublet (100 Hz) with an inter-pulse interval of 10 ms during a voluntary contraction (Figure 1). Torque signals were sent through a strain gauge amplifier with the superimposed force isolated and further amplified by the software computer program (AcqKnowledge III, BioPac Systems Inc., Holliston, MA). An interpolation ratio was calculated comparing the amplitude of the superimposed doublet with the post-contraction potentiated doublet to estimate the extent of inactivation during a voluntary contraction (interpolated doublet force / potentiated doublet force x 100 = % of muscle inactivation (Behm et al. 1996)).

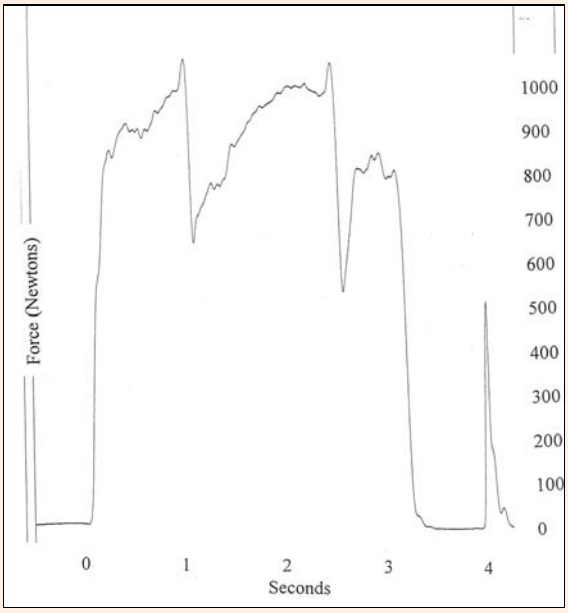

Figure 1. The figure illustrates the interpolated twitch technique (ITT) which was used with a maximal voluntary contraction (MVC) to estimate the extent of inactivation during a voluntary contraction by comparing the amplitudes of evoked doublets superimposed upon a MVC, with the post-contraction potentiated doublet (interpolated doublet amplitude / potentiated doublet amplitude x 100 = percentage of muscle inactivation).

Statistical analyzes

Dependent variables such as force and EMG were analyzed using a 3-way ANOVA with repeated measures on the last two factors (GB-Stat Software: Dynamic Microsystems Inc.). The 3 way ANOVA factors (2 X 2 X 2) included groups (ME, MI), state of knowledge of IT imposition (expected and unexpected) and presence of stimulus (stimulus versus no stimulus). Inactivation as measured by the ITT was analyzed with a 2 way ANOVA (2 X 2) which included state of knowledge and groups (ME, MI). F ratios were considered significant at $p < 0.05$. If significant main effects or interactions were present, a Bonferroni (Dunn's) post-hoc test was conducted. Dependent variables included force, quadriceps inactivation (ITT), and quadriceps and hamstrings EMG activity. Descriptive statistics include means ± standard error of the mean (SEM).

Results

Effect of state of knowledge on ITT

Subjects force, ITT inactivation, and quadriceps and hamstrings EMG activity remained similar whether they knew they were going to receive a stimulus or when it was unknown whether or not they would receive a superimposed stimulus during a contraction (i.e. the dependent variables were the same when the subjects received a stimulus or thought they might receive a stimulus). On the other hand when subjects knew they were not going to receive a stimulus, MVC forces were significantly higher. Thus, there was no difference in the dependent variables (force, EMG, ITT) when an IT was expected (delivered or not), but significant decrements were apparent when compared to a MVC performed knowing there would be no stimulus applied.

If there was the possibility of a superimposed stimulus (IT), the knowledge or lack of knowledge of an IT occurring during a contraction did not result in significant overall differences in force, ITT inactivation, quadriceps or hamstrings EMG activity.

However, significant force decrements were apparent when comparing MVCs with the possibility or expectation of an IT to MVCs that subjects knew would not involve stimulation.

Force: There were main effects for the knowledge of IT imposition on force (no expectation > expectation of IT) and groups (ME > MI). Overall, the MVC forces with no expectation of an IT exceeded ($p < 0.0001$) the MVC forces with the expectation of an IT by 9.5%. The group main effect demonstrated that ME produced 14.5% significantly ($p = 0.0001$) greater force than MI (Table 2). Significant interactions showed that ME experienced a non-significant force decrease of 6.6% when anticipating or receiving a stimulus, whereas MI force significantly ($p< 0.01$) decreased 12.4% when anticipating or being subjected to an IT (compared to performing a MVC with no expectation of an IT).

EMG: There were no significant group main effects for quadriceps or hamstrings EMG differences between ME and MI (Table 3). There was however a main effect for the state of knowedge of the stimulus. Quadriceps EMG activity significantly ($p < 0.0001$) decreased by 14.9 %, when expecting or receiving a stimulus. There was no significant change in hamstrings EMG activity. Significant interactions occurred with ME exhibiting non-significant decreases of 8.9% in quadriceps EMG activity when expecting or receiving an IT, whereas, MI had a significant ($p < 0.0001$) decrease of 20.9%.

ITT: There was a significant group main effect ($p < 0.0001$) on inactivation (greater activation). ME subject inactivation levels were 8.5% ± 0.9 whereas MI subject inactivation levels were 18.9% ± 1.4.

Likert-pain analog scale: With a scale ranging from 0 – 6 (0 = no perceived pain and 6 = extreme pain) the ME score of 1.2 was significantly ($p < 0.001$) less than the MI score of 1.9.

Table 2. Maximal force (Newtons) outputs with either an expectation or no expectation of an interpolated twitch (IT).

	MVC with no expectation of an IT	MVC with expectation of an IT	Mean difference within groups
Male Experienced (ME)	757.7 N ± 50.2	707.6 N ± 66.1	6.6% ↓ Non-significant
Male Inexperienced (MI)	668.6 N ± 34.7	584.9 N ± 43.7	12.4% ↓ $p < 0.01$
Mean difference between groups	11.7% $p < 0.0001$	17.3% $p < 0.0001$	

Table 3. Quadriceps electromyographic (EMG %) activity with either an expectation or no expectation of an interpolated twitch (IT).

	MVC with no expectation of an IT (average of the 4 MVCs used for normalization)	MVC with expectation of an IT	Mean Difference within groups
Male Experienced (ME)	100%	90.1% ± 6.6	8.9% ↓ Non-significant
Male Inexperienced (MI)	100%	79.1% ± 7.2	20.9% ↓ $p < 0.0001$
Mean Difference between groups		12.2% Non-significant	

Activity inventory questionnaire: There were no significant differences in physical activity profiles between the groups.

Discussion

One of the most important findings of this study was the loss of quadriceps' force and activation (EMG) when receiving or expecting an interpolated stimulus (IT) during a MVC. Average quadriceps MVC force and EMG decreased by 9.5% and 14.9% when expecting or receiving an IT during a MVC. The expectation of a noxious electrical stimulus led to a decline in force and activation. A number of studies (Frontera et al. 2000; Priori et al. 2000) have identified that maximum pain tolerance from electrical stimuli occurs at 36% to 55% of a quadriceps MVC. The relative forces of evoked stimuli in the present study are similar to the maximum pain tolerance reported in the literature (Frontera et al. 2000; Priori et al. 2000). Thus, the decreased force and EMG activity may have signified a conscious or subconscious decrease in central nervous system neural drive. Most studies implement an orientation session prior to experimentation. The current study demonstrates that a single orientation session (7 MVCs with 3 ITTs) is not sufficient to prevent performance decrements associated with the expectation of an electrical stimulus.

Deficits in force and activation were more pervasive with MI. ME did not exhibit statistically significant deficits in activation with the expectation of an IT. Perhaps the ME were less affected by the IT, due to a learning effect from the previous experience of receiving electrical stimulation of similar or greater intensity (Behm et al. 2001a; 2002a; 2002b). The significantly lower scores on the pain analog scale by the ME suggested a greater pain tolerance may have been developed.

Furthermore the ME exerted 14.5% more force, as well as 10.4% less ITT inactivation (greater activation) than the MI. In contrast, Behm and St-Pierre (Behm and St-Pierre, 1998) reported no significant trained state differences in muscle activation with a cross-sectional study comparing university athletes and untrained students. Although the MI were physically active in various dynamic sporting activities and had similar anthropometric characteristics (age, height and weight) and physical activity profiles as the ME, a transfer of strength did not occur for MI when performing the MVCs. Dynamic contractions have been shown to correlate poorly with static contractions (Bigland-Ritchie et al., 2000; Brown and Loeb 1998; Gullich and Schmidtbleicher 1996). The concept of contraction-specific training adaptations has been well documented in the literature (Behm, 1995; Sale, 1988; Sale and MacDougall, 1981). The ME were previously involved in a series of 10 or more experimental sessions involving 3 or more MVCs with IT within a 2 month period. Although ME and MI had performed similar daily physical activities; MI had performed approximately 5 submaximal and 7 MVC isometric contractions in the previous week. The 30 or more contractions by the ME over the previous 2 months may have contributed to a contraction-specific training program, resulting in the increase in isometric strength and activation.

The results indicated that individuals produced the highest amount of force when they were told that during the MVC no IT would be present. On the other hand, subjects force declined when it was known that the MVC would include an IT or there was a possibility that an IT would be delivered during the MVC. This suggests that during a MVC the possibility or expectation of discomfort and pain that is induced by the IT may; 1) have a similar force reducing effect as the actual presence of discomfort and pain but they are not additive or 2) be responsible for the decrement in force instead of the actual discomfort and pain.

In the present study, doublets were superimposed upon the voluntary contraction to ameliorate the signal to noise ratio. It has been suggested that using multiple evoked stimulation with the ITT enhances the signal-noise ratio (Behm et al., 1996) and is a more sensitive tool compared to a single evoked stimulation (Kent-Braun and Le Blanc, 1996; Miller et al., 1999). However, others have indicated no significant difference when comparing single twitches, doublets, quadruplets (Allen et al., 1995), quintuplets (Behm et al., 1996) or tetanic (Behm et al., 2001b) stimulation. Thus, if the increased force and pain associated with multiple, high frequency stimuli provides questionable advantages in identifying and measuring the extent of inactivation, the use of less painful twitches would be recommended.

In summary, the validity of the ITT for estimating the extent of full muscle activation must be viewed with caution, since the expectation of IT discomfort may inhibit the individual's ability to exert maximum force, especially with inexperienced participants. Methodologies should allow for a suitable orientation period to decrease anxiety towards the electrical stimulus. According to some studies in the literature (Behm et al. 1996; Behm et al. 2001b), higher frequency stimulation may not provide more accurate estimates of muscle activation. Less painful, but more tolerable single twitches might be preferable over higher frequency stimulation. Due to training specificity, strength and activation adaptations achieved with dynamic contractions may not translate to improved performance with the ITT. Future research should investigate the number of conditioning sessions needed to ensure accommodation of the IT.

Conclusion

This study illustrated that a single orientation session may not be adequate for a valid estimation of muscle activation using the ITT.

Acknowledgements
This research was supported by the Natural Sciences and Engineering Research Council (NSERC) of Canada as well as a Research Infrastructure Grant through Memorial University of Newfoundland.

References

Allen, G.M., Gandevia, S.C. and McKenzie, D.K. (1995) Reliability of measurements of muscle strength and voluntary activation using twitch interpolation. *Muscle and Nerve* **18**, 593-600.
Behm, D.G. and St-Pierre, D.M.M. (1997) The muscle activation force relationship is unaffected by ischaemic recovery. *Canadian Journal of Applied Physiology* **22**, 468-478.
Behm, D.G (1995) Neuromuscular implications and applications of resistance training. *Journal of Strength and Conditioning Research* **9**, 264-274.
Behm, D.G., Anderson, K. and Curnew, R.S. (2002a) Muscle force and activation under stable and unstable conditions. *Journal of Strength and Conditioning Research* **16**, 154-162.
Behm, D.G., Button, D. and Butt J. (2001a) Factors affecting force loss with stretching. *Canadian Journal of Applied Physiology* **26**, 262-272.
Behm, D.G., Power, K. and Drinkwater, E. (2001b) Comparison of interpolation and central activation ratios as measures of muscle inactivation. *Muscle and Nerve* **24**, 925-934.
Behm, D.G. and St-Pierre, D.M.M. (1998) Fatigue mechanisms in trained and untrained plantar flexors. *Journal of Strength and Conditioning Research* **12**, 166-172.
Behm, D.G., St-Pierre, D.M.M. and Perez, D. (1996) Muscle inactivation: assessment of interpolated twitch technique. *Journal of Applied Physiology* **81**, 2267-2273.
Behm, D.G., Whittle, J., Button, D. and Power, K. (2002b) Inter-muscle differences in activation. *Muscle and Nerve* **25**, 236-243.
Belanger, A.Y. and McComas, A.J. (1981) Extent of motor unit activation during effort. *Journal of Applied Physiology* **51**, 1131-1135.
Bigland-Ritchie, B., Zijdewind, I. and Thomas, C.K. (2000) Muscle fatigue induced by stimulation with and without doublets. *Muscle and Nerve* **23**, 1348-1355.
Brown, I.E. and Loeb, G.E. (1998) Post-activation potentiation - A clue for simplifying models of muscle dynamics. *American Zoology* **38**, 743-754.
Chapman, S.J., Edwards, R.H.T., Greig, C. and Rutherford, C. (1985) Practical application of the twitch interpolation technique for the study of voluntary contraction of the quadriceps muscle in man. *Journal of Physiology (London)* **353**, 3P-4P.
Frontera, W.R., Suh, D., Krivickas, L.S., Hughes, V.A., Goldstein, R. and Roubenoff, R. (2000) Skeletal muscle fiber quality in older men and women. *American Journal of Physiology (Cell Physiology)* **279**, C611-C618.
Gullich, A. and Schmidtbleicher, D. (1996) MVC-induced short-term potentiation of explosive force. *New Studies in Athletics* **11**, 67-81.
Hortobagyi, T., Lambert, N., Tracy, C. and Shinebarger, M. (1992) Voluntary and electromyostimulation forces in trained and untrained men. *Medicine and Science in Sports and Exercise* **24**, 702-707.
Kalmar, J.M. and Cafarelli, E. (1999) Effects of caffeine on neuromuscular function. *Journal of Applied Physiology* **87**, 801-808.
Kent-Braun, J.A. and Le Blanc, R. (1996) Quantitation of central activation failure during maximal voluntary contractions in humans. *Muscle and Nerve* **19**, 861-869.
Martin, A., Carpentier, A., Guissard, N., Hoecke, J. and Duchateau, J. (1999) Effect of time of day on force variation in human muscle. *Muscle and Nerve* **22**, 1380-1387.
Miller, M., Downham, D. and Lexell, J. (1999) Superimposed single impulse and pulse train electrical stimulation: a quantitative assessment during submaximal isometric knee extension in young, healthy men. *Muscle and Nerve* **22**, 1038-1046.
Phillips, S.K., Bruce, S.A., Newton, D. and Woledge, R.C. (1992) The weakness of old age is not due to failure of muscle activation. *Journal of Gerontology* **47**, M45-M49.
Priori, A., Pesenti, A., Cappellari, A., Scarlato, G. and Barbieri, S. (2000) Post-contraction depression of reciprocal inhibition in human forearm muscles. *Muscle and Nerve* **23**, 1335-1343.
Rice, C.L., Vollmer, T.L. and Bigland-Ritchie, B. (1992) Neuromuscular responses of patients with multiple sclerosis. *Muscle and Nerve* **15**, 1123-1132.
Rutherford, O.M. and White, P.D. (1991) Human quadriceps strength and fatiguability in patients with post viral fatigue`. *Journal of Neurology Neurosurgery and Psychiatry* **54**, 961-964.
Sale, D. (1988) Neural adaptation to resistance training. *Medicine and Science in Sports and Exercise* **20**, 135-145.
Sale, D. and MacDougall, J.D. (1981) Specificity in strength training: a review for the coach and athlete. *Canadian Journal of Applied Sports Science* **6**, 87-92.
Strojnik, V. (1995) Muscle activation level during maximal voluntary effort. *European Journal of Applied Physiology* **72**, 144-149.
Urbach, D. and Awiszus, F. (2000) Effects of transcranial magnetic stimulation on results of the twitch interpolation technique. *Muscle and Nerve* **23**, 1125-1128.

Key points

- A single orientation session may not be adequate for a valid estimation of muscle activation using the ITT.
- The expectation of an electrical stimulation whether delivered or not can impair performance.
- The validity of the ITT for estimating the extent of full muscle activation must be viewed with caution, since the expectation of IT discomfort may inhibit the individual's ability to exert maximum force, especially with inexperienced participants.

AUTHORS BIOGRAPHY

David BEHM
Employment
Prof., School of Human Kinetics and Recreation at Memorial Univ. of Newfoundland, Canada, Research Fellow, Univ. of Ballarat, Australia and Universitaet Kassel, Germany.
Degree
PhD
Research interest
Neuromuscular responses to acute and chronic activity.
E-mail: dbehm@mun.ca

Duane BUTTON
Employment
Post-doctoral fellow at the Faculty of Medicine at Memorial University of Newfoundland, Canada
Degree
PhD
Research interest
Human and animal models in basic and applied neuromuscular physiology.
E-mail: dbutton@mun.ca

✉ **David Behm, PhD**
School of Human Kinetics and Recreation, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1C 5S7