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THE EFFECTS OF SPINAL MANIPULATIVE THERAPY ON ISOKINETIC STRENGTH AND POSTACTIVATION POTENTIATION

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THE EFFECTS OF SPINAL MANIPULATIVE THERAPY ON ISOKINETIC STRENGTH AND POSTACTIVATION POTENTIATION

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
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By
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ABSTRACT OF DISSERTATION

THE EFFECTS OF SPINAL MANIPULATIVE THERAPY ON ISOKINETIC STRENGTH AND POSTACTIVATION POTENTIATION

Spinal manipulative therapy (SMT) is a therapeutic procedure employed by various healthcare practitioners for alleviating acute and chronic musculoskeletal complaints. This form of treatment is also delivered to enhance the performance and augment the rehabilitation of athletes. However, despite research findings alleging the strength-modulating effects of SMT alongside numerous professional athletes' positive anecdotal claims concerning its results, the physiological processes to explain its effects remain largely unexplained. Therefore, the purpose of this work was to investigate the effects of SMT in a college-aged sample population with two experiments.

The first study examined the effect of SMT targeting the lumbosacral region on concentric force production of the knee extensors and flexors. A randomized, controlled, single-blind crossover design was utilized with 21 subjects. Isometric and isokinetic peak torques (Nm) were recorded during maximal voluntary isometric contractions (MVIC) or maximal voluntary contractions (MVC) post-treatment of either SMT or a sham manipulation. The second study incorporated the same experimental design with 20 subjects to examine the effects of SMT on central nervous system (CNS) excitability. This was accomplished by assessing postactivation potentiation (PAP), measured with the Hoffmann Reflex (H-reflex). PAP is an enhanced neuromuscular response to prior contractile activity, and the H-reflex is the electromyographic (EMG) recording of submaximal electrical stimulation of the Ia monosynaptic reflex pathway. Subsequent to SMT and/or a plantar flexion MVIC, EMG amplitudes and isometric twitch torque generation of the gastrocnemius and soleus muscles were recorded during tibial nerve stimulations.

The results of the first study indicate that SMT did not produce a significant strength-modulating effect during isometric and isokinetic contractions of neither knee extension nor flexion. Similarly, the second study revealed that SMT immediately preceding the MVIC to induce PAP did not significantly increase H-reflex EMG amplitudes of either muscle or the simultaneous isometric twitch torque generation compared to the MVIC only. These data from both investigations suggest that SMT does not enhance strength or PAP. The positive anecdotal claims of athletes who utilize SMT

may be due to other factors, such as the clinical efficacy of the treatment in addressing musculoskeletal injuries or a placebo effect.

KEYWORDS: Spinal manipulation, isokinetic strength, H-reflex, postactivation potentiation, central nervous system

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Chapter 1: Introduction

Background

Spinal manipulative therapy (SMT) is a therapeutic procedure that has been performed for thousands of years[1-3] and is employed today by healthcare practitioners such as chiropractors, osteopaths, physical therapists and athletic trainers.[4] SMT is defined by Stedman's Medical Dictionary as a "manual method of osseous movement using high-velocity techniques that take the joint beyond the passive-range end barrier (without exceeding the anatomic limit) to what is known as the paraphysiologic space."[5] The primary goal of this form of treatment is to reduce spinal and peripheral joint restriction, thereby promoting a normal range of motion (ROM). The technique is also referred to as a Grade V mobilization[1] and by chiropractors as a spinal adjustment, the most common of which being high velocity, low amplitude (HVLA).[1,2,6] SMT has been shown in several studies to be both efficacious and cost-effective for acute and chronic musculoskeletal complaints such as neck pain, low back pain and headache.[7-16]

There are several types of manipulation or adjustment techniques, all with the intent of ameliorating joint hypomobility and positively influencing neurological functioning.[1,2,6] According to Haldeman,[17] these techniques include nonspecific long-lever manipulation, specific short-lever manipulation, toggle-recoil, joint play, traction and distraction and mechanically assisted. Evidence from a variety of peer-reviewed journals also suggests that back pain patients experience enhanced pain relief when SMT is employed in tandem with other treatment approaches such as exercise, massage and acupuncture.[18-22] While HVLA manipulations are most commonly utilized for the treatment and management of mechanical back pain, the procedure has also been shown to be effective in the reduction of extremity joint pain.[1,2,23] In addition to high patient satisfaction[24-27] and global utilization within the clinical setting,[4] this form of treatment is also delivered for the purpose of enhancing the performance and augmenting the rehabilitation of collegiate and professional athletes.[2,28,29] Notable examples include the World Ice Hockey Championships, the World Games and the Olympic Games.[30,31,32] Since 1980, Olympic athletes have utilized SMT from chiropractors as part of their injury care and prevention and possible performance enhancement.[6] The provision of SMT is also evident in settings such as the NFL,[33] in which all 32 teams have a chiropractor on staff to incorporate SMT into their sports medicine programs.

Research efforts from the past few decades have investigated the effects of SMT on topics such as strength modulation, muscle inhibition, electromyographic activity, motor training/reaction time and balance.[28] Regarding strength, at least 22 different studies have recorded changes in force exerted during maximal voluntary contractions (MVC) post-manipulation. Within these articles, a range of muscle groups were selected, such as the quadriceps femoris, cervical musculature, thoracolumbar erector spinae, biceps brachii, shoulder external rotators, lower trapezius and gluteus maximus, in addition to measurements of knee flexion and grip strength.[34-54,55] Many of these studies reported increases in strength and/or increased electromyograph (EMG) amplitudes, and are important in the establishment of foundational knowledge of the effects of SMT on

strength modulation. However, the validity of a number of the results is decreased by questionable methodology.

In a review of the related literature, 18 studies have shown a statistically significant increase in strength post-manipulation and/or decrease in muscle inhibition, while 3 reported no significant difference and 1 was a case study.[34-54,55] Within these 22 articles, several different muscle groups were focused on, with the most predominant being the quadriceps femoris and also measurements of grip strength. Nonetheless, only 10 of the aforementioned studies utilized a randomized, controlled experimental design.[34,36,39,43,44,49-51,54,55] Of these 10, even fewer employed the most reliable strength measurement methods of isokinetic dynamometry or a load cell[34,36,39,50,54,55] (the exception being an investigation of trunk muscle activity measured with surface electromyography[44]). In addition, the majority of the studies' purported strength increases contained sizeable standard deviations. Another aspect is the subject population. Interestingly, the three studies that also did not reveal significant increases in strength post-SM[45,47,51] were among the nine that tested an asymptomatic population.[34,38,45,47,49,50,53,54,55] A common conclusion from the studies which included symptomatic subjects was the view that the participants' disability afforded a greater opportunity for strength increases, as there was a decrease in pain and related muscle inhibition post-manipulation. This concept is discussed in greater detail in the literature reviewed for this work (Chapter 2).

Regardless of the methodologies and results of previous investigations, they are all measures of gross muscle activity, which can be affected by several variables such as the ability to recruit motor units, current level of fitness and intrinsic motivation.[56-58] The theory and research related to SMT, however, is concerned primarily with the effects on the central nervous system (CNS). Accordingly, a phenomenon related to both CNS function and athletic performance is postactivation potentiation (PAP). PAP is an immediate, augmented increase in explosive muscle force generation following heavy resistance exercise.[59] It has been purported that the preceding heavy loading causes a large amount of CNS stimulation, which results in increased motor unit recruitment and force production.[60-62] Two explanations for this occurrence are widely recognized. The first is that an increase in the phosphorylation of myosin regulatory light chains occurs during the preceding heavy lifting, allowing troponin to become more receptive to calcium ions released from the sarcoplasmic reticulum.[60,61,63,64] This will in turn enhance the force production and speed of contraction rates during subsequent explosive movements.[59,60,63] The second explanation is based on findings from use of the Hoffmann Reflex (H-reflex), that increased CNS activity may also provide a neural contribution to potentiation post-conditioning acitvity. The H-reflex is the submaximal electrical stimulation of the Ia monosynaptic reflex pathway to measure the efficacy of the Ia-alpha motor neuron (αMN) synapse in the venral horn of the spinal cord.[65,66] Analogous to mechanically-induced tendon reflexes, the measurement is most reliable when performed via the tibial nerve.[65] Measurement of the reflex latency can be employed clinically to aid in the diagnosis of radiculopathies, and in kinesiological research for estimating the size of the motor neuron pool able to be recruited under various conditions.[67] The stimulation results in a compound muscle action potential (CMAP) from which reflexive motor unit

activity can be measured, thus indicating the excitability of the CNS.[65,67] Moreover, it has been found that H-reflex EMG amplitudes are enhanced during PAP, signifying an increase in the firing rate of action potentials to the contracting muscle.[65]

Statement of the Problem

Concerning the effects of SMT, it may be possible that one of the reasons for athletes' anecdotal claims of increased performance post-treatment is due to increased potentiation. While the H-reflex has been studied to elucidate the neurophysiological effects of SMT, it has never been conducted to measure the effects of SMT on PAP, with possible implications for a greater increase in power production versus that which would occur in a control group not receiving SMT. In addition to addressing the gap in the literature, this investigative effort is directly related to the proposed neurophysiological effects of SMT. Several authors have stated the need for further investigations of how SMT may modulate neuromuscular activity outside of the clinical setting,[68] particularly when delivered pre-competition.[28,69,70] As such, this research may contribute to the advancement of the use of SMT within the chiropractic, osteopathic, physical therapy and athletic training professions in the treatment of athletes. Additionally, despite research findings alleging the strength-modulating effects of SMT and numerous professional athletes' use of SMT and positive anecdotal claims concerning its seemingly beneficial results, the physiological processes to explain its effects in this area remain elusive. This coincides with the fact that while several contemporary models exist pertaining to various aspects of SMT,[49,71-74] a clear, comprehensive paradigm does not exist for the physiological sequelae of chronic intervertebral joint fixation and the corresponding therapeutic effects of SMT.[75] The results of this endeavor may serve to add another dimension to what is known regarding the physiological results and significance of SMT, which may help further promote the creation of such a model. The lack of understanding in this area is a problem because complete understanding of the treatment's effects may result in the implementation of new, more effective protocols by various clinicians. In addition, this knowledge may lead to a change in the frequency and/or timing of the procedure's inclusion in athletes' training regimens to possibly enhance the neuromuscular effects of strength and conditioning programs and ultimately, athletic performance.

Purpose

This work was completed to investigate effects of SMT in a college-aged sample population by focusing on strength modulation to compare to previous studies and CNS excitability changes to add to neurological effect. This was accomplished with two experiments.

<u>The first study</u>

The first investigation examined the effect of manual, HVLA spinal manipulations targeting the lumbar spine and/or sacroiliac joint on concentric force production of the knee extensors and flexors measured with an isokinetic dynamometer. It was hypothesized that statistically significant differences in peak torque generation during MVC/MVICs post-treatment would occur comparing the two treatments of SMT or a sham manipulation. This knowledge is important because it provided sound

instrumentation by incorporated isokinetic dynamometry, the most reliable strength measurement method.[76] In addition, the topic addresses the growing presence of SMT in athletics, apparent in numerous sports organizations including the U.S. Olympic Committee (USOC). The fact that Michael Reed, DC, DACBSP was hired by the USOC in 2008 as one of the medical directors of the Sports Performance Division further warrants this type of investigation. Most recently at the Sochi 2014 Games, six chiropractors were included among the sports medicine staff, alongside the physical therapists and physiatrists also likely to deliver SMT. Furthermore, Bill Moreau, DC, DACBSP, CSCS oversees the delivery of healthcare to elite athletes by fulfilling the role of USOC managing director of the sports medicine division in the three U.S. Olympic Training Centers.[77]

This study was also innovative because only isometric contractions post-SMT have been measured in the literature; no information presently exists in relation to strength changes after spinal manipulation measured during dynamic contractions. The results can also be added to the studies which recruited a healthy population,[34,38,45,47,49,50,54,55] which is important because a symptomatic population is commonly tested in the manual therapy literature. However, the results of the first experiment revealed that SMT did not give rise to a statistically significant strength-modulating effect on either isometric or isokinetic strength. Yet, similar studies on SMT in the manual therapy literature and athletes' positive anecdotal claims concerning the treatment's performance enhancing effects provide reasons to further investigate the possible-strength modulating effects of SMT. Increased CNS activity, reported to occur following SMT and thought to possibly increase the efficacy of PAP,[65] may create an effect that can be demonstrated in a resistance-trained sample population that did not occur with the largely recreationally active subjects in the first study. The most likely explanation is the relatively greater amount of Type IIx fibers found in the resistance-trained participants. Therefore, the second experiment was performed to look deeper into CNS function while including stricter inclusion criteria and greater subject homogeneity.

The second study

The goal of the second experiment was to increase the current knowledge base regarding the neurophysiological effects of SMT by expanding on the results of the first experiment with a sample population in the same age range. This was completed through the determination of changes in excitability and resulting neural drive to muscle, using PAP as a tool, measured by the H-Reflex. The central hypothesis was that the posited neurophysiological effects of SMT may work synergistically with a commonly proposed PAP mechanism of increased neural drive to the muscle following the subsidence of fatigue post-contractile activity. Specifically, SMT delivered to the lumbosacral region would create a neurological effect of significantly increased spinal reflex excitability. This increase would result in enhanced potentiation of the gastrocnemius/soleus complex following voluntary contractile activity compared to potentiation resulting from contractions alone. Enhanced PAP would be reflected by an increase in electrically-evoked isometric twitch torques during tibial nerve electrical stimulations. It was thought that concurrent alterations in motor unit recruitment would occur, as measured by increased H-reflex peak-to-peak EMG amplitudes. This hypothesis was formed based on

similarities in the mechanisms reported to contribute to the neuromuscular effects of both SMT and PAP in the manual therapy and exercise science literature. It has been found that PAP enhances H-reflex amplitudes post-conditioning activity, which would in turn indicate an increase in the firing rate of action potentials to the contracting muscle.[65] Inferences will be made from these measurements of isometric twitch torques and EMG amplitudes regarding the further possibility of increased power generation during the performance of explosive activities such as sprinting, jumping and throwing. PAP has been shown to occur in resistance-trained subjects and to the greatest degree in elite athletes.[78] Given the widespread utilization of SMT by professional athletes, it is possible that the delivery of SMT immediately preceding resistance training may induce a greater neural contribution to PAP than what would otherwise occur after muscular contractile activity. To determine the possible likelihood of this occurrence, measurements of physiological activity, such as the H-reflex, are necessary to establish valid conclusions.

The knowledge gained from this experiment is important because it addresses the fact that the physiological processes underlying the efficacy of SMT are largely undetermined in both the clinical and athletic populations. One factor contributing to this limitation is that all of the published research incorporating H-reflex EMG recordings post-SMT in both symptomatic and asymptomatic subjects have been performed only under resting conditions.[79-88] Each of these studies have also reported attenuation of CNS excitability for less than one minute post-SMT. However, the H-reflex has never been used to measure the possible neurological effects of SMT on PAP, with possible implications for a greater increase in power production compared with repeated measurements of contractile activity which do not include SMT. In light of other neurological findings derived from different forms of instrumentation post-SMT, some revealing increased CNS excitability under resting conditions, it is plausible that H-reflex EMG amplitudes and concomitant motor neuron recruitment after this minute time frame will be augmented immediately following a conditioning activity to induce PAP.

Enhanced H-reflex amplitudes revealing increased CNS excitability and resulting neural drive to the muscle have been cited as evidence for potentiation following resistance exercise of moderate to heavy intensity.[60] Previous studies on the effects of SMT on spinal reflex excitability under resting conditions have revealed fairly consistent responses in EMG amplitudes within one minute of treatment. Specifically, a transient decrease has been reported to occur in H-reflex EMG amplitudes post-SMT. It is not known, however, if the inclusion of a conditioning activity during the average minute of attenuated H-reflex EMG amplitudes post-SMT will result in the further modulation of spinal reflex excitability. Therefore, this research would not only address the gap in the literature pertaining to the effect of paired SMT and muscular contractile activity on spinal reflex excitability, but would do so through a novel combination of the fields of manual therapy and exercise science with the measurement of PAP. Thus, increased H-reflex amplitudes correlated with greater plantar flexion torques produced during the muscular twitches evoked during the tibial nerve electrical stimulations may reveal a synergistic effect of SMT with the CNS-related mechanisms believed to contribute to PAP. A repeated measures design to compare the temporal factors of H-reflex amplitudes resulting from an MVIC post-lumbosacral SMT with the MVIC only will yield

information on this possible outcome. These results are expected to increase understanding of the neurophysiologic effects of SMT, with specific regard to the possible enhancement of power production in explosive athletes.

Finally, only a few studies of PAP[64,89,90] have utilized concurrent measures of neurophysiological potentiation and mechanical performance, and it has been suggested that more work is needed to measure both factors.[89] A recent meta-analysis[78] revealed that the potentiating effects of prior contractile activity occur in a resistance-trained population, and most prominently in elite athletes. This conclusion further substantiates the need to test the PAP-generating effects of a MVIC with and without SMT in at least a resistance-trained sample population; this requirement is especially apparent when considering that recreationally active subjects have been most commonly tested in previous experiments of PAP. It is hoped that in addition to the possible advancement of knowledge in the fields of manual medicine and exercise physiology, that greater collaboration between the two will be promoted. The resulting possibility of continued related research may ultimately provide clinicians and athletes with a novel method of incorporating SMT within training regimens and pre/post-competition.

Chapter 2: Review of the Literature

Introduction

As with any therapeutic intervention, a complete understanding of the effects of spinal manipulation necessitates an initial inspection of the condition being treated. Therefore, the purported negative effects of chronic intervertebral joint hypomobility shall serve as the first of five primary topics within this literature review. Emphasis will be placed on clinical identification and hypothesized consequences of spinal joint motion restrictions, such as aberrant afferent information and joint dysafferentation. The ameliorative effects of SMT on intervertebral joint restriction then follows as the second aspect, with a review of the proposed primary and secondary events of this chronic condition, as well as other effects documented in the manual therapy literature. Accordingly, the third topic is instrumentation and measurement of the effects of SMT, with special consideration of reported changes in H-reflex amplitudes subsequent to treatment delivery. The fourth main topic, PAP, serves as a transition to the possible strength-enhancing effect of SMT. Following a review of the most commonly proposed physiological mechanisms of PAP will be a discussion of how SMT may influence PAP. Within this fifth primary aspect, the possible enhancement of strength, PAP, and/or explosive athletic performance is explained in light of various results from clinical investigations of SMT.

Intervertebral joint hypomobility

Clinical identification

Restricted spinal motion has been referred to by numerous synonyms, such as vertebral dyskinesia, neuroarticular dysfunction, segmental vertebral hypomobility, spinal kinesiopathology and manipulable lesion.[1,6] A definition of joint fixation set forth by Peterson and Bergmann is "The state whereby an articulation has become temporarily immobilized in a position that it may normally occupy during any phase of physiologic movement; the immobilization of an articulation in a position of movement when the joint is at rest or in a position of rest when the joint is in movement."[91] This condition is theorized to have numerous causes, such as physical trauma, intervertebral disc degeneration, congenital factors, muscular imbalances, emotional tension, chronic postural stress and fibrous adhesions that develop in and around the joint complex as a result of chronic intersegmental hypomobility.[1,6,92] This state of a mechanical restriction is often followed by a reflexive increase in muscle tone contiguous with the vertebral segment. Evaluation of intervertebral joint fixation is conducted following a thorough case history, a complete physical examination incorporating an orthopedic and neurological evaluation in addition to other examination methods if indicated, such as diagnostic imaging (plain film radiograph, MRI, CT) and occasionally, laboratory tests (such as a blood chemistry panel and complete blood count with white blood cell differential). These procedures not only support or refute the differential diagnoses, but also serve to rule out contraindications to SMT when devising the treatment plan. The clinician then assesses the region of complaint using methods of observation and palpation to detect the manipulable lesions. These procedures most commonly include postural and gait observation, soft tissue and osseous palpation, and global range of motion (ROM) and segmental ROM testing.[6] Static palpation is employed for detecting

malpositions, anomalies, landmarks and tenderness. The mobility of the joints are evaluated with motion palpation, in which restrictive barriers to movement within the joint's active ROM and the end range of passive motion are identified.[1]

The characteristic palpation findings which indicate uncomplicated joint hypomobility and associated dysfunction are provocation of pain, abnormalities in alignment, abnormal resistance to joint movement and altered tissue texture. Peterson and Bergmann have classified the five diagnostic criteria for the identification of joint fixation with the acronym PARTS: pain and tenderness, asymmetry, altered ROM, abnormality of tone, texture, temperature and tenderness and also special tests (such as leg length evaluation or radiographic examination).[1] Vertebral misalignment is then designated according to a listing system based on a static or dynamic description of the restriction relative to the inferior vertebra of the intervertebral segment. For example, a vertebra could statically be listed as PLI, meaning the spinous process has shifted posterior, left and inferior of center. This is analogous to a dynamic motion listing of a left rotation and right lateral flexion restriction.[1] However, numerous studies have revealed low inter and intraexaminer reliability of static and motion palpation of various regions of the spine;[93] yet, validity has been shown to be high,[94] as well as sensitivity and specificity in identifying a painful segment in subjects with uncomplicated back pain.[95] While this can be a limiting factor in research, the clinical application of palpation is different, being one aspect of a holistic, multi-faceted approach to the patient/subject evaluation. This is because in clinical practice, static and motion palpation are not performed in isolation, but as two of several steps in concert with the previously described diagnostic procedures that all contribute to the overall clinical impression. For example, the combined presence of myofascial trigger points within the scalenes, upper trapezius and levator scapulae muscles, forward head carriage, scapular protraction, hypertonicity of the pectoralis and upper trapezius muscles and weakness of the deep neck flexors, lower trapezius and serratus anterior are commonly associated with restrictions in the cervicothoracic region of the spine, in agreement with Janda's Upper Crossed Syndrome.[96] As a result, the application of SMT to vertebral segments specifically identified as restricted within this region is more justified than being based simply on palpation findings, as what commonly occurred during previous reliability studies.[91] Depending on the individual patient's case, the manipulation would commonly be delivered in conjunction with other in-office procedures, including modalities (such as therapeutic ultrasound, interferential current, thermotherapy/cryotherapy), myofascial trigger point release and passive/PNF stretching, and home care recommendations such as corrective exercises, stretches, postural retraining and nutritional guidance.

Hypothesized effects

Daniel David Palmer, the founder of the chiropractic profession, introduced the neurodystrophic hypothesis as one of the earliest perspectives concerning the effects of intervertebral joint hypomobility.[97] Dr. Palmer proposed that neural dysfunction arising from spinal nerve impingement within a fixated vertebral segment is harmful to visceral organs and other tissues, and may in turn negatively affect immune responses and alter the autonomic function of the involved nerves.[2,97] However, in contrast to the earliest theories of Palmer, direct osseous nerve compression does not occur when the diameter

of the intervertebral foramen (IVF) is partially decreased as a result of intervertebral hypomobility.[98] This is especially apparent in the lumbar spine, where the largest IVF widths are located. Nonetheless, the nerve roots, dorsal root ganglia and recurrent meningeal nerves are in fact vulnerable to foraminal encroachment instead from the areolar and adipose tissues that surround these structures. Spondylosis can cause this otherwise supportive meshwork to compress these structures within itself and against transforaminal ligaments. This condition includes disorders such as osteoarthritis and bulging discs,[99] which result in degenerative changes such as osteophyte formation, articular cartilage deterioration and adhesion formation, leading to progressive immobilization of the joint complex.

The immobilization of the joint from a chronic intervertebral joint motion restriction has been theorized to cause similar degenerative effects, particularly in regard to the cartilage of the vertebral articulating surfaces and facet joint capsules, thus also possibly leading to foraminal encroachment.[100] This concept is important because the spinal nerve roots have less protective epineurium compared to peripheral nerves. As a result, it is likely that the nerve roots within the IVF are susceptible to compression from any source of compromised biomechanical integrity of the joint complex.[98,100] Mechanical irritation may lead to an inflammatory reaction, possibly producing noxious stimuli along the segmental distribution of the nerve root.[102] In addition, decreased action potential propagation has been shown to occur in varying degrees as a result of compression, torsion, stretching or angulation of the nerve root from the foraminal encroachment or fibrous adhesion formation of a an intervertebral segment.[98] Altered sensory input from affected joints, ligaments, tendons and muscles of the involved joint segment also have been shown to affect reflexive efferent neural conduction.[103-106]

The contemporary hypotheses regarding the aforementioned effects of restricted spinal motion on nervous activity (primarily concerning mechanical back pain) are numerous. These concepts include Gillet's Fixation Theory,[2] Mennel's Joint Dysfunction Theory,[107] Seaman's model of joint dysafferentation[108] as well as Faye's five-component model[75] and Lantz's hierarchical nine-component model of joint fixation.[109] Osteopathic physicians refer to this state as acute and chronic somatic dysfunction, defined as "Impaired or altered function of related components of the somatic (body framework) system: skeletal, arthrodial and myofascial structures, and their related vascular, lymphatic, and neural elements."[91] Other investigations of the maladaptive effects of intervertebral hypomobility have been conducted by investigators such as W. Herzog,[110,111] H. Haavik,[112-116] B. Murphy,[112-116] J. Burke,[83,85,117] J. Dishman[81,87,118] and J. Pickar.[119,120] From these authors' studies, it may be deduced that intervertebral hypomobility negatively influences neural functioning by inciting aberrant mechanoreceptive, afferent activity within the CNS, and promoting concurrent dysafferentation of mechanoreceptors and nociceptors within the intervertebral joint complex.

Aberrant afferent information

According to the clinical results of several authors, such as I.M. Korr, restricted spinal motion can affect reflex responses of the segmentally innervated structures. Korr's

experiments demonstrated that increased nerve excitability and sustained hypersensitivity of afferent nociceptors were correlated with palpable movement restrictions in the spine.[121] Korr also reported consistent increases in galvanic skin response measurements at specific vertebral levels that he called the facilitated (hyperactive) segment.[104,122-124] Korr theorized that an increase in gamma motor neuron activity resulting from the dysfunctional intervertebral joint complex causes a reflexive increase in αMN activity, resulting in hypertonicity of the associated musculature.[122] The concept is mirrored in the pain-spasm-pain cycle proposed by Travell et al.,[125] in which chemosensitive nociceptors from group III afferents (Aδ fibers) and group IV afferents (C fibers) presumably have an excitatory effect on the efferent gamma motor neurons. This increases the sensitivity of the intrafusal fibers to stretch and thus increases the activation of the αMNs, which perpetuates the continuation of the cycle.[104,122]

Additionally, Haavik and Murphy have proposed that "altered afferent feedback from an area of spinal dysfunction alters the afferent 'milieu' into which subsequent afferent feedback from the spine and limbs is received and processed, thus leading to altered sensorimotor integration of the afferent input, which may be responsible for maladaptive central plastic changes."[113,114] Seaman[108] and Pickar[120] have also identified that this altered afferent information arises from proprioceptive structures of the dysfunctional segment such as the facet joint capsule, dorsal root ganglion, intervertebral disc and muscle spindles and golgi tendon organs of the instrinsic muscles of the spine. Because of the rich supply of mechanoreceptive and nociceptive afferent input from these structures within the intervertebral motion segment,[126] abnormal intervertebral biomechanics as a result of hypomobility may result in pain due to in increased nociception and decreased mechanoreception.[2,108]

Joint dysafferentation

The concept of joint dysafferentation was proposed by Seaman to describe abnormal afferent input as a result of chronic joint restriction, involving a decrease in the activity of large diameter mechanoreceptor afferent fibers coupled with a simultaneous increase in activity of nociceptive fibers.[108,127] Seaman also investigated biochemical properties to further assert that nociceptors are irritated by mechanical insult (resulting from macro or microtrauma, including joint restriction) and pro-inflammatory molecules (such as prostaglandin E-2, leukotriene B-4, histamine and bradykinin.[75] Further details of this concept centered on the process of associated nociceptive input from A-delta and C-fibers entering the spinal cord and causing excitation of interneurons originating in the dorsal horn. The sequelae include local and/or sclerotogenous pain referral patterns and the production of autonomic symptoms such as the excitation of visceral afferent neurons and somatic efferent neurons. Together this would allegedly produce sympathetic vasoconstriction and reflexive muscle spasm.[108] The possible end result is local tissue vasoconstriction and muscle spasm, which may contribute to a reduction in joint mobility. Local nociceptors may be further irritated by this muscle spasm and increased sympathetic stimulation, creating even greater spasm and vasoconstriction. Seaman concluded that as the joint in question becomes more hypomobile, it is probable that the various biochemical and kinesiological components of the maladaptive process will become more prominent and lead to greater irritation of local nociceptors.[127]

Chiropractic and osteopathic theory assert that chronic inflammation and hypertonicity of the musculature contiguous with the fixated vertebral segment may result in progressive immobilization of the segment with a compensatory hypermobility of the adjacent segments.[102] It is documented that the degenerative effects of immobilization of an intervertebral joint complex include factors such as decreased disc height (from water released from proteoglycan molecules) and connective tissue fibrosis which stimulates abnormal cross-linking and a concomitant loss of elasticity, ultimately leading to pain and decreased ROM.[2] Nonetheless, several authors (such as Haavik and Murphy[128]) have further explained that the specific results of their studies which included SMT as a treatment intervention serve as various singular components of the multi-faceted mechanism of HVLA SMT in the amelioration of several of the theoretical negative effects of intervertebral hypomobility.

Effects of spinal manipulative therapy on intervertebral joint hypomobility

SMT has been purported to relieve a number of the aforementioned effects through several means, with the primary goal of increasing joint mobility and possibly improving neurological functioning in restricted vertebral and extremity joints in which contraindications to manipulation are not present.[129] The components of this dynamic mechanical stimulus most relevant to the current study have been classified by several authors[104,119,120,130,131] into primary/direct and secondary/indirect events. Primary refers to a response resulting directly from the abrupt change in neural activity stimulated during the manipulative impulse. A secondary response stems from a change in spinal biomechanics caused by the manipulation.[104,119,120]

Primary and secondary events

Nociceptive input is only registered in the brain as pain if it reaches the thalamus via the fasciculus cuneatus/gracilis of the spinothalamic tract and then is processed in other brain regions, namely the somatosensory cortex and limbic system.[132] The majority of nociceptive signals do not reach the thalamus due to several "closed gates" within the spinal cord, as described by Melzack and Wall[133] in the gate control theory of pain. The theory further expounds that noxious stimuli triggers an increase in afferent non-nociceptive signals within the dorsal horn of the spinal cord that inhibits synaptic transmission of pain signals, most commonly from C-fibers, from reaching the thalamus.[134] Accordingly, it has been extensively reported that the impulse during HVLA SMT stimulates a barrage of non-nociceptive input from large diameter, myelinated Group II afferent fibers.[2,115,128,135] Concerning the primary events of SMT, this afferent barrage within the CNS is theorized to be a result of the HVLA thrust during the manipulation stimulating the mechanoreceptors located within and around the intervertebral joint complex.[128,136] Consequently, the clinical function of SMT may in part be attributed to its likely role of modulating the pain gate mechanism in the dorsal horn by decreasing the amount of nociceptive signals that reach the thalamus in musculoskeletal complaints. During the manipulation, both groups of mechanoreceptive afferent neurons (Ia, Ib, and II(Aβ) fibers) are presumed to respond. This is because their mechanical thresholds are less than 20-30N,[137] and the average force imparted during manual SMT targeting the thoracic or lumbopelvic spine has been affirmed by Herzog to

be approximately 400 N,[111] and by Pickar to occurr in <150 ms with an amplitude of <3 mm.[119]

The hypoalgesic effects may be linked with a transient decrease in reflexive αMN activity documented in several studies post-SMT, indicating a relaxation response.[68,119,138] These reported findings are in contrast with facilitated (hyperactive) reflex responses recorded during muscle hypertonicity[139] or experimentally-induced pain,[140] revealed by shortened latencies of reflexive EMG amplitudes recorded during tendon taps and/or H-reflex electrical stimulations. This transitory relaxation response creates a possible explanation for several studies' reported increases in pain thresholds post-SMT, measured from various experimentally-induced nociceptive input, including thermal,[130,141-144] mechanical (pressure),[71-73,145-154] chemical[74] and electrical stimuli.[103] The afferent barrage immediately post-SMT has also been found to also stimulate the endogenous opioid system,[155] such as the release of enkephalins from the periaqueductal grey within descending pathways of the CNS.[156]

Korr further postulated that spinal manipulation increases joint mobility by evoking a bombardment of afferent impulses from proprioceptors, such as intrafusal nuclear bag fibers along the Ia reflex pathway, thereby suppressing facilitated gamma motor neuron activity and restoring normal muscle tone.[157] At the same time, the stretching of the local musculature to theoretically silence the facilitation of the segmentally-related spindle reflexes may decrease the state of hypertonicity and pain-spasm-pain cycle.[131] This amelioration of vertebral kinematics following SMT may be the result of releasing impinged intraarticular synovial folds, breaking up adhesions,[92] diminishing distortion in the intervertebral disc,[131] and/or by gapping of the facet joints,[158-163] which may increase the ROM of the restricted joint.[164] In addition to the mechanical stimulus during the delivery of SMT, the subsequently improved intervertebral joint motion may also down-regulate the gain of the muscles spindles of the joint complex in the Ia reflex pathway.[98,105,120,165] Consequently, the intervertebral motion segment is better able to respond to the demands of body movement, and thus the state of hypertonicity is decreased.

Neural responses occurring secondary to the biomechanical changes may be due to normalized transmission within the afferent axons (compared to the previously facilitated state). These changes have been suggested to occur at the receptive endings and/or along the transmission pathways from these afferent nerve endings.[119] Furthermore, afferent signals from chemoreceptors may also be altered by the manipulation, as the restoration of normal articulation of the joint surfaces may reduce possible inflammatory conditions resulting from chronic joint fixation.[98]

Other effects

Other effects following SMT have been documented by Haavik and Murphy, including differences in sensorimotor integration and motor control.[2,6,112-116] Sensorimotor integration, which occurs within the CNS, is the coordination of afferent information from different parts of the body with the motor system to control movement.[112,115] As such, several implications regarding the neurological effects of SM

may be drawn from their studies. One example is that sensory evoked potential (SEPs), the ratios of which reveal the assimilation and organization of afferent input from different levels of the somatosensory system, have been shown to reflect decreased filtering efficiency in subjects with neck pain or musculoskeletal disorders.[166] These authors and others have reported that ratios recorded following SMT of dysfunctional cervical segments in several experiments reveal an earlier integration of input, and thus an enhanced ability to filter sensory imformation.[112,114,115] More specifically, among the cortical SEP amplitude peaks measured, the N30 peak is thought to be indicative of a complex cortical and subcortical pathway that connects brain regions such as the basal ganglia, thalamus, pre-motor areas and primary motor cortex.[136] Accordingly, the widely accepted functional application of the N30 peak is as an indication of sensorimotor integration.[167] Functionally, this implies that the amelioration of cervical intervertebral hypomobility via SMT can alter cortical reception and integration of sensory information from the upper limb with concomitant motor functioning. This premise has been demonstrated by two other experiments by the same authors, who further deduced that manipulating restricted cervical intervertebral segments positively influences cortical motor control of the upper limb. This was further hypothesized to be accomplished by altering pain-induced maladaptive central plastic processes by affecting inhibition and facilitation of intracortical processes.[135,168] These results were registered the by modulation of SEP peak amplitudes from the stimulation of the median and ulnar nerves after cervical spine SMT[136] (via the brachial plexus). The implications for enhancing any of the seven skill-related components of physical fitness[169] are thus still speculative, yet considering these brain regions, the inclusion of full-spine manipulation may have the potential to augment whole body coordination.

Another example is provided by experiments that have demonstrated changes in feed-forward activation (FFA). FFA is the action of the CNS to recruit appropriate postural muscles of the trunk in order to provide the stability necessary for distal movements, such as throwing a ball.[170] Delays in feedforward activation have been shown to occur in chronic low back pain patients, which is believed to negatively influence postural stability.[171,172] Accordingly, experiments conducted by Marshall and Murphy[170,171,173] analyzed EMG onset times of trunk musculature such as the transversus abdominis, internal oblique and erector spinae of the thoracolumbar and lumbar regions during rapid, distal movements in healthy[170] and low back pain[173] subjects. In subjects who presented with baseline measurements of delayed FFA, the onset latency (implicating inefficient postural sway) was significantly reduced after SMT to the side of dysfunction.[170] A prospective experiment by the same authors[171] revealed that subjects presenting with chronic low back pain who received an extended course of SMT and/or exercise continued to demonstrate comparatively decreased delays in FFA times versus those who only performed exercises at a follow-up six months later.[173] Nonetheless, B. Murphy suggested that plastic changes in sensorimotor integration within the CNS were likely to have occurred in these experiments and other related studies with different response variables. In agreement with other authors,[112,128,136] it was concluded that it is currently unknown if these observed changes were due to the restoration of the biomechanical integrity of the fixated intervertebral joint complex or merely a

consequence of the afferent bombardment in the CNS from the proprioceptive structures stimulated by the high velocity, low amplitude thrust.

An additional alleged effect of SMT on intervertebral hypomobility is the reduction of muscle inhibition. Five studies employed the interpolated twitch or burst superimposition technique to examine the effect of SMT in symptomatic subjects on inhibition of the quadriceps after lumbar[36] and sacroiliac joint manipulations[37,174] as well as the elbow flexors post-cervical manipulation.[46] In the fifth study, healthy subjects were used to measure quadriceps inhibition following lumbopelvic manipulation.[34] Torque measurements during all five investigations were recorded during a MVIC with an isokinetic dynamometer or a load cell. Accordingly, four of the five studies[34,36,37,46] revealed a decrease in inhibition as per decreased force deficit post-SMT. However, the study measuring biceps brachii inhibition[46] did not have a control group and the experiment focusing on the lower trapezius[49] measured force with a handheld dynamometer.

A possible explanation for the reported decrease in quadriceps inhibition following SMT[36,37] lies in the results of an experiment by Indahl et al.[175] on the effects of porcine (pig) zygapophyseal (facet) joint saline injections. The authors recorded decreased muscle activation in the paraspinal muscles during joint distention, and speculated that the stretch of the facet joint capsule caused excitation of an inhibitory interneuron and thus a transient, reflexive inhibition of αMN activity. This mechanism arising from the facet joints may be related to the autonomic neural activity and relaxation response postulated to occur during SMT from stimulation of all of the mechanoreceptive structures of the intervertebral joint complex, provided that the facets actually gap during the HVLA manipulation. The delivery of SMT to vertebral and extremity joints is often accompanied by an audible cracking sound, termed a cavitation.[1] This sound is attributed to the release of vapor and gas bubbles within the synovial fluid resulting from the local reduction of pressure.[92] Cavitation is thought to be a result of facet gapping at the end range of passive joint motion during the impulse of the manipulative procedure. This indeterminate issue of facet gapping during HVLA SMT has been addressed by Cramer and colleagues with six studies.[158-163] In each manuscript, lumbar zygapophyseal joint spaces were measured with magnetic resonance imaging (MRI) after side posture SMT in both healthy and low back pain populations. It was concluded from each of the endeavors that greater separation of the lumbar zygapophyseal joints occurred after side-posture SMT compared to what occurred in subjects placed in a side-posture position without SMT. Of course, this concept can only remain hypothetical until many more future related studies yield the same results in different spinal regions and with other subject populations.

Additional findings supporting the theory that SMT induces intervertebral motion and ensuing neuromuscular reflex responses in the segmentally innervated musculature are provided by an in vivo study by Colloca, Keller and Gunzberg.[176] During a laminarthrectomy to reduce spinal stenosis at various levels (all including L5/S1), four patients' vertebral motion and electromyographic responses to mechanically assisted, short-lever SMT with the hand-held Activator II Adjusting Instrument were measured.

These recordings were completed with an accelerometer mounted to the spinous process and indwelling electrodes placed bilaterally in the multifidus musculature and curved around the spinal nerve roots. Two instrument force settings (the low setting delivered approximately 30 N and the high setting delivered approximately 150 N, both with a duration of less than 5 milliseconds (ms)) and two impulse vectors (posterior-anterior superior and posterior-anterior inferior) were utilized. The impulses were administered to the skin overlying the sacral base and L5-S1 facet joints as well as directly to the osseous structures when exposed. It was reported that the 150 N impulses applied internally to the facet joints and externally to the overlying skin both similarly produced the greatest mean axial displacement of nearly 0.25 mm. In addition, positive EMG amplitude changes in the multifidus muscles and compound action potential responses of the nerve roots were both recorded with a duration of several milliseconds. Despite variation in the latency and magnitude of reflexive EMG activity arising from the rapid vertebral displacement during the impulses, neurophysiological responses were registered in all four patients. The authors concluded that the magnitude of transient neurological responses to the manipulative impulse were associated with the amount of force (30 N or 150 N) and reactive vertebral motion.

An overall summary of the proposed effects of intervertebral joint hypomobility and the possible amelioration of these effects by SMT has been illustrated by Haavik and Murphy[128] in Figure 1 below. Reprinted from the Journal of Electromyography and Kinesiology, Volume 22, Haavik H and Murphy B, The role of spinal manipulation in addressing disordered sensorimotor integration and altered motor control, pp. 768-76, Copyright 2012, with permission from Elsevier (license # 3678350421344).

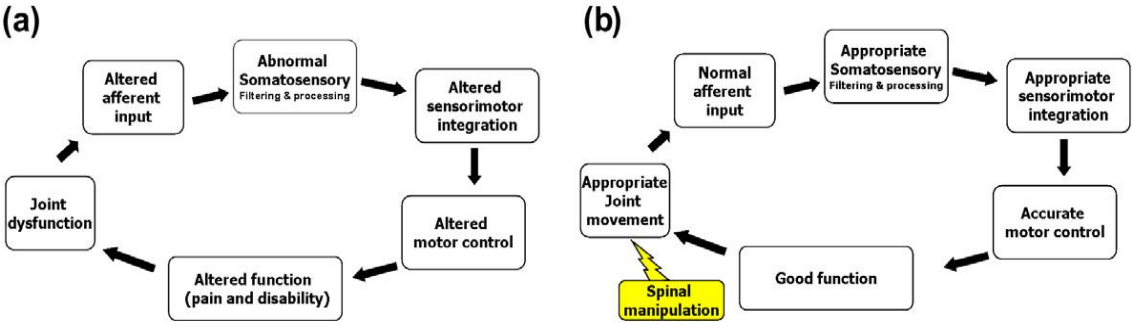

Figure 1. (a) Diagram depicting a simplified view of the proposed effects of spinal dysfunction, leading to altered sensorimotor integration which over time in some susceptible individuals may lead to pain and gross dysfunction. (b) Schematic view of proposed effects of spinal manipulation leading to normalization of afferent input and restoration of appropriate sensorimotor integration and function.

Instrumentation and measurement of the effects of spinal manipulative therapy

Experimental findings pertaining to the neurophysiological effects of SMT have been derived from six forms of measurement, using symptomatic and asymptomatic subject populations. Symptomatic participants are defined by individual studies' inclusion criteria, and generally include those with mechanical back or neck pain occurring without serious comorbidities such as bone and joint diseases, cancer or fracture. These measures include electromyography (EMG),[177-182] twitch interpolation

(TI),[34,36,37,46,174] motor evoked potentials (MEP),[117,118,135,167,183,184] sensory evoked potentials (SEP),[168,185,186] pain sensitivity measures[71-74,103,130,141-153,154] and the H-reflex.[79-88] EMG is the recording and analysis of myoelectric signals during the depolarization and repolarization of the sarcolemma, which can be acquired during rest and contractile activity with surface and indwelling electrodes.[187] TI is the application of a supramaximal electrical stimulus to a peripheral nerve to assess the extent of skeletal muscle activation during a voluntary contraction. MEPs are produced within the spinal cord and peripheral muscles by transcranial magnetic stimulation (TMS) of the motor cortex and measured with EMG or evoked potential equipment.[118] In addition to several clinical uses, such as an intraoperative neurological monitoring, the generation of MEPs is used in kinesiological research to evaluate CNS excitability and sensorimotor integration of afferent input resulting from treatments such as SMT.[118] SEPs are measurements of the function of the somatosensory system by applying an electrical stimulus to peripheral nerves and measuring the latency of the impulses generated by the stimulus with scalp recording electrodes.[112] Like MEPs, SEPs are also useful for measuring changes in sensorimotor integration.[115] The fifth method is the assessment of changes in pain sensitivity following the use of different types of stimuli, such as thermal, chemical and pressure.[103] Changes in pain pressure thresholds were most commonly used in the studies examining the effects of SMT. The sixth method is the H-Reflex, which differs from the tendon-tap spinal stretch reflex in that it is induced by stimulating the peripheral nerve without the involvement of the muscle spindle. As a result, it can assess changes in monosynaptic reflex activity in the ventral horn of the spinal cord, giving an estimate of CNS excitability. This measurement can therefore be utilized to determine the response of the CNS to SMT at the spinal level. The information gathered may provide insight into possible neurologic contributions to exercise responses such as PAP, but not direct inferences since changes in myosin head positioning and calcium sensitivity of troponin are not measured.

An important consistency is apparent in the results of experiments utilizing TMS, EMG and the H-Reflex to measure responses to SMT. MEPs recorded from TMS post-SMT in two studies indicated no change in amplitudes in neither symptomatic[188] nor asymptomatic[189] participants. Conversely, in two studies by Dishman and colleagues in 2002[117] and 2008,[118] a transient increase in αMN excitability occurred post-SMT in asymptomatic individuals. Haavik and Murphy reported similar findings,[113,114,116] and attributed the facilitation of MEPs post-SMT to altered sensorimotor integration due to plastic changes in CNS processing of proprioceptive input. Although the results of MEP modulation post-SMT are still inconclusive, SMT may nonetheless have the potential to increase CNS excitability. The studies utilizing EMG post-manipulation revealed either no change or a decrease in amplitudes in resting muscle activity, depending on if the tissue was hypertonic pre-intervention. However, significant increases in EMG amplitudes were recorded during a back extension MVIC in symptomatic subjects (individuals with mechanical low back pain).[44] In addition, similar increases in muscle activation or strength were reported in three of five studies which investigated the effect of SMT on muscle inhibition.[34,37,46] Although these EMG results during voluntary activation are reported in only four studies, the investigations have revealed that SMT may be able to increase the EMG amplitudes of working muscle post-treatment.

Spinal manipulative therapy and the Hoffmann Reflex

The H-reflex studies revealed decreased amplitudes post-SMT for varying lengths of time. The transient attenuation of alpha motor unit activity occurred consistently within the asymptomatic populations, with amplitudes returning to baseline within one minute.[80-83,85-87] However, one study reported that within the symptomatic populations, amplitudes would also decrease and then return to +/- 25% of baseline (also within one minute).[84] It must be noted that two studies[80,81] did not include a control group that did not receive SMT. The results instead were derived by comparison of SMT delivered to different spinal regions or between different forms of SMT. Nonetheless, the clinical significance of the attenuation of surface EMG amplitudes in both groups is not understood, and seems paradoxical in relation to the other two methodologies of TMS and EMG. So to put the overall effects of SMT in perspective on a basic level: MEPs have registered increased CNS excitability, EMG revealed no change or a decrease in amplitude at rest and in some cases an increase with activity, and the H-Reflex demonstrated a transient, segmental attenuation of αMN activity at rest. What is not known, however, is the H-reflex response after SMT with the incorporation of voluntary motor unit recruitment during muscular activity. In consideration of the whole person, if increased excitability has been recorded in both the CNS (at the cortical and spinal levels) and peripheral nervous system under resting conditions after SMT, then it may be plausible that the same increase in CNS excitability would be revealed, possibly to a greater extent, with the H-reflex post-MVC or MVIC as what previously recorded EMG amplitudes have revealed.

The reasons for the transient decreased H-Reflex amplitudes immediately post-SMT are not fully understood. One possible explanation is based on the role of inhibitory interneurons, because the H-reflex response has been shown to be vulnerable to presynaptic inhibition of Ia afferents that intervene in the reflex response.[190,191] Presynaptic inhibition has been attributed to the function of GABA-ergic[101,192] interneurons which synapse directly with the presynaptic terminals of Ia afferent fibers, and are thus capable of diminishing the amplitude of the H-Reflex response post-SMT. If SMT generates inhibition of Ia afferent fibers by stimulating presynaptic inhibitory interneurons, then the decrease in the amplitude of the H-reflex response may occur unrelated to alterations in the excitability of the αMN pool following the manipulation.[117]

Studies that were completed primarily by J. Pickar and colleagues[165,193-195] provide insight into muscle spindle stimulation post-SMT. Their work involved mechanically applied impulses to feline lumbar vertebrae of equal force and duration as what has been recorded during the pre-load and impulse phases of manually delivered high velocity, low amplitude SMT. [193-195] Muscle spindle responses were measured from the dorsal rootlets of the segment manipulated. Afferents were recognized as originating from muscle spindles located in lumbar multifidus or longissimus muscles based on several criteria such as their responses to the administration of intra-arterial succinylcholine and/or to an electrically-induced muscle twitch. As a result, the mechanical impulse was found to significantly increase the discharge rate of the deep lumbar paraspinal muscle spindles compared to the pre-load phase. The time course of

the spindle responses were similar to the results of other reports of H-Reflex attenuation occurring within the same 60 second range.[80-83,85-87]

An additional consideration is that subject repositioning between the SMT procedure and H-Reflex testing may cause movement artifacts that authors of several similar studies[80-83] have concluded as significant reflex attenuation results. A study in 2005 by Suter, McMorland and Herzog addressed this issue.[84] The authors included H-Reflex findings from both asymptomatic and symptomatic subjects pre and post-SMT. It was found that the reflex responses depended on the experimental position of the measurement. Specifically, within the healthy population, significant changes in motor neuron excitability were not found when testing and SMT were both performed in the same side-posture position. However, a significant depression of H-reflex amplitudes post-SMT was observed in the population with nonspecific low back pain. Nonetheless, the results of previous studies after repositioning of asymptomatic subjects[80-83,85-87] may not be invalid in view of a more current investigation by Fryer and Pierce[86] in which MEPs and H-Reflex amplitudes were both recorded in the same subject during the treatment and control interventions of a repeated measures design in which the subjects were repositioned. The MEP and H-Reflex amplitudes were recorded with the subject prone, while SMT and the control were both in the side posture position. However, in contrast to other studies of increased cortical excitability, there was a modest decrease in MEP amplitudes, while attenuation of H-reflex amplitudes was more pronounced. The authors postulated that decreases in CNS excitability post-SMT may occur to a greater degree at the level of the spinal cord than the attenuation that occurred within the motor cortex. The H-Reflex measurements were taken five minutes post-SMT delivery (after MEP recordings), and a depression was still evident. This was in contrast to each of the other related studies which stated that the amplitudes returned to baseline within one minute, with the exception of Murphy and others.[88]

Concerning the H-reflex responses of symptomatic populations, these data are in contrast to an increase in H-reflex amplitudes post-SMT reported by Floman and others[79] in subjects diagnosed with an L5/S1 disc herniation confirmed by CT or MRI. Baseline H-reflex recordings revealed abnormal amplitudes in 13 of the patients. Immediately following lumbar SMT, significant increases were registered in the H-reflex amplitudes of these patients. However, in the subjects who demonstrated normal H-reflex responses pre-intervention, the amplitudes remained the same post-SMT. The authors concluded that SMT may only modulate abnormal H-reflex measurements.[79] In view of these results on the effects of SMT on H-reflex amplitudes, it may be that motor neuron excitability is altered post-SMT only in the symptomatic population. In addition, the specific condition of the symptomatic subjects (nonspecific low back pain[84] versus L5/S1 disc herniation[79]) may contribute to differences in spinal reflex responses post-SMT. Still, the clinical use of the H-reflex from these experiments on resting subjects only provides general insight into the possible effect of SMT on changes in CNS excitability following contractile activity, such as during PAP induced by a MVIC.

Postactivation potentiation

Following a protocol involving moderate to high intensity force production such as a MVIC, squats or counter movement jumps, processes of muscular fatigue and potentiation occur simultaneously. However, several authors have stated that enhanced power generation and explosive performance immediately following moderate or high intensity resistance exercise depend on the balance between the two factors.[196] PAP occurs instantly post-contractile activity, and when the volume of the conditioning activity is low with minimal resulting fatigue, immediate performance is slightly enhanced. For the greatest amount of potentiation to be realized, the contractions must induce a greater amount of fatigue, but not to such a magnitude that the possibility of resulting potentiation is diminished. It has been determined from several studies that effective utilization of PAP requires a rest period between the conditioning activity of heavy lifting or MVIC and the subsequent, potentiated explosive activity.[59] This reported range varies, depending on the volume and intensity of the activity performed and the physical conditioning of the subjects.[62,78,197] In addition, needle biopsies of the vastus lateralis in a study by Hamada, Sale and MacDougall[61] revealed that subjects with a predominance of IIx muscle fibers displayed greater muscle twitch tension and PAP than subjects with more Type I fibers after maximal and fatiguing knee extension isometric protocols. These results, coupled with similar data of other studies[60,63] have shown that PAP may be induced to the greatest degree in activities requiring explosive movements because of the associated high proportion of Type IIx fibers required for successful performance.[196,198,199] Other studies have supported this conclusion with data that reveal the greatest PAP response occurring in muscles with the shortest twitch contraction time and rate of force development.[60] This finding may be related to a greater rate of myosin phosphorylation post-conditioning activity in these athletes[61,62,200] and faster calcium reuptake by the sarcoplasmic reticulum.[56] PAP has also been found to occur to a greater degree in high level athletes than recreationally active individuals, most likely due to the athletes' greater amount of Type IIx fibers.[62,78,200]

Conflicting results have been published concerning the potentiating effects of the most pertinent factors found to determine the likelihood of a potentiated response after volitional and electrically-induced muscular activity. These factors include conditioning activity (static or dynamic), intensity (percent of one repetition maximum), training status (athlete, resistance-trained or recreationally active) and rest periods. Conversely, other authors have found that heavy resistance conditioning activities did not improve subjects' performance measured during subsequent activities. These data were collected from countermovement and drop jump height,[201,202] bench press throws on a Smith machine,[203] jump squats[204] and also ground reaction forces correlated with explosive push-ups[205] and jump[206] and countermovement jump height.[207] To address this matter, two meta-analyses were recently conducted on the influence of these factors.[78,208]

The inclusion of 32 studies by Wilson and colleagues[78] revealed that the optimal rest intervals were different for participants of each of the three levels of training. In addition, the level of training also influenced the extent of the potentiation, such that athletes experienced a greater amount than resistance-trained, while untrained/recreationally active subjects in some cases demonstrated deficits in their

performance after the conditioning activities. The greatest potentiation occurred within athletes after rest periods of three to seven minutes. The resistance-trained group, however, displayed the greatest potentiation with 7 – 10 minute rest intervals. What was common to all three was that greater potentiation occurred after multiple conditioning sets as compared to a single set, and completed at moderate intensities (60 - 84% of one repetition maximum). The authors also concluded that there was no significant difference between the potentiation induced by static versus dynamic activities,[78] as both increase calcium sensitivity and phosphorylation of myosin regulatory light chains. [60,61,63,64] Another meta-analysis, carried out by Gouvea and others[208] of 14 studies, focused specifically on the results of varying rest intervals as measured by jumping performance. It was found overall that rest times of 0 - 3 minutes brought about a detrimental effect on jump performance, while 8 – 12 minutes had the greatest positive influence. Despite that fact that the authors did not distinguish between athletes and trained subjects (considering them all as one group), their findings are still in agreement with the findings of Wilson and others[78] in regard to resistance-trained subjects.

Postactivation potentiation and the Hoffmann Reflex

Several studies have incorporated H-Reflex recordings to measure PAP.[209,210,89,211,90] Enoka, Hutton and Eldred[210] recorded amplitudes from H-Reflex and tendon tap stimulation in 17 subjects in order to distinguish central and peripheral contributions to subject responses after 50% and full effort MVICs. The authors found that over a 50 second period after both contractions, the H-wave displayed a depression, while excitability was demonstrated after the tendon tap. The mean of both results neared baseline values at 50 seconds. The authors speculated that an increase in post-contraction neural discharge and stretch sensitivity of the spindle afferents significantly contributed to the opposite responses of the two types of stimulation.[210] The subjects did not display PAP, only a depression in soleus H-reflex amplitudes immediately post-conditioning activity. However, although PAP occurs immediately, it may not be evident until fatigue subsides several minutes after the conditioning activity, and may remain up to 18 minutes,[89,90,211] potentiation may have been shown if the authors had measured the H-Reflex amplitudes for a longer duration. Experimentation by Trimble and Harp[211] revealed a significant overall potentiation of the lateral gastrocnemius in 10 subjects, which did not reach statistical significance within the soleus muscle. After the conditioning activity of eight sets of concentric and eccentric plantar flexion measured by isokinetic dynamometry, it was also found that postactivation depression (PAD) occurred for 10 – 60 seconds. This depression in the H-Reflex amplitudes lasted for up to three minutes in the subjects who did not demonstrate PAP, with reflex amplitudes instead returning to baseline. These results are also in line with previous experiments that assert PAP occurs to a greater degree in Type IIx fibers than Type I.[60,61,63]

H-Reflex amplitudes in the same two muscles were also measured by Güllich and Schmidtbleicher in 17 subjects,[90] after 5 sets of 5 second plantarflexion MVICs. Subjects were classified according to their level of athletic training as either speed-strength athletes or untrained physical education students. PAD or no change in reflex amplitudes occurred in a similar time frame as reported by Trimble and Harp,[211] with potentiation occurring to a greater degree in the gastrocnemius muscle 4 - 11 minutes after the

maximal contractions. It was also revealed that between the two groups tested, the strength-speed athletes demonstrated greater potentiation. In addition, the onset of PAP varied considerably between subjects, congruent with results of the other related studies.[210,211] The most recent investigation was conducted by Folland, Wakamatsu and Fimland.[89] The quadriceps femoris maximum twitch torque, H_{max}/M_{max} ratio and the associated ratio of twitch torques at H_{max} and M_{max} were recorded for 18 minutes in 8 recreationally active subjects after a 10 second MVIC. It was found that the H_{max}/M_{max} ratio was significantly potentiated for 5 - 11 minutes following the MVIC, with the highest values recorded at 5 min. The twitch torque at H_{max} was potentiated from 5 to 9 min post and the associated twitch potentiation (the M-wave) was greatest 10 s after iMVC and remained elevated for 18 min. These results are also consisted with the minimum three minute delay of PAP that was recorded in the aforementioned studies. It was also revealed that during the interim between the initial heavy lifting and the measured response in power output, PAD occurs immediately following the conditioning activity. This reduction of the H-Reflex has been theorized to be caused at the presynaptic level by a reduced amount of neurotransmitter[212] and/or presynaptic inhibition of Ia afferents.[213]

How spinal manipulative therapy may influence postactivation potentiation

In consideration of all of the neurophysiological effects of SMT postulated to ameliorate the sequelae of chronic intervertebral hypomobility, several of these clinical factors may have implications on strength modulation and PAP. These aspects include: improvement of possibly hampered impulse-based mechanisms of nerve conduction arising from nerve root compression and inflammation; decrease in muscle inhibition; and the generation of an afferent bombardment within the CNS from the mechanoreceptors of the intervertebral motion segment during the HVLA thrust which may 1) silence facilitated gamma motor neuron activity and restore normal muscle tone, thus possibly improving ROM and the length tension-relationship of the intrinsic muscles of the spine, and 2) enhance PAP with a synergistic increase in CNS excitability and neural drive, resulting in increased αMN recruitment, firing rate and resulting force generation.

The three primary factors that determine a muscle's ability to generate force are the cross-sectional area of the muscle, the number of motor units recruited and the rate of action potentials fired by the alpha motor neuron.[56,57] While SMT cannot alter the first factor, it may affect motor unit recruitment and frequency of firing through at least one of the aforementioned aspects. A further explanation includes several factors. First, the amplitude of the electrically evoked H-reflex is an indication of the number and size of recruited motor units.[65,214] Taking this into account, modulation of H-wave amplitude with respect to a fixed stimulation intensity and consistent efferent motor response (M-wave) is suggestive of synaptic modification in the spinal cord. Assuming proper methodology has been adhered to (particularly the minimization of subject movement and normalization of the H wave to the M wave amplitude), this occurrence can be attributed to at least three possibilities. These include a change in motor neuron excitability, the amount of neurotransmitter released by the afferent terminals and/or type of motor neurons recruited.[60,65,212,214,215] Accordingly, an increase in reflex amplitude

resulting from a fixed stimulation intensity indicates an equivalent increase in synaptic transmission between Ia afferents and αMNs of the segmentally innervated muscle. Motor unit recruitment evoked by submaximal electrical stimulation via the Ia afferent pathway transpires according to the size principle.[56,57,65,216] Consequently, if the reflex amplitude is increased post-contraction, then it is presumed in light of this standard that the next units to be recruited would be the larger, high-threshold, fast-twitch motor units. The ability to activate as many of these types of motor units as possible and have them discharge at a frequency high enough to induce a tetanic contraction is a prime determinant of the maximal rate of force development and peak force production.[90,196] If a potentiated reflex response occurs following contractile activity, thus indicating an augmented neural drive, then the result may be an increase in the effectiveness of successive voluntary neuromuscular activation and consequent rate of force development.[60,196,217]

Attenuation of αMN has also been shown to occur in PAP studies momentarily for 10 – 60 seconds,[89,90,209-211] or in some cases continue for several minutes.[89,210,211] Interestingly, this H-Reflex attenuation which has been documented in each of these studies follows a similar time course as what occurs after SMT. The difference between SMT and contractile activity is that the reflex amplitude responses in the majority of the SMT studies all returned to baseline within 60 seconds in both asymptomatic and symptomatic populations. Only two studies reported comparatively prolonged attenuations post-SMT.[88,152] It is plausible that the CNS mechanisms responsible for the transition from PAD immediately post-contraction to resulting PAP will be augmented with what could be a synergistic effect of similar processes occurring post-SMT in the same time frame, resulting in a shorter delay of potentiation.

A crossover study revealing a significant increase in the H-reflex amplitudes after the delivery of SMT paired with a MVIC compared to an MVIC only would indicate greater synaptic transmission between Ia afferents and alpha motor neurons. The resulting implications are an enhanced rate and magnitude of volitional force production by optimizing the reflexive component of neural drive within the CNS to result in increased motor unit recruitment. Muscular power is determined by the product of the velocity of shortening and the load.[56] As such, the possible greater increase post-SMT in the subject's rate of force development during PAP may produce functional improvements similar to the results of numerous performance-related outcomes reported in previous investigations of PAP.[62,90,198,218,219,238] It could also be inferred from reported measurements of modulated MEP, EMG, H-Reflex, and SEP amplitudes post-SMT that an increase in CNS excitability can occur. This increased excitability is essential to augment the neural mechanisms reported to contribute to PAP, resulting in increased power production during explosive athletic activities.[57,62] The neurological effects of SMT recorded from each of these specific measures may have implications on enhancing PAP, most notably: increased cortical excitability has been revealed by increased MEP amplitudes in some studies using asymptomatic subjects; decreased muscle activation latencies in studies investigating FFA; increased EMG amplitudes recorded during MVICs; and instantaneous increases in H-Reflex amplitudes post-SMT have been recorded in subjects suffering from an L5/S1 disc herniation (while this particular

investigation was limited to a symptomatic population, the results nonetheless provide further possible support for the theory that SMT results in increased neural drive within the musculoskeletal system).[79] These factors may all serve as components of a possible synergistic effect post-SMT that occurs within the CNS during PAD and recovery from fatigue to ensuing PAP. These data have possible application to the specific theory of PAP being caused by increased recruitment of higher order motor units.[90,196] This consideration becomes especially pertinent with the involvement of cortical and subcortical structures such as the primary motor cortex and basal ganglia as indicated by alterations in N30 peak amplitudes.[128]

Chapter 3: Study #1 The effects of lumbosacral manipulation on isokinetic strength of the knee extensors and flexors in healthy subjects: A randomized, controlled, single-blind crossover trial.

Abstract

PURPOSE: This study investigated the effect of manual manipulations targeting the lumbar spine and/or sacroiliac joint on concentric knee extension and flexion forces. Torque production was measured during isometric and isokinetic contractions.
METHODS: A randomized, controlled, single-blind crossover design was utilized with 21 asymptomatic, college-aged subjects who had never received spinal manipulation. During two separate sessions, subjects' peak torques were recorded while performing maximal voluntary contractions on an isokinetic dynamometer. Isometric knee extension and flexion were recorded at 60° of knee flexion, in addition to isokinetic measurements obtained at 60°/s and 180°/s. Baseline measurements were acquired before either treatment form of lumbosacral manipulation or sham manipulation, followed by identical peak torque measurements within five and twenty minutes post-treatment. Data were analyzed with a repeated measures analysis of variance.
RESULTS: A statistically significant difference did not occur between the effects of lumbosacral manipulation or the sham manipulation in the percent changes of knee extension and flexion peak torques at 5 and 20 minutes post-treatment. Similar, non-significant results were observed in the overall percent changes of isometric contractions (Spinal manipulation 4.0 ± 9.5 vs. Sham 1.2 ± 6.3, $p = 0.067$), isokinetic contractions at 60°/s (Spinal manipulation -4.0 ± 14.2 vs. Sham -0.3 ± 8.2, $p = 0.34$) and isokinetic contractions at 180°/s (Spinal manipulation -1.4 ± 13.9 vs. Sham -5.5 ± 20.0, $p = 0.18$).
CONCLUSION: The results of the current study suggest that spinal manipulation does not yield a strength-enhancing effect in healthy, college-aged subjects when measured with isokinetic dynamometry.

Introduction

Spinal manipulation (SM) is a therapeutic procedure employed by healthcare practitioners such as chiropractors, osteopaths and physical therapists with the intent of ameliorating joint hypomobility and positively influencing neurological functioning.[4,120] In addition to global utilization within the clinical setting to alleviate acute and chronic musculoskeletal complaints,[120] this form of treatment is also delivered for the purpose of enhancing the performance and augmenting the rehabilitation of collegiate and professional athletes.[28]

Research efforts from the past few decades have investigated the effects of SM on topics such as strength modulation, muscle inhibition, electromyographic activity, motor training/reaction time and balance.[28] Regarding strength, at least 22 different studies have recorded changes in force exerted during maximum voluntary contractions (MVCs) post-SM. Within these articles, a range of muscle groups were selected, such as the quadriceps femoris, cervical musculature, thoracolumbar erector spinae, biceps brachii, shoulder external rotators, lower trapezius and gluteus maximus, in addition to measurements of knee flexion and grip strength.[34-55] While many of these studies reported increases in strength and/or increased electromyograph (EMG) amplitudes, an important

consideration is that only isometric contractions have been measured (with a hand dynamometer, isokinetic dynamometer, or load cell). Presently, no information exists in relation to strength changes after SM measured at various angular velocities during dynamic contractions. This information would prove useful in generating a more complete picture of the mechanisms occurring within the muscle after chiropractic treatment, as different motor recruitment patterns exist for concentric and isometric contractions. Since all athletic actions involve dynamic force generation, the data gathered would have a greater application than the single measurement of a maximal voluntary isometric contraction (MVIC). The addition of knee flexion peak torque recordings would also add to the results of previous experiments which measured the effects of SM on knee extension torque production.[28,34-37]

Furthermore, it was hypothesized that significant differences would be found between the peak torques following HVLA (High Velocity, Low Amplitude) SM and the sham manipulation at 5 minutes post-treatment, but not at 20 minutes. This postulation was congruent with previous authors' findings that strength modulating effects of SM do not exceed 10 to 20 minutes.[28,37,47] It was also estimated that the significant increase in peak torque generation would be most notable during the isometric contractions, also in line with what other researchers have reported.

Methods

A randomized, controlled, single-blind crossover design was utilized with 21 asymptomatic subjects (12 males, 9 females) between the ages of 20 to 35 (23.6 ± 3.1 years) who had never received chiropractic treatment. Participants were recruited from various locations both on and off the university campus via flyers (Appendix A) and word of mouth. The testing procedure took place over the course of three sessions, all conducted in the University of Kentucky Biodynamics Laboratory. During the initial visit, an intake form (Appendix B) pertaining to the volunteer's medical history was completed to ensure that the volunteer was eligible to participate in the study. This was followed by the completion of an informed consent form (Appendix C) and a subsequent physical exam (Appendix D) to rule out any further contraindications to SM. All forms and procedures were approved by the University of Kentucky Medical Institutional Review Board (IRB #12-0280-F1V). This study was not supported by grants or other funding from any organization. The principal investigator (PI) performed all procedures during each of the three sessions. The final aspect of the physical exam included static and motion palpation of the patient's lumbar spine and sacroiliac (SI) joints to determine the levels of segmental restrictions to be manipulated during the second or third session. If eligibility had been met, the participants then completed an initial familiarization session with the isokinetic dynamometer. Strength testing then began at least two days later.

Peak Torque Recordings

During the next two sessions, strength measurements were obtained using the Biodex Multi-Joint System 3 isokinetic dynamometer with the Biodex Advantage software (Biodex Medical Systems, Shirley, New York). During the testing, participants were seated in an upright position on the dynamometer and were stabilized with two

shoulder straps, a waist strap, and a thigh strap. The participant's range of motion was then established at the knee joint (15° to 95° of knee flexion). MVICs of knee extension and flexion were measured at 60° of knee flexion.[220] Isokinetic, concentric MVCs of knee extension and flexion were performed at 60°/s and 180°/s. The specific testing sequence of isometric and isokinetic contractions, as well as the order of SM and sham manipulation delivery was determined for each subject with a random number generator using Microsoft Excel.

Participants began the second and third sessions by completing a low-intensity 5-10 minute warm-up on an upright cycle ergometer, followed by five 50% submaximal concentric repetitions of knee extension and flexion at both angular velocities. After a two-minute rest, testing began with baseline measurements. This entailed three sets of maximal isometric contractions lasting five seconds each during knee extension, and the same occurring with knee flexion. The isokinetic measurements included three maximal repetitions of concentric knee extension and flexion, recorded at both angular velocities. The peak torques (Nm) were recorded as the highest of the three five-second isometric contractions for both knee extension and flexion, as well as the highest of the three isokinetic, concentric contractions during knee extension and flexion at both velocities.

Table 1. *Summary of experimental procedures.*

1st Visit	History & informed consent	Physical exam	Warm-up	Familiarization session		
at least 1 day in between						
2nd Visit	Warm-up	MVC/ MVIC Testing	Manipulation or sham	MVC/ MVIC Testing	20 minute rest	MVC/ MVIC Testing
at least 3 days in between						
3rd Visit	Warm-up	MVC/ MVIC Testing	Manipulation or sham	MVC/ MVIC Testing	20 minute rest	MVC/ MVIC Testing

As depicted above in Table 1, peak torques were recorded three times during both testing sessions: at baseline prior to the treatment (spinal manipulation or sham procedure), within 5 minutes post-treatment and again after 20 minutes. The PI administered both the treatment and the testing. To limit bias, the PI did not give verbal encouragement during any of the isometric and isokinetic peak torque recordings. At least three days later, the procedure was repeated, this time incorporating the opposite treatment. If the subject presented with any delayed onset muscle soreness (DOMS) as a result of the previous strength testing or other physical activity, and/or caffeine ingestion during the past several hours, then data collection was rescheduled. Also, to account for possible hormonal changes as a result of circadian rhythms and their effects on muscle strength, subjects' data were collected at approximately the same time of day during both testing sessions.

Spinal manipulation and sham manipulation treatments

Diversified technique, the most common method of chiropractic treatment, was utilized in the administration of HVLA manipulations of the lumbar spine and/or SI joints on a chiropractic treatment table (T2000 Portable Drop Table, Inline Tables, Magalia, CA). This form of manual therapy was chosen in order to include the vertebral segments from which the ventral roots of L2-S1 originate. The anatomical basis for the importance of these levels lies in their innervations of the quadriceps and hamstrings muscles via the femoral and sciatic nerves, respectively. This was accomplished by placing the patient in a side posture position as described by Peterson and Bergmann,[1] with downward pressure applied to the patient's upside flexed knee and a pisiform contact to the mammillary process of the fixated lumbar vertebra or upside SI joint (the selection of which based on the motion palpation findings of the restricted joint complex). SM was delivered bilaterally to all subjects, necessitated by multiple motion restrictions being found in all cases. This procedure also resembled typical in-office treatment of HLVA SM being delivered to both sides of the patient's lumbosacral region. Within five minutes after the restrictions were manipulated, the subject was repositioned on the isokinetic dynamometer and peak torque recordings began.

The sham procedure involved the use of the lumbar drop mechanism, a component of the treatment table that utilized a spring-loaded apparatus. It was set by an adjustable tension to hold the patient's lumbar or thoracic region in a half-inch "up" position before the impulse was delivered. A reinforced, unilateral hand contact was employed during a prone, non-specific thrust through lumbar paraspinal musculature. Care was taken to ensure that no vertebral or pelvic contact occurred, as the PI applied pressure only to the lumbar soft tissue on the ipsilateral side of the thigh being tested. The movement and sound of the drop piece returning to its original position resembled the impulse of the PI and cavitations that occurred during the side-posture manipulations.

This procedure differed from a drop table/Thompson Chiropractic Technique manipulation. While Thompson Technique requires specific osseous contacts and lines of drive to correct misalignments of pelvic/sacral obliquity, neither were applied during the sham; consequently, the identified vertebral and pelvic restrictions were not corrected. This sham manipulation was incorporated so that the subjects, specifically recruited without ever having received any form of spinal manipulative therapy and unfamiliar with drop table manipulation, perceived the procedure to also be a valid manipulation technique. This ensured that the subjects were blinded to which treatment was the therapeutic or sham manipulation. An obvious control procedure, such as being positioned in side-posture without any contact from the PI, was avoided because of the possibility of affecting the subjects' motivation to put forth maximal effort during the subsequent isokinetic and isometric testing. Therefore, it was believed that the delivery of this sham treatment in the same manner as the side-posture manipulation would minimize the impact of this demand characteristic.

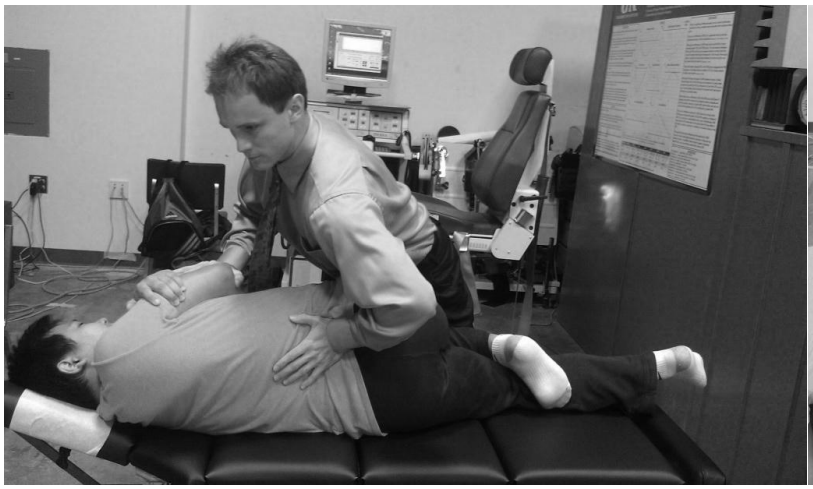

Figure 2a. Side-posture lumbosacral manipulation set-up

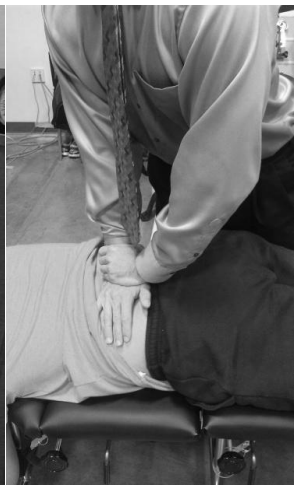

Figure 2b. Drop table sham manipulation set-up

Statistics

All data analyses were performed using Microsoft Excel and SPSS version 20.0 (SPSS, Inc., Chicago IL). A repeated measures analysis of variance (ANOVA) was utilized to analyze the peak torque recordings, with an α level of 0.05 considered significant for all tests. The power analysis was calculated with an effect size of 0.4 based on the averages of previous studies' reported increases in strength post-SM, with an α error probability of 0.05 and at a 1-β error probability of 0.8.[221] All raw data are included in Appendix E.

Results

No statistically significant differences were revealed between the effects of lumbosacral SM or the sham manipulation in the percent changes of knee extension and flexion peak torques at 5 and 20 minutes post-treatment, displayed below in Figures 3 and 4, respectively. Equivalent results were observed in the percent changes of knee extension and flexion peak torques averaged from both time points post-treatment, illustrated below in Figure 5. A significant difference was also not observed between the treatment effects in the overall percent changes of combined knee extension and flexion during the isometric contractions (SM 4.0 ± 9.5 vs. Sham 1.2 ± 6.3, $p = 0.067$), isokinetic contractions at 60°/s (SM -4.0 ± 14.2 vs. Sham -0.3 ± 8.2, $p = 0.34$) nor isokinetic contractions at 180°/s (SM -1.4 ± 13.9 vs. Sham -5.5 ± 20.0, $p = 0.18$). The changes in all peak torque means ranged from 9.6 to -4.6 Nm post-SM and from 7.1 to -3.3 Nm post-sham manipulation.

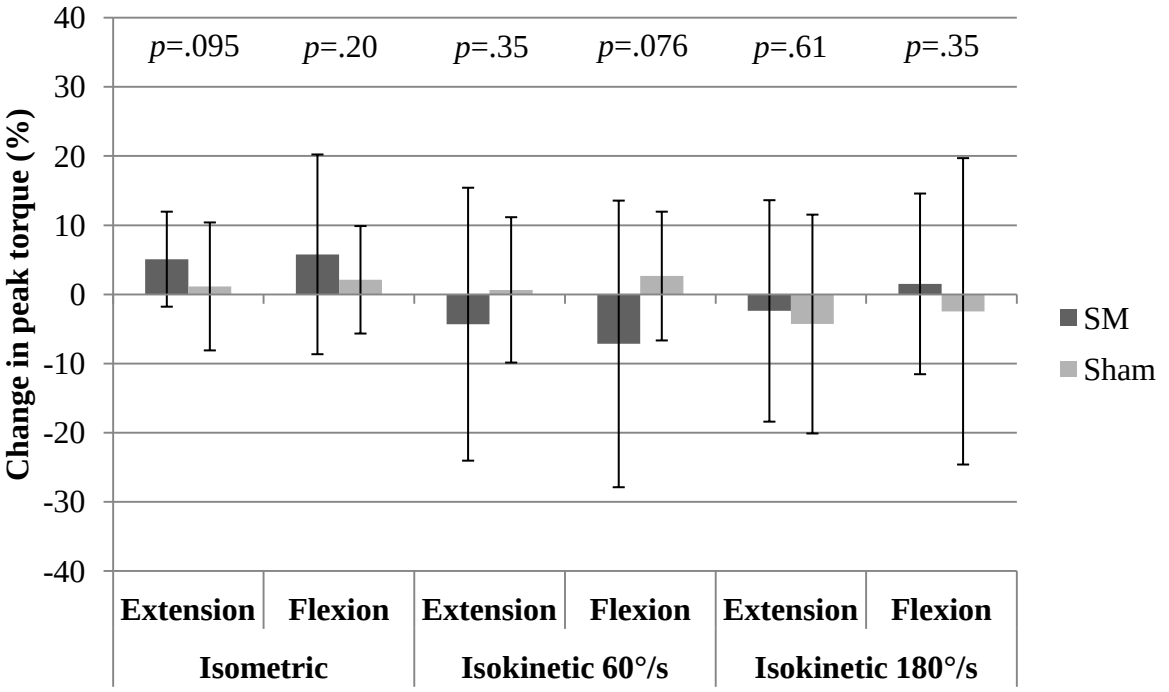

Figure 3. *Percent changes in peak torques at five minutes post-treatment compared to baseline. Mean ± SD.*

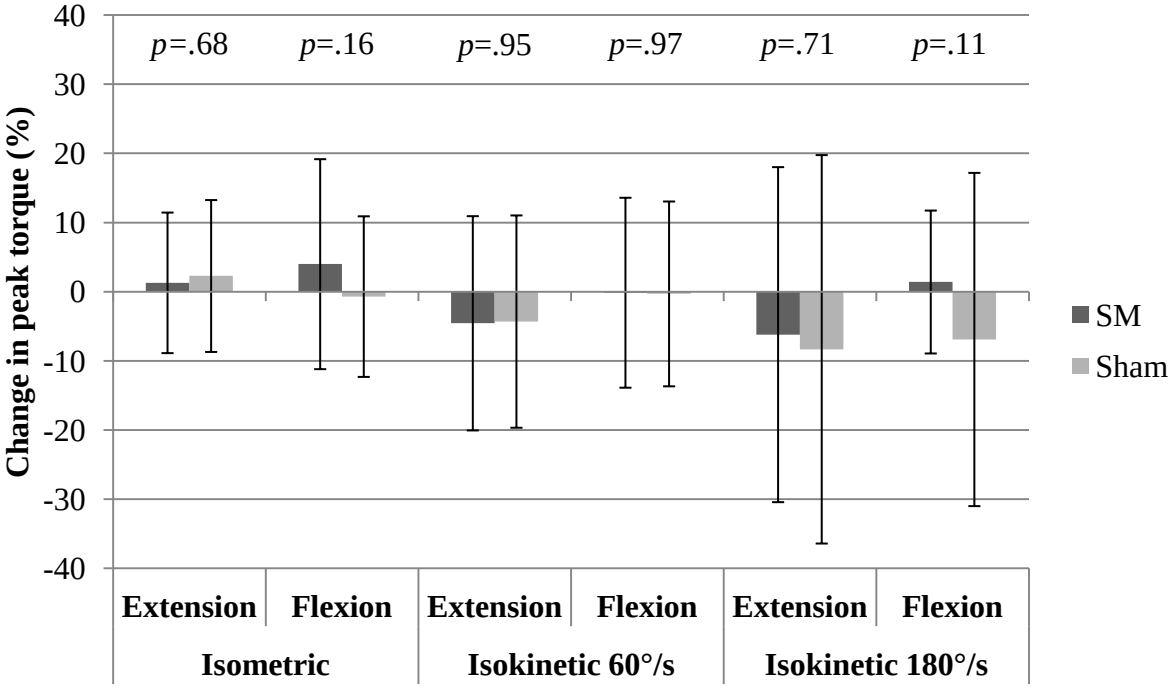

Figure 4. *Percent changes in peak torques at 20 minutes post-treatment compared to baseline. Mean ± SD.*

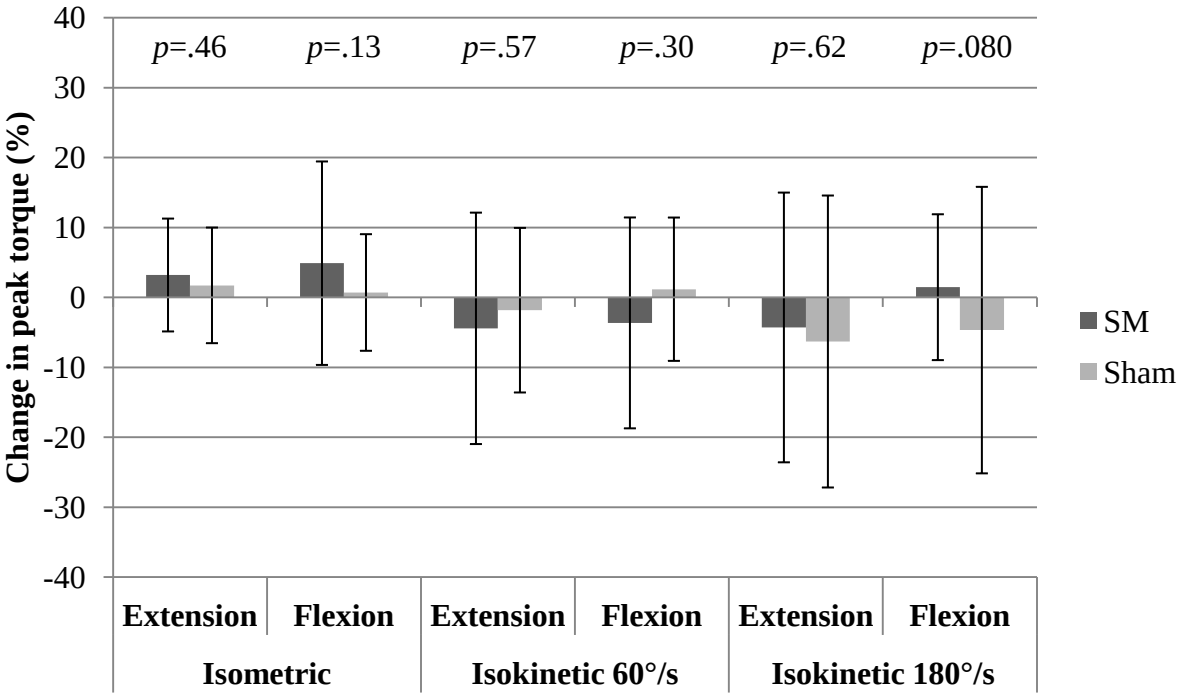

Figure 5. *Percent changes in peak torques averaged at both time points post-treatment compared to baseline. Mean ± SD.*

Discussion

The results of this study indicate that side-posture, HVLA manipulation targeting the lumbosacral spine did not significantly increase the strength of the knee extensors and flexors in comparison to the sham treatment. It was found that neither isometric nor isokinetic measurements revealed a significant increase in strength compared to the sham treatment at 5 and 20 minutes compared to baseline. At present, the factors that caused the discrepancy between these results and the majority of other studies' findings are unknown. Even with a repeated measures design, which increases testing performance reliability because of deceased variability from subjects serving as their own controls, in addition to the established reliability of isokinetic dynamometry,[76,222] the strength-modulating effect of SM was still not statistically significant.

Of particular interest to the current investigation is the pilot study by Shrier, MacDonald and Uchacz from the British Journal of Sports Medicine conducted in 2006.[69] It is interesting to note that it was the only manuscript published in a non-chiropractic related journal, included the most sound methodology and is the most relevant to the current investigation. The authors employed a crossover design with 17 elite healthy athletes to compare the changes in jump height and running velocity after pre-event high velocity, low amplitude (HVLA) lumbosacral manipulation with those measured after a control intervention. The athletes competed in a variety of events, which primarily included the bobsled. After a 15 minute warm-up, baseline measurements included flying

40 meter sprint time and countermovement jump height. Then after being evaluated by a sports chiropractor, subjects were randomized to receive thoracolumbar, lumbar and/or lower extremity HVLA manipulations based on evaluation or placebo (simulated performance-enhancement tape). Then after a 60 minute rest, the subjects performed another 15 minute warm-up and were retested. The protocol was repeated 48 hours later with the opposite intervention. The mean of two sprints and three jumps were analyzed, as well as peak performances. It was found that the pilot study was underpowered due to greater than expected variability in the results. The athletes tended to perform better after HVLA manipulation for both sprint times and countermovement jump height, but none of the results were statistically significant. Nonetheless, the authors concluded that pre-event HVLA SMT warrants further study.[69]

A notable aspect is the substantial standard deviations of the peak torque means. The overall percent change in isokinetic extension torque at 180°/s serves as the most extreme example. This particular measurement generated a standard deviation more than six times greater than the mean post-manipulation, and nearly five times greater post-sham. Nonetheless, the wide spread in the data around the mean apparent in all of the measurements, regardless of treatment randomization, can be partially explained by the variability inherent in strength testing. It has been suggested that the lowest amount of intersession variability attainable during repeated MVC/MVICs is a coefficient of variation range of 5 to 10%,[223,224] and a standard error of the mean of 5%.[225]

While the overall magnitude of the changes in strength post-lumbosacral manipulation was not large enough to overcome this variability, statistically significant changes in measurements of central nervous system processing have been reported in previous investigations of the physiological effects of SM.[44,45] These studies incorporated techniques such as electromyography (EMG), transcranial magnetic stimulation and the Hoffmann reflex. Accordingly, Pickar and Bolton[119] have concluded that alterations in central nervous system processing following SM may be produced by a surge of elevated discharge frequencies from paraspinal mechanoreceptors and primary afferent neurons involving temporal and/or spatial summation. Similarly, Haavik and Murphy[128] have elaborated on the neuroplastic changes found to occur within the central nervous system (CNS), placing emphasis on how sensorimotor integration appears to be augmented with the correction of intervertebral hypomobility and associated dysfunction. Nonetheless, the authors conclude that it is currently unknown whether the changes are due to one of two probable explanations. The first is that SM normalizes the input and processing of aberrant afferent input within the CNS as a result of restoring the biomechanical and neural integrity of the joint complex. The other likely explanation is that the effects are attributable to the impulse of the manipulation producing a bombardment of afferent information from the multiple sensory receptors,[119] congruent with Korr's theory of the facilitated segment.[104]

An additional consideration is an immediate change in EMG amplitudes in response to SM, reported in several investigations.[44,174,179,181,189] One example is measurements of resting paraspinal activity, in which temporary changes in EMG amplitudes have been recorded in symptomatic and asymptomatic subjects post-

manipulation.[174,179] Other studies have reported similar results of both excitatory (increased force production or increased EMG mean/peak amplitudes) and inhibitory (decreased EMG amplitudes) responses after manual and mechanically-assisted SM.[44,174,181,189,197] SM has further been shown to produce these effects through a complex process of positively altering somatosomatic reflexes.[80,118,119,135,167] These results might offer additional insight into the differences in subjects' torque measurements within the current study beyond the variability inherent in any form strength testing.

Limitations

Several limitations were evident in this study. First, data collection ended due to time constraints with 21 subjects, despite the preliminary sample size estimate of 52 subjects needed. The fact that the study was underpowered provides another likely explanation for the lack of statistically significant differences in the treatment effects between SM and the sham manipulation. Additionally, despite denying the presence of DOMS or recent caffeine ingestion, participants' activities between testing sessions could have negatively impacted their ability to generate maximal contractions (such as inadequate sleep and/or caloric intake). Another consideration is the diversity in the amount of physical activity that each subject regularly engaged in, which ranged from competitive bodybuilder to sedentary. Consequently, the resulting heterogeneity in physical fitness levels increased the variability in the subjects' ability to recruit all motor units in the production of the MVC/MVICs. This was mostly likely due to the comparative lack of neural recruitment factors in those who were only recreationally active or sedentary. Likewise, antagonist muscle activity presented another probable source of error in these particular subjects, particularly during the isometric contractions.[226] The discrepancy in subjects' motivation to elicit maximal contractions was another limiting factor, especially when considering that verbal encouragement was not given during any of the peak torque recordings.

In addition to intrinsic performance factors, there was difficulty in obtaining perfect measurement accuracy. Despite the high reliability of the Biodex isokinetic dynamometer, measuring human subjects presents the challenge of completely isolating the involved joint complex. Likewise, it was observed during testing that the action of the MVC/MVIC caused the knee to slightly translate superiorly during flexion and inferiorly during extension. This somewhat altered axis of rotation, in tandem with a concurrent slight depression of the ankle pad during the initiation of movement, altogether provided further hindrances to completely accurate torque measurements.

Because the results of this experiment were different from other similar investigations, it seems apparent that more studies need to be completed. Accordingly, future related research is needed involving a larger sample size, a sample population that is physically more homogenous and highly motivated to generate maximal contractions, and ideally conducted within an environment to allow control of all physical activity. Muscle activation measurements such as the interpolated twitch technique are also necessary to validate that subjects are exerting maximal effort during the MVC/MVICs. Fatiguing contractions should also be measured post-manipulation to generate an idea of the effect on recruitment of Type I fibers for comparison to what has been found

involving MVC/MVICs. Finally, in addition to the work of Wang and Meadows,[48] more experiments must also be designed to compare symptomatic and asymptomatic groups of subjects.

Funding sources and conflicts of interest

This study was not supported by grants or other funding from any organization. None of the authors have any conflicts of interest.

Chapter 4: Study #2 The effects of spinal manipulative therapy on postactivation potentiation

Abstract

PURPOSE: This study investigated the effects of spinal manipulative therapy on central nervous system excitability by assessing changes in postactivation potentiation, measured with the Hoffmann Reflex. It was hypothesized that significantly greater potentiation would be stimulated by a plantar flexion contraction with lumbosacral manipulation delivered immediately beforehand than the potentiation arising from the contraction only.

METHODS: A randomized, controlled, single-blind crossover study design was utilized with 20 healthy, resistance-trained subjects between the ages of 20 and 35 years. Electromyographic amplitudes during two stimulation intensities (H_{max} and M_{max}) and isometric twitch torques of the gastrocnemius and soleus muscles were recorded during tibial nerve stimulations subsequent to one of three randomized treatments during three separate sessions: side-posture, high velocity, low amplitude spinal manipulation targeting the lower lumbar vertebral segments and sacroiliac joint; a ten-second plantar flexion maximal voluntary isometric contraction or the manipulation immediately preceding the contraction. Data were collected during at 17 time points during the 20 minute stimulation protocol post-treatment. Differences in the electromyographic amplitudes and twitch torques of both muscles following each treatment were analyzed with a two-way repeated measures analysis of variance. A Bonferroni correction served as the post-hoc analysis.

RESULTS: A statistically significant difference in the within-subjects effects of the three treatments was found in the percent change from baseline of M_{max} twitch torques between the manipulation and the plantar flexion contractions and between the manipulation and the combination of the manipulation and contractions at six time points ($F(18, 342) = 3.843$, $p = 0.005$). However, significant differences were not present in the temporal changes of the gastrocnemius H_{max}/M_{max} ratio ($F(18, 342) = 1.171$, $p = 0.331$) and the percent changes from baseline ratios ($F(18, 342) = 1.035$, $p = 0.393$), the temporal changes in the soleus H_{max}/M_{max} ratio ($F(18, 342) = 1.343$, $p = 0.243$) and the percent change from baseline ratios ($F(18, 342) = 0.808$, $p = 0.548$), the temporal changes in twitch torques at H_{max} ($F(18, 342) = 1.684$, $p = 0.143$) and the percent changes from baseline ($F(18, 342) = 1.497$, $p = 0.181$) nor the temporal changes in twitch torques at M_{max} ($F(18, 342) = 1.978$, $p = 0.389$). The manipulations delivered without any contractile activity resulted in a depression of EMG amplitudes for two minutes, followed by a return to baseline levels.

CONCLUSION: The results suggest that spinal manipulation delivered immediately before a maximal voluntary contraction does not enhance postactivation potentiation in resistance-trained subjects.

Introduction

Spinal manipulative therapy (SMT) is a therapeutic procedure employed by health care practitioners such as chiropractors, osteopaths and physical therapists[4] for the purpose of reducing movement restrictions within spinal and peripheral joints, thereby promoting a normal range of motion (ROM).[5] In addition to the clinical efficacy of SMT in the treatment of acute and chronic musculoskeletal conditions such as neck pain, low back pain and headache,[7-16] numerous professional athletes have made anecdotal claims of enhanced performance post-treatment. Accordingly, research efforts from the past few decades have investigated the effects of SMT on several aspects of athletic performance.[28] For example, regarding strength, at least 22 different studies have recorded changes in force exerted during maximal voluntary contractions (MVC) post-manipulation. Within these articles, a range of muscle groups were selected, such as the quadriceps femoris, cervical musculature, thoracolumbar erector spinae, biceps brachii, shoulder external rotators, lower trapezius and gluteus maximus, in addition to measurements of knee flexion and grip strength.[34-55] Many of these studies reported increases in strength and/or increased electromyograph (EMG) amplitudes. However, despite possible modulation of gross muscle activity, the theory and research related to SMT is concerned primarily with the effects on the central nervous system (CNS). In spite of this understanding, very little research regarding the effects of SMT on the nervous system has been conducted. One concept related to both the neuromuscular system and the possible enhancement of athletic performance is postactivation potentiation (PAP).

PAP is a phenomenon in which muscular force production is increased as a result of preceding contractile activity of moderate to high intensity.[59,78,208] The most common theory explaining this occurrence is increased phosphorylation of myosin regulatory light chains, which increases the calcium sensitivity of troponin.[60,196,217] It has also been purported that the preceding conditioning activity incites a large amount of CNS stimulation, which results in increased motor unit recruitment and force production.[60-62] This possible contributing factor to PAP generation[59,60,63] is partly based on findings from use of the Hoffmann Reflex (H-reflex). The H-reflex is the submaximal electrical stimulation of the Ia monosynaptic reflex pathway to measure the efficacy of the Ia-αMN synapse in the ventral horn of the spinal cord.[65,66] Analogous to mechanically-induced tendon reflexes, the measurement is most reliable when performed via the tibial nerve.[65] Measurement of the reflex latency can be employed clinically to aid in the diagnosis of radiculopathies, and in kinesiological research for estimating the size of the motor neuron pool able to be recruited under various conditions.[67] The stimulation results in a compound muscle action potential (CMAP) from which reflexive motor unit activity can be measured, thus indicating the excitability of the CNS.[65,67] Moreover, it has been found that H-reflex EMG amplitudes are enhanced during PAP, signifying an increase in the firing rate of action potentials to the contracting muscle.[65]

It may be possible that one of the reasons for athletes' anecdotal claims of increased performance following SMT is due to increased potentiation. While the H-reflex has been employed in attempts to elucidate the clinical effects of SMT, it has never been used in exercise science to measure a possible neural effect of SMT on PAP; the

potential implication of which is a greater increase in explosive force production following a conditioning activity to induce PAP. Several authors have stated the need for further investigations of how SMT may modulate neuromuscular activity outside of the clinical setting,[68] particularly when delivered preceding resistance training or competition.[28,69,70] As such, it was hoped that the insights gained from this research would increase understanding of the treatment's effects. This knowledge may lead to a change in the frequency and/or timing of the procedure's inclusion in athletes' training regimens to possibly enhance the neuromuscular effects of strength and conditioning programs and ultimately, athletic performance.

Purpose

The purpose of this study was to examine the effects of SMT on central nervous system (CNS) excitability by assessing postactivation potentiation (PAP). The magnitude of PAP was determined subsequent to SMT and/or a plantar flexion MVIC by changes in isometric twitch toques and EMG amplitudes of the gastrocnemius and soleus during a tibial nerve H-reflex electrical stimulation protocol. The central premise was that SMT may enhance PAP by increasing neural drive to the muscle immediately following contractile activity. Specifically, it was hypothesized that SMT delivered to the lumbosacral region would significantly increase CNS excitability at the spinal level, resulting in enhanced potentiation of the gastrocnemius/soleus complex following voluntary contractile activity compared to potentiation resulting from the contractions alone. This event would be indicated by significantly higher H-reflex peak-to-peak EMG amplitudes following SMT paired with a plantar flexion MVIC compared to amplitudes following the MVIC only. The result would be a possible neurological contribution to PAP, which is directly indicated by an increase in the concurrent isometric twitch torques of the gastrocnemius and soleus during the tibial nerve electrical stimulations. This premise was formed based on the results of previous studies on the effects of SMT with measurements of both central and peripheral nervous system responses. Examples of the measurements post-SMT in asymptomatic subjects include increased MEP amplitudes during TMS[117,118] and decreased muscle activation latencies while investigating FFA.[170]

Four effects were hypothesized to result from the experimental protocol: significantly greater potentiation would be evoked by SMT when paired with the MVIC compared to the MVIC only; SMT paired with the MVIC would also decrease the duration of initial postactivation depression (PAD) in the EMG amplitudes and twitch torques (Nm) of the gastrocnemius and soleus, and thus bring about an earlier onset of PAP compared to the MVIC only; the gastrocnemius muscles would yield much greater potentiation than the soleus; and that SMT only would result in PAD for less than one minute, followed by the return of EMG amplitudes and isometric twitch torques to baseline levels. The first two hypotheses are based on the presumption that SMT will induce a synergistic effect with PAP mechanisms in the CNS, resulting in a faster, more pronounced potentiated response from increased motor unit recruitment subsequent to the MVIC. The significance of this result is that a greater proportion of the MN pool will be capable of being activated after the fatigue subsides from the MVIC. From these measurements, inferences will be made regarding the possibility that the incorporation of SMT within high intensity resistance training regimens and/or pre-competition may

enhance PAP with an increase in CNS excitability. The implication of augmented PAP is that greater neuromuscular activation will lead to increased power generation during the performance of explosive athletic activities such as sprinting, jumping and throwing.[59,60,206]

Methods

Participants

The study sample included 25 healthy, resistance-trained subjects (16 males, 9 females) between the ages of 20 and 35 years. All subjects were required to meet minimal resistance training and weekly activity level criteria; these included at least one year of resistance training experience and current completion of at least three training sessions per week. Additionally, males needed to be able to back squat a minimum load of 1.5 x body weight, and females 1 x body weight.[78,227-229] Subject characteristics are depicted below in Table 2. NCAA Division I athletes were not recruited, so resistance-trained individuals were selected (identified by Wilson and colleagues[78] as the second tier of subjects most likely to respond to PAP). In addition to standard resistance training, most of the participants also engaged in a wide range of physical activities, including Olympic lifting, powerlifting, bodybuilding and figure competition, various forms of cardiovascular endurance training, CrossFit and NAIA Division I baseball.

Table 2. *Subject characteristics*

	Mean (SD)	Min - max
Age (y)	25.6 (4.1)	21 - 32
Height (cm)	172.1 (8.1)	152.4 - 185.4
Weight (kg)	74.2 (13.7)	49.9 - 108.6
Back squat 1RM (kg)	126.2 (45.3)	54.4 - 204.1

The exclusion criteria included contraindications to SMT or H-reflex testing, which consisted of: pain in the lower back, abdomen or legs and/or surgeries performed in these areas; history of vertigo; dizziness or fainting with certain head movements associated with nausea/vomiting; recent onset of severe headache or neck pain/stiffness; bilateral radicular extremity symptoms; diabetic neuropathy; fractures; dislocations; acute muscle spasm; as well as past diagnosis of cardiovascular disease, any blood clotting disorder, stroke, aneurysm, thromboembolism, vascular/neurogenic claudication, lumbar disc herniation, cauda equina syndrome, spondylolisthesis, scoliosis, diabetes, any type of arthritis or bone/joint disease and/or an allergic reaction to silver.

Subjects were recruited from various locations on campus, via flyers (Appendix F) and word of mouth. Both male and female subjects were enrolled, as a recent meta-analysis has concluded that there is no difference in the occurrence of PAP between male and female subjects.[241] Also, the subjects were not monetarily compensated for participation; however, they were presented with the option of a free Dual-Energy X-ray Absorptiometry (DXA) scan within the Body Composition Core Laboratory. The measurements acquired from the scan are for the participant's information only, and were not included in the results of the study.

Study design overview

A randomized, controlled, single-blind crossover study design was utilized, in which the PI conducted all study procedures. Allocation of 20 subjects to the treatment group and 5 to the control group was determined with a random number generator using Microsoft Excel. Concerning the treatment group, the three independent variables were SMT, a 10 second plantar flexion MVIC or SMT immediately preceding the MVIC. Each of the four dependent variables were evoked during the tibial nerve H-reflex stimulation protocol at the conclusion of each session, and included the H_{max}/M_{max} ratio (%) of the gastrocnemius and soleus muscles and the isometric twitch torque occurring at H_{max} and at M_{max}. The treatment order was randomized for each of the three sessions before the tibial nerve H_{max} / M_{max} stimulation protocol, and included SMT only, the 10 second MVIC only or SMT preceding the MVIC. Changes were then measured by H-reflex amplitudes and concurrent isometric twitch torque generation of the gastrocnemius-soleus complex during the H_{max}/M_{max} tibial nerve stimulation protocol. Table 3 provides an overall view of the protocol.

Control group

In addition to the 20 subjects who underwent the three treatment procedures during the three separate data collection sessions, a control group of five subjects was also necessary. These five participants were randomly assigned into the control group after meeting the inclusion criteria. Control group selection was determined with random number generation using Microsoft Excel in the same manner as the treatment order for the other 20 subjects. The five control subjects did not perform plantar flexion MVICs or receive any form of treatment. Their purpose instead was to complete the H-reflex electrical stimulation protocol twice (with a 20 minute rest interval) during two separate sessions. The sessions were conducted at the same time of day, at least 24 hours apart. The results were used to test the reliability of the H-reflex testing within and between sessions. The same initial procedures were performed during the first session (health history questionnaire, informed consent process and physical examination). During both sessions, the H_{max}/M_{max} recruitment curve and subsequent confirmation of H_{max} were followed by a 20 minute rest before the completion of both H_{max}/M_{max} stimulation protocols. The PI performed all control group procedures as well.

Table 3. *Summary of experimental procedures.*

1st Session	Health history questionnaire, informed consent and physical exam	Biodex familiarization and electrode placement	Tibial nerve stimulation familiarization	Rest 20 minutes	Hmax and Mmax recruitment curve	Determine Hmax and Mmax stimulation intensities	Confirm Hmax	2 sets of 5 second plantar flexion MVICs	Rest 20 minutes	SMT or 60 second rest	10 second MVIC or 10 second rest	Hmax/Mmax stimulation protocol
2nd Session	Subject positioning on table and dynamometer, electrode placement	Rest 20 minutes	Hmax and Mmax recruitment curve	Determine Hmax and Mmax stimulation intensities	Confirm Hmax	2 sets of 5 second plantar flexion MVICs	Rest 20 minutes	SMT or 60 second rest	10 second MVIC or 10 second rest	Hmax/Mmax stimulation protocol		
3rd Session	Subject positioning on table and dynamometer, electrode placement	Rest 20 minutes	Hmax and Mmax recruitment curve	Determine Hmax and Mmax stimulation intensities	Confirm Hmax	2 sets of 5 second plantar flexion MVICs	Rest 20 minutes	SMT or 60 second rest	10 second MVIC or 10 second rest	Hmax/Mmax stimulation protocol		

Red = Data collection

3 randomized treatments: SMT only, MVIC only or SMT+MVIC			
1)	SMT	no MVIC	Hmax/Mmax protocol
2)	60 s rest	MVIC	Hmax/Mmax protocol
3)	SMT	MVIC	Hmax/Mmax protocol

Initial procedures

All study procedures are depicted above in Table 3, and were approved by the University of Kentucky Medical Institutional Review Board (IRB # 14-0507-F6A). Subjects were tested on three different occasions at the University of Kentucky Human Performance Laboratory located in the Multidisciplinary Science Building. During the initial visit, a health history questionnaire (Appendix G) pertaining to the volunteer's medical history was completed to ensure that the volunteer was eligible to participate in the study. The function of the questionnaire was also to confirm that the subject was asymptomatic with regard to low back, pelvic or lower extremity pain, and to confirm that surgery has not been performed in these regions. Next, the subject read the informed consent form (Appendix H), and the PI answered any related questions. After the subject signed the informed consent form, a physical exam (Appendix I) was then performed by the PI to rule out any further contraindications to SMT or H-reflex electrical stimulation.

The physical exam included: blood pressure; cervical/thoracic/lumbar active and passive range of motion; motor and sensory evaluation of C5 though T1 and L1 through S1; tendon reflexes of the biceps brachii, brachioradialis, triceps, patellar ligament and Achilles; Hoffmann's and Babinski's Tests for pathological reflexes as well as Kemp's, Bechterew's, Patrick's/Fabere and Yeoman's Tests. The final assessment included Gillet's Test and motion palpation of the patient's lumbar spine and sacroiliac joints to determine the levels of segmental restrictions to be manipulated. Subject confidentiality was maintained by assigning subjects a participant number under which all data were stored.

Once eligibility had been met, the subject was then familiarized with the Biodex System 4 isokinetic dynamometer (Biodex Medical Systems, Shirley, NY) and tibial nerve stimulation and evoked twitch responses in the lateral gastrocnemius and soleus muscles via a constant-current stimulator (DS7AH, Digitimer Ltd., Welvyn Garden City, UK). Data were collected at approximately the same time of day during all three sessions. If the subject experienced any muscle soreness as a result of the previous testing or other physical activity, data collection was rescheduled.

Subject positioning and electrode placement

As discussed previously, the H-reflex is susceptible to modulation which arises from peripheral feedback from structures such as muscle spindle receptors and golgi tendon organs, which are stimulated during movement.[47,48,108] In light of this information, all measurements were made with the subject in a side-lying position, thus eliminating the need for repositioning prior to or during the EMG and isometric torque recordings as well as the control and HVLA manipulation procedures. The dynamometer head was tilted to 90°, allowing torque recordings from the foot plate at an angle perpendicular to what is commonly utilized.

Bipolar, single differential surface EMG (SEMG) sensors (Model DE-2.1, Delsys, Inc., Natick, MA) were attached to the lateral gastrocnemius muscle belly at one-third of the proximal distance from the fibular head to the calcaneous and soleus muscle belly at four centimeters distal to the inferior margin of the gastrocnemius.[194,218] The sensor

contacts were 99.9% silver bars, each with a surface area of 10 x 1 mm, arranged in a parallel-bar geometry spaced 1 cm apart. The electrodes were attached parallel to the orientation of the muscle fibers with a 2-slot adhesive surface interface (Delsys Inc., Natick, MA) between the skin and electrode in addition to surgical tape placed over the electrode. The polycarbonate case of the recording electrode was rectangular in shape, measuring 41 x 20 x 5 mm. The self-adhering, two inch diameter disposable reference electrode (Dermatrode, Irvine, CA) was adhered to the contralateral patella. The cables from the recording and stimulating electrodes were also adhered to the side of the treatment table with surgical tape to prevent artifacts in the EMG signal. The rubber stimulating electrodes (Covidien LLC, Mansfield, MA) were 2 cm x 3 cm in size and secured in the popliteal fossa (cathode) and two centimeters proximal to the superior border of the patella (anode).[61,65,200] Ultrasound transmission gel was placed on the stimulating electrodes before also being attached with surgical tape, and then further secured with an ACE bandage wrapped over the distal thigh, knee and proximal shank. Before electrode application, these five specific areas were shaved, lightly abraded with 120 grit sandpaper and cleansed with an alcohol pad. Then, if skin impedance (E2M5 Grass Electrode Impedance Meter, Grass Instruments, Warwick, RI) was determined to be less than 10 KOhm,[187] the recording electrodes and stimulating electrodes were attached. If impedance was measured as more than 10 KOhm, the areas were again shaved, abraded and swabbed with an alcohol pad. The five electrode-skin interfaces were then retested with the impedance meter.

The subject was then positioned in side posture on a physical therapy treatment table (electric high/low elevation table, model ADP 300, Chattanooga Group, DeQueen, AR) for the duration of the experimental procedures, with the upside foot attached to the foot plate of the ankle attachment secured to the dynamometer head. This positioning set-up is depicted below in Figure 6a. Selection of the right or left foot was made during the final step of the physical exam (static and motion palpation of the subject's lumbar spine and sacroiliac joints). The decision was made in conjunction with Gillet's test and observance of a functional (non-anatomical) leg length discrepancy, most likely indicating one of several possible sacroiliac motion restriction listings. The side chosen during the first session was also used for the second and third sessions, with the ipsilateral lumbar/sacroiliac joint manipulated during the randomized treatment protocol.

Figure 6a. *Subject positioning.*

Figure 6b. Ankle attachment set-up

Figure 6b provides a close inspection of how the foot and ankle were secured to the foot plate. The dynamometer head was tilted 90° and rotated to face the foot end of the treatment table. A folded sheet of quilt batting was placed between the subject's heel and the plastic heel cup of the ankle attachment to prevent abrasion. An ACE bandage was folded and placed over the dorsum of the subject's foot before the two ankle attachment straps were secured over the tibiotalar joint and metatarsophalangeal joints. The subject also wore an ankle brace with side stabilizers (Walgreens Deluxe Adjustable Ankle Stabilizer, product # 317952) to prevent the heel from lifting off of the foot plate of the ankle attachment while plantar flexion occurred during the MVICs and tibial nerve electrical stimulations. The ankle brace was tightly secured with a 12 inch long, 1.5 inch wide Velcro strap from one side of the brace to the other around the bottom of the ankle attachment. Further stabilization was provided by accessory Biodex padded restraint straps tightly secured over the subject's upside femuroacetabular joint and downside medial thigh.

A carpenter's square was used to position the ankle in 90° of flexion before the H_{max}/M_{max} recruitment curve, confirmation of H_{max}, plantar flexion MVICs and the H_{max}/M_{max} stimulation protocol. The anatomical landmarks used were the lateral tibial condyle and lateral malleolus in reference to the foot plate of the ankle attachment. Vigilance was exercised for the entirety of the session to also verify that the subject's upside knee was maintained in full extension. This was facilitated by the placement of a foam, wedge-shaped pillow (Original Contour Leg Pillow, Contour Products, Inc., Charlotte, NC) between the subject's knees. The subject's head was supported by two pillows in front of the table headrest, which was set in the highest raised position. To help maintain subject comfort, the subject had two opportunities during the session to sit up and/or move off of the treatment table (during both 20 minute rest periods before the recruitment curve and before the randomized treatment protocol at the session's conclusion). During this time, the subject's foot was unstrapped from the ankle attachment and the padded straps were loosened or removed. If the subject asked to unstrap his or her foot from the dynamometer at any other time, then data collection was delayed for this purpose.

After proper positioning and electrode set-up, the subject then underwent a short familiarization with tibial nerve stimulation. The process was carried out by increasing the stimulation intensity in 2 milliamp (mA) increments every 10 seconds[66,89] starting from 0 mA to reach 10 mA. All stimulations were a square-wave pulse width for a duration of 1 ms. If the subject did not experience any unusual discomfort or pain, the session continued with a 20 minute rest preceding the H_{max} and M_{max} recruitment curve. The purpose of this rest was for any potentiation to dissipate from the subject's previous movement and tibial nerve stimulation familiarization.[89] At this point, the remainder of the procedures were the same for all three separate sessions.

Determination of H_{max}, M_{max} and maximal plantar flexion torque

Initial measurements of the tibial nerve stimulation intensities (mA) that elicit maximal H-reflex (H_{max}) and full muscle response (M_{max}) peak-to-peak EMG amplitudes (mV) in the lateral gastrocnemius and soleus were recorded during the stimulus-response curve (Bagnoli-8 EMG System and EMGworks 4.0 signal acquisition and analysis software, Delsys Inc., Natick, MA). This procedure is also referred to as the recruitment curve, because the tibial nerve Ia afferent fibers and αMNs are progressively recruited with increasing stimulation intensity. The specific stimulation intensities which evoked H_{max} and M_{max} reflexive EMG amplitudes were used in the H_{max}/M_{max} stimulation protocol at the conclusion of each session. Temporal changes in the H_{max}/M_{max} ratio in response to the two fixed stimulation intensities are thought to indicate alterations in CNS excitability,[67] and therefore, the effect of the treatment. The value of H_{max} was then confirmed through a similar process with five stimulation intensities, followed by the determination of the subject's peak plantar flexion isometric torque using the isokinetic dynamometer. Before the treatment protocol was initiated, the subject was instructed to rest once more for 20 minutes, again for any potentiation generated during the recruitment curve and strength testing to dissipate.[89]

H_{max} and M_{max} recruitment curve procedures

The recruitment curve was acquired with the methods described by Palmieri et al.[65] During this time, stimulation intensities were progressively increased from zero in 2 mA increments in 10 second intervals to determine the reflexive lateral gastrocnemius and soleus EMG amplitudes at H_{max} and M_{max}. Figure 7 provides an illustration of the process, followed by an explanation of the six highlighted events.

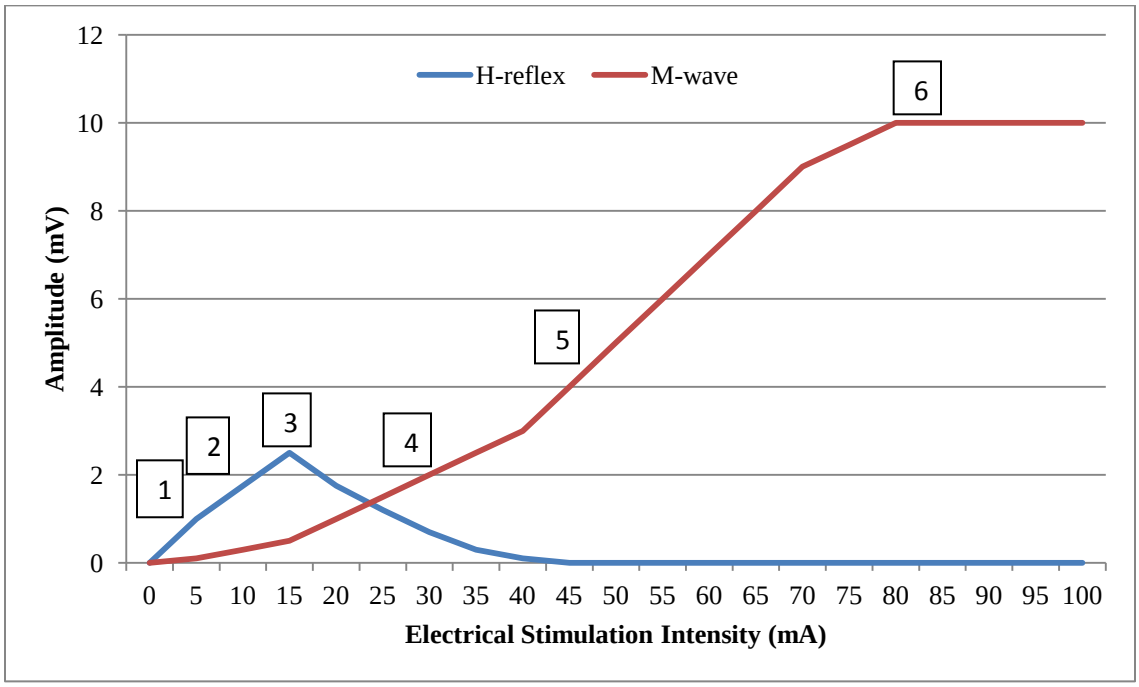

Figure 7. *Example of a common H_{max} and M_{max} recruitment curve.*

1) Tibial nerve electrical stimulation at low amplitudes elicits a response in only the large diameter, low threshold Ia afferent fibers, generating impulses toward the spinal cord and resulting in the firing of αMNs, causing a twitch response (the H-reflex) of the gastrocnemius-soleus complex. The appearance of the H-reflex tracing on the electromyograph occurs approximately 30 ms after the stimulation. This latency is due to the distance travelled by the signal within the monosynaptic reflex arc from the tibial nerve afferent fibers in the popliteal fossa to the synaptic cleft at the Ia-αMN synapse in the ventral horn of the spinal cord, and then orthodromically (in the correct direction toward or away from the spinal cord) along the axons of the αMNs.

2) Continuing to increase the electrical stimulus intensity (mA) induces a greater response in Ia afferents and begins to directly activate the smaller diameter efferent motor axons, which have a higher depolarization threshold. Stimulation of these fibers causes a direct muscle response (the M-wave), which generally occurs 5 ms after the stimulation and preceding the H-reflex on the electromyograph. The shorter latency of the M-wave in comparison to the H-reflex is because of the shorter path that the action potentials must travel for a muscle twitch response to occur, without having to synapse in the ventral horn. Moreover, the action potentials fire in all directions, both orthodromically and

antidromically (traveling in the wrong direction toward the spinal cord in the motor axons). As a result, antidromic collision occurs, in which the volley of electrical activity collides with the reflexive orthodromic volley which has proceeded up the sensory axon and passed through the spinal cord. In the motor axons of the reflex pathway, if the antidromic volley is smaller than the orthodromic volley propagated on the same motor axons, then the orthodromic volley is reduced but continues to the muscle. This explains why the H-reflex tracing in the recruitment curve starts to decrease after reaching a plateau. When the size of the antidromic volley is equal to or larger than the afferent, orthodromic volley, no signal proceeds to the muscle, and the H-reflex disappears from the tracing. However, because the action potentials traveling along the Ia monosynaptic reflex pathway are greater than the antidromic impulses at the current low stimulus intensity, there is only a slight reduction in H-reflex amplitudes.

3) H_{max}, the highest H-reflex amplitude, has now been reached. H_{max} is an indication of the greatest possible reflex activation; as such, it is an estimate of the number of MNs a subject is capable of activating in a given state.[65,216] Considering the M-wave, antidromic collision begins to occur to a slightly greater degree.

4) The H-reflex is still apparent, now on the descending aspect of the recruitment curve. Despite comparatively higher M-wave amplitudes, the stimulation does not recruit all motor axons. Accordingly, the antidromic impulses do not collide with all action potentials resulting from the orthodromic activity.

5) The intensity of the electric stimulus results in activation of all motor axons. Only the M-wave appears on the EMG tracing because antidromic collision blocks all H-reflex action potentials resulting from orthodromic activity.

6) Further increases in the stimulation intensity have caused the M-wave to reach its highest amplitude, M_{max}, which represents full muscle activation.[65,89] Specific to the current investigation, M_{max} indicated activation of the total volume of the gastrocnemius/soleus MN pool. Consequently, the value of this EMG amplitude remained stable even during additional increases in stimulation intensity.[65,89,194,216,218]

<u>Confirmation of H_{max}</u>

After the stimulation intensities which induced H_{max} and M_{max} were determined, H_{max} was reassessed. This was completed with 5 stimulations, each 10 seconds apart, with the intensity of the previous H_{max} as the 3rd stimulation. For example, if H_{max} was recorded at 10 mA, then stimulation intensities would then be set at 6, 8, 10, 12 and 14 mA. The H-reflex tracings were then visually inspected in conjunction with the peak-to-peak EMG amplitudes at each of the 5 stimulation intensities, and then compared to the H_{max} amplitude obtained during the recruitment curve.[89] If the stimulation intensity that induced H_{max} was two mA higher or lower than the first measurement, then the second intensity was used during the stimulation protocol.

Maximal plantar flexion torque

The subject then performed two sets of five second plantar flexion MVICs to determine the maximal torque-generating capacity of his or her gastrocnemius/soleus complex, measured by the isokinetic dynamometer. The procedure was performed using a specially designed protocol in the isokinetic dynamometer (Biodex Advantage software, Version 4.X). Subjects warmed up by performing several sets of isometric plantar flexion contractions of progressively increased force. The subject then rested for 30 seconds, after which peak torques (Nm) were recorded from two sets of maximal effort plantar flexion contractions performed for five seconds each with 30 seconds of rest between sets. The subject was able to watch the screen of the desktop attached to the dynamometer for the line graph of torque produced. The knee joint was maintained in full extension during all sets, and the ankle was maintained in 90° of flexion in reference to the foot plate of the ankle attachment. Verbal encouragement was given to each subject in a uniform manner for the duration of both sets. The reason for conducting this portion of the session was for the highest peak torque of the two sets to be used as a basis of comparison during the treatment protocol, in which the subject was required to exert maximum plantar flexion torque to induce PAP.

Treatment protocol

Following the second 20 minute rest, one of three randomized treatment sequences were implemented (Table 2). These included: (1) lumbosacral SMT followed by a 10 second rest and then the H_{max}/M_{max} stimulation protocol; (2) a 60 second rest, 10 second plantar flexion MVIC and then the H_{max}/M_{max} stimulation protocol or (3) lumbosacral SMT preceding the 10 second plantar flexion MVIC and then the H_{max}/M_{max} stimulation protocol. The specific treatment sequence carried out at the end of each session was determined with random number generation using Microsoft Excel. The other two sessions included the same initial subject preparation and subsequent procedures to determine Hmax, Mmax and peak isometric plantar flexion torque, and randomly included one of the other two treatment sequences.

Spinal manipulation

Diversified Technique, the most common chiropractic treatment method, was utilized in the administration of HVLA SMT. The manipulation was specifically delivered to the lower lumbar spine and sacroiliac joint in order to include the vertebral and sacral segments from which the ventral roots of L4-S2 originate within the lumbosacral plexus. These spinal levels were important because of the distal innervations of the gastrocnemius and soleus muscles via the tibial nerve. The manipulation was accomplished by first unstrapping the subject's foot from the isokinetic dynamometer ankle attachment. The subject remained positioned in side posture as described by Peterson and Bergmann,[1] as the PI applied downward pressure to the subject's upside bent knee and a pisiform contact to the subject's posterior superior iliac spine of the upside ilium. An impulse through the lumbar segment or sacroiliac joint was then delivered in the posterior to anterior, superior to inferior and medial to lateral direction from the PI's contact hand. The force stemmed from a drop in the PI's weight toward the floor, with the line of drive directly through the hypomobile lumbar intervertebral joint or sacroiliac joint.

10 second maximal voluntary isometric contraction

The purpose of the MVIC was to induce PAP, and was completed with methodology similar to that employed by Hamada et al.[61] and Folland, Wakamatsu and Fimland.[89] The torque (Nm) generated for the duration of the 10 second MVIC needed to be within ± 5% of the peak torque obtained during the 2 sets of 3-5 second MVICs 20 minutes prior in order to be considered a valid maximal effort. Torque production that exceeded this value was also accepted.

The procedure was conducted with an additional specially designed protocol in the Biodex Advantage software. With the upside foot again securely fastened to the ankle attachment, the subject was instructed to perform a warm-up of several sets of plantar flexion contractions of progressively increasing intensity. The participant was reminded of his/her previous peak torque, and was then instructed to exert enough effort once again to match or surpass the previous peak torque. As with the previous strength testing, the subject was provided with visual feedback of his/her effort from the Biodex desktop monitor displaying the line graph of torque produced in real time, with a fixed horizontal line on the graph set by the PI at this minimum torque value. Uniform verbal encouragement was given in the same manner as during the strength testing for the duration of the 10 second MVIC.

H_{max}/M_{max} stimulation protocol

The purpose of the stimulation protocol was to identify variation post-treatment in the temporal profiles of the EMG amplitudes and isometric plantar flexion twitch torque evoked during the two fixed stimulation intensities at H_{max} and M_{max}. Given that H_{max} is an inference of the number of MNs being recruited, and M_{max} constitutes the entire motor neuron pool, the proportion of the entire MN pool capable of being recruited can be deduced with the H_{max}/M_{max} ratio.[65] The amplitude of the H-reflex varies among subjects due to differences in factors such as skin resistance, subcutaneous fat mass, and proximity of the nerve relative to the stimulating electrode. Thus, H_{max} must be normalized to M_{max} to enable between-subject comparisons.[65] Because this normalization procedure requires the M_{max} amplitude to be a stable value, a stimulation intensity of 120% of the value of M_{max} determined during the recruitment curve was used to maintain consistency of the Mmax amplitude,[89] thus allowing changes in the H_{max}/M_{max} ratio to be correctly attributed to changes in H_{max}.

During the stimulation protocol, the electrical stimulation intensities (mA) which were found to actuate H_{max} and M_{max} EMG amplitudes were delivered once more in alternating sequence for 20 minutes post-treatment. This method allowed for the calculation of the H_{max}/M_{max} ratio, to indicate changes in spinal reflex excitability. The specific timing and number of stimulations was similar to those employed by Folland, Wakamatsu and Fimland.[89] The timing of the stimulations was controlled by a customized MATLAB code (Mathworks Inc., Natick, MA). A total of 29 stimulations occurred, as depicted in Figure 4. The fixed M_{max} stimulation intensity was delivered at 10 seconds, 30 seconds, 50 seconds, 1:30, 2:30, 3:30, 4:30, 5:30, 6:30, 7:30, 8:30, 9:30, 11:00, 13:00, 15:00, 17:00 and 19:00 post-treatment. The fixed H_{max} stimulation intensity was delivered at 20 seconds, 40 seconds, 1:00, 2:00, 3:00, 4:00, 5:00, 6:00, 7:00, 8:00,

9:00, 10:00, 12:00, 14:00, 16:00, 18:00 and 20:00 post-treatment. The subject was instructed to remain as still and relaxed as possible, and to refrain from talking until the completion of the protocol.

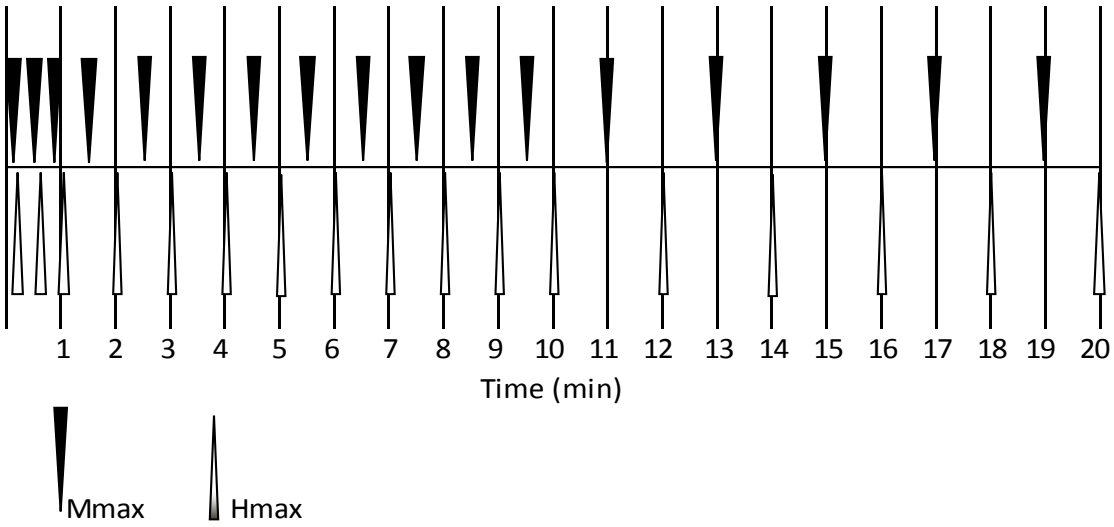

Figure 8. *H_{max}/M_{max} stimulation protocol*

Data collected during the H_{max}/M_{max} stimulation protocol were analyzed to identify changes in the H/M ratio, twitch torque at H_{max} and twitch torque at M_{max}. Folland, Wakamatsu and Fimland[89] have identified subcategories of PAP revealed by these measures. According to these authors, the H_{max}/M_{max} ratio is a measure of electrical potentiation, as it provides insight into the proportion of the entire motor neuron pool capable of being recruited under the testing circumstances. Twitch torque at M_{max} is considered mechanical potentiation, which is widely thought to be produced by increased phosphorylation of myosin regulatory light chains.[60,61,63,64] Also, twitch torque at H_{max} is regarded as the combination of electrical and mechanical potentiation, and therefore, the most complete measure of PAP.[89]

Electromyographic and twitch torque data collection

Data from the SEMG sensors and the isokinetic dynamometer were collected during the electrical stimulations of the H_{max} and M_{max} recruitment curve and the H_{max}/M_{max} stimulation protocol. EMG signals were amplified with the Delsys Bagnoli-8 amplifier by a gain of 1000. MATLAB digital signals to the muscle stimulator were changed to analog by a 16-bit analog-to-digital converter (model BNC-2659, National Instruments, Austin, TX). All analog signals from the muscle stimulator, isokinetic dynamometer and Delsys EMG input module (into which the SEMG recording electrodes and reference electrode were connected) were acquired with the Bagnoli-8 input unit and converted to digital signals in EMGworks 4.0. Data were sampled at 2000 Hz, and the EMG signals were bandpass filtered between 20-450 Hz. The peak torque analog signals were filtered with a fourth order zero-lag Butterworth filter, with a residual analysis identifying a cutoff frequency of 24 Hz.[230] All filtered peak-to-peak EMG amplitude

(mV) and peak twitch torque (Nm) data were then identified in EMGworks 4.0, recorded and graphed in Microsoft Excel (2013) and statistically analyzed in SPSS Version 21 (IBM Corp., Armonk, NY). An instrumentation schematic is included in Appendix J, and all subject data are presented in Appendix K.

Data analysis

The H_{max}/M_{max} ratio was determined by division of the EMG peak-to-peak amplitudes (mV) evoked at H_{max} by the preceding M_{max} EMG peak-to-peak amplitudes. In the treatment group, differences in each of the four dependent variables (H_{max}/M_{max} ratios of the gastrocnemius and soleus and the peak twitch torques evoked at H_{max} and M_{max}) following each treatment form of SMT, MVIC or SMT + MVIC delivered during the three data collection sessions on three separate days were determined with a two-way (treatment × time point) repeated-measures ANOVA. Percent changes from baseline were also calculated for each of the dependent variables, and the same type of ANOVA was used to determine differences in the effects of each treatment. A Bonferroni correction served as the post-hoc analysis by pairwise comparisons of treatment means. Significance was set at $P < 0.05$. Intraclass correlation coefficiants (2,1) were used with the five control group subjects to determine the within and between-session reliability of the H_{max}/M_{max} stimulation protocol. Data means of the first three dependent variables were analyzed at 10 time points post-treatment: 0:20, 1:00, 2:00, 4:00, 6:00, 8:00, 10:00, 12:00, 16:00 and 20:00. Because each M_{max} stimulation preceded each H_{max} stimulation, data means for the fourth dependent variable (peak twitch torque at M_{max}) were analyzed at 0:10, 0:50, 1:30, 3:30, 5:30, 7:30, 9:30, 11:30, 15:00 and 19:00 post-treatment.

All 17 time points post-treatment were not able to be analyzed because of the limited number of subjects recruited. The 10 time points analyzed, however, constitute an evenly-spaced distribution of the 17 measurements of H_{max} and M_{max} post-treatment and include the expected time ranges of treatment effects. PAP occurs immediately post-conditioning activity, but according to the literature is not measureable in resistance-trained subjects until the concurrent fatigue subsides after seven to 10 minutes,[78,208] so the inclusion of 6:00, 8:00 and 10:00 in the analysis includes this general time range.

Results

A total of 30 participants were recruited, and data were collected from 25. The five subjects excluded were due to scheduling difficulties with one individual, a calf spasm post-testing in another subject, and because an H-reflex could not be elicited in the other three participants.

Treatment group

A statistically significant difference in the within-subjects effects of the three treatments (SMT, MVIC or MVIC + SMT) was found in one dependent variable, the percent change from baseline of M_{max} twitch torque ($F(18, 342) = 3.843$, $p = 0.005$), depicted in Figure 16. A statistically significant difference also occurred in the main effects of the three treatments (with the dependent variable means collapsed across time) on the H_{max}/M_{max} ratio of the soleus ($F(2, 38) = 5.190$, $p = 0.017$) and the M_{max} twitch torque ($F(2, 38) = 5.842$, $p = 0.007$). However, significant differences were not present in

the treatment main effects on the H_{max}/M_{max} ratio of the gastrocnemius ($F(2, 38) = 1.796$, $p = 0.185$), the percent change from baseline of the gastrocnemius H_{max}/M_{max} ratio ($F(2, 38) = 0.257$, $p = 0.700$), the percent change from baseline of the soleus H_{max}/M_{max} ratio ($F(2, 38) = 0.117$, $p = 0.860$), the H_{max} twitch torque ($F(2, 38) = 3.395$, $p = 0.053$), the percent change from baseline of H_{max} twitch torque ($F(2, 38) = 1.315$, $p = 0.280$) nor the percent change from baseline of M_{max} twitch torque ($F(2, 38) = 3.132$, $p = 0.062$).

Figures 9, 11 and 13 show that the H_{max}/M_{max} ratio of both muscles and the twitch torque at H_{max} returned to and then exceeded baseline percentages at 2:00 to 3:00 post-MVIC with and without SMT. PAP is evidenced by the immediate increase in M_{max} twitch torque post-MVIC in Figures 15 and 16. The delivery of SMT only did not induce PAP, and resulted in the furthest immediate decreases in EMG amplitudes of the H/M ratios of both the gastrocnemius and soleus (Figures 9 – 12). The H_{max} and M_{max} twitch torques following SMT gravitated the least from baseline levels.

Temporal changes in the gastrocnemius H_{max}/M_{max} ratio are illustrated below in Figure 9 ($F(18, 342) = 1.171$, $p = 0.331$) and the percent changes from baseline ratios are depicted in Figure 10 ($F(18, 342) = 1.035$, $p = 0.393$). The Hmax/Mmax ratio is higher following SMT for all time points, even though it is not statistically significant. The immediate decrease in the peak-to-peak amplitudes did not return to baseline values until 2:00 after each of the three treatments; there was a trend for the ratios to continue to increase until 4:00.

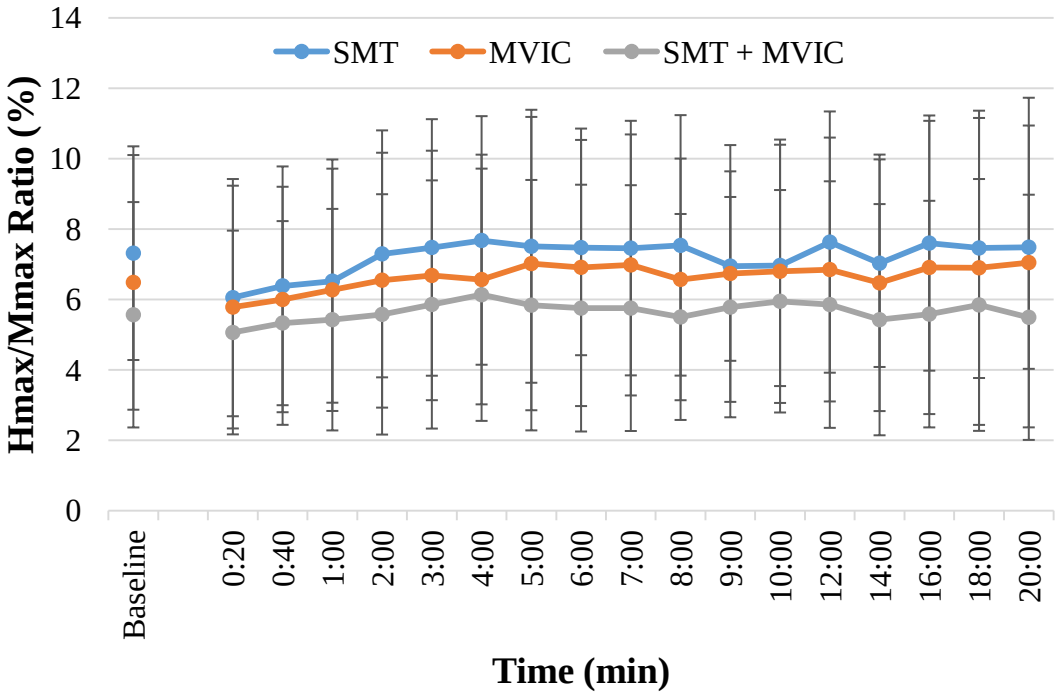

Figure 9. *Temporal changes in the gastrocnemius H_{max}/M_{max} ratio. Mean ± SD.*

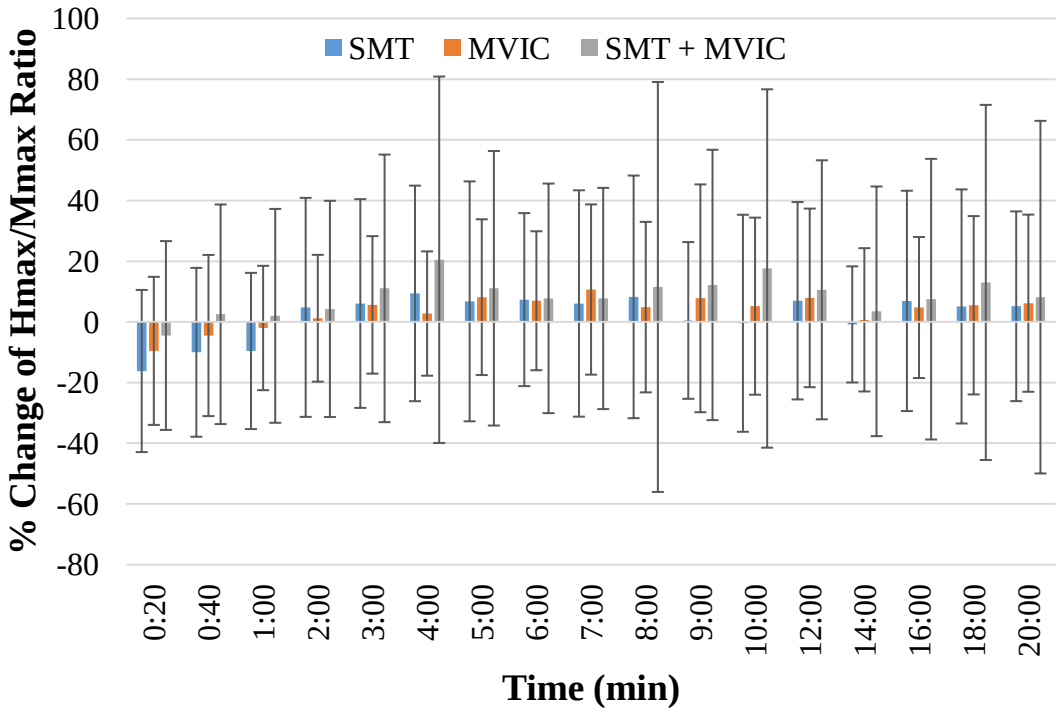

Figure 10. *Temporal changes in the gastrocnemius H_{max}/M_{max} ratio relative to baseline amplitudes following each of the experimental conditions. Mean ± SD.*

Temporal changes in the soleus H_{max}/M_{max} ratio ($F(18, 342) = 1.343$, $p = 0.243$) are depicted below in Figure 11, and the percent change from baseline ratios ($F(18, 342) = 0.808$, $p = 0.548$) in Figure 12. Similar to the gastrocnemius, the Hmax/Mmax ratio is higher following SMT for all time points. Ratios were depressed following SMT until 2:00. This short PAD was not significant, after which the ratios remained near baseline. Amplitudes following the MVIC were depressed until 3:00, also not significant, followed by further, gradual depression for the duration of the 20 minutes. The mean EMG amplitudes following SMT + MVIC were depressed below baseline levels for all 20 minutes. This depression in amplitudes was also not significant.

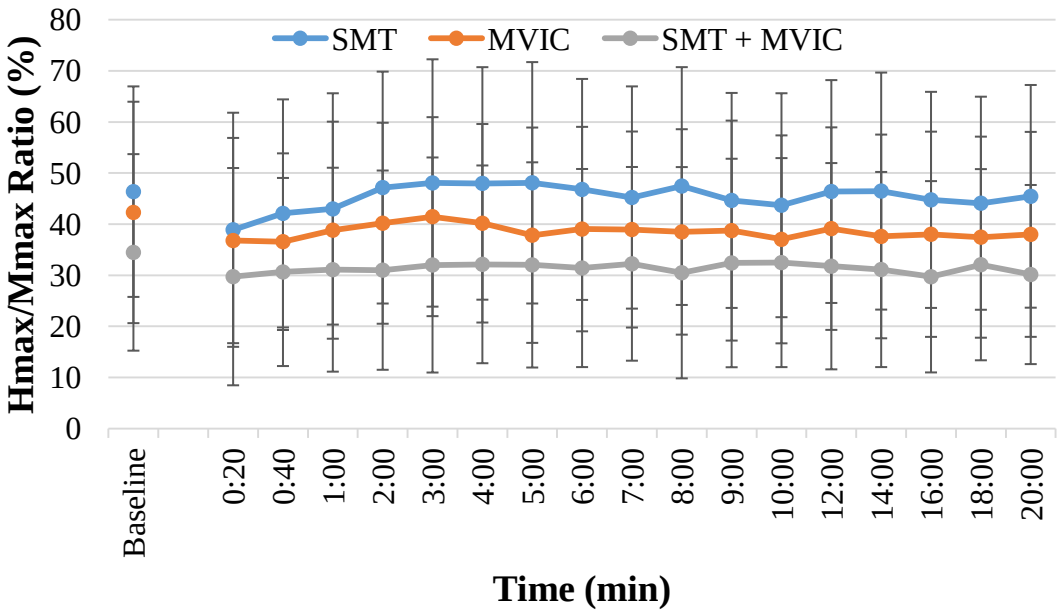

Figure 11. *Temporal changes in the soleus H_{max}/M_{max} ratio. Mean ± SD.*

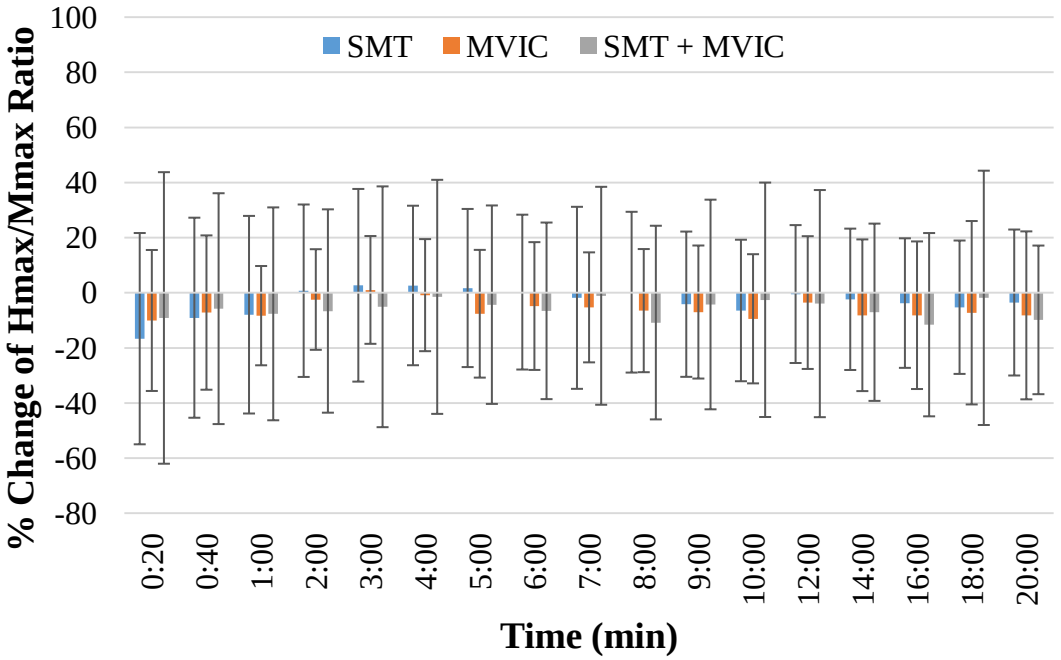

Figure 12. *Temporal changes in the soleus H_{max}/M_{max} ratio relative to baseline amplitudes following each of the experimental conditions. Mean ± SD.*

Temporal changes in twitch torques at H_{max} are presented in Figure 13 ($F(18, 342) = 1.684$, $p = 0.143$) and the percent changes from baseline in Figure 14 ($F(18, 342) = 1.497$, $p = 0.181$). Figure 13 shows that the H_{max} twitch torque rose above baseline at 40 seconds post-MVIC, and immediately post-SMT + MVIC. Each of these increases in twitch torque was not significant. Twitch torque peaked following both treatments at 2:00 (but did not reach statistical significance), followed by a gradual decline. This response is also apparent in the percent changes from baseline in Figure 14, in which the peak increases are also not significant. H_{max} twitch torque following SMT remained near baseline levels until 9:00 and then progressively decreased.

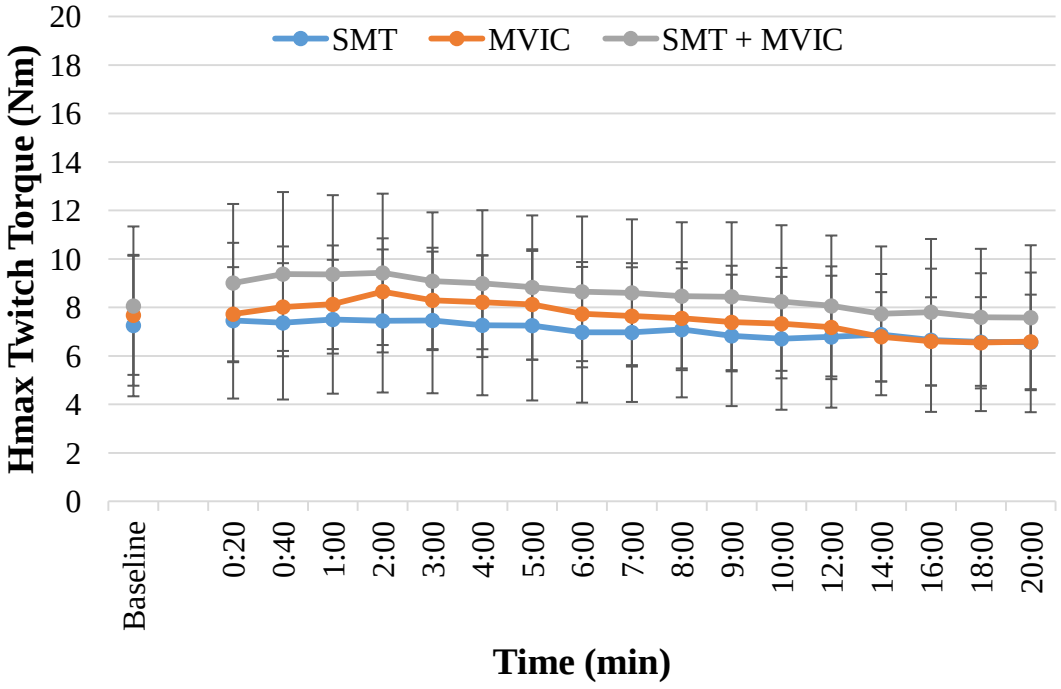

Figure 13. *Changes in the H_{max} isometric twitch torque post-treatment. Mean ± SD.*

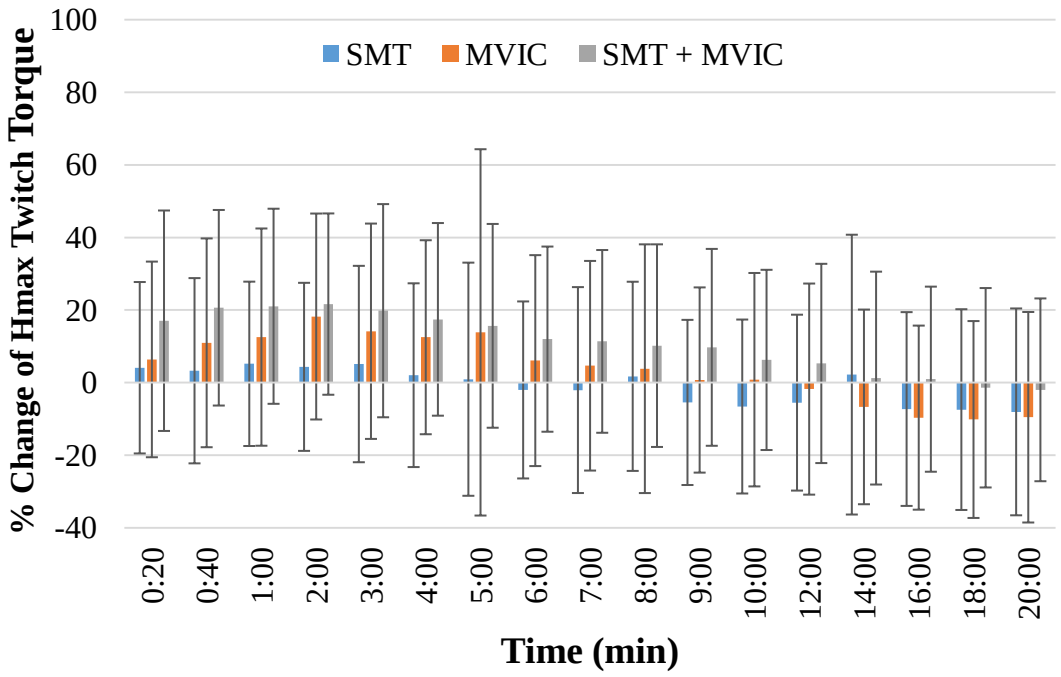

Figure 14. *Percent change of H_{max} isometric twitch torque from baseline following each of the experimental conditions. Mean ± SD.*

Twitch torque at M_{max} ($F(18, 342) = 1.978$, $p = 0.389$) is illustrated below in Figure 15 and percent changes from baseline of twitch torque at M_{max} are presented in Figure 16. Twitch torque was immediately elevated following all three treatments, which remained above baseline levels after the MVIC, until 15:00 following SMT + MVIC and until 7:30 after SMT. Significance was not reached during the increases in twitch torque following any of the three treatments (Figure 15).

In the percent change from baseline of M_{max} twitch torque ($F(18, 342) = 3.843$, $p = 0.005$), significant post-hoc differences were identified in the percent change from baseline of M_{max} twitch torque at several time points, which occurred: at 10 seconds between SMT and MVIC ($p = 0.006$), and between SMT and SMT + MVIC ($p = 0.024$); at 50 seconds between SMT and MVIC ($p = 0.015$); at 1:30 between SMT and MVIC ($p = 0.008$); at 3:30 between SMT and MVIC ($p = 0.006$); at 5:30 between SMT and MVIC ($p = 0.037$); and at 7:30 between SMT and MVIC ($p = 0.038$).

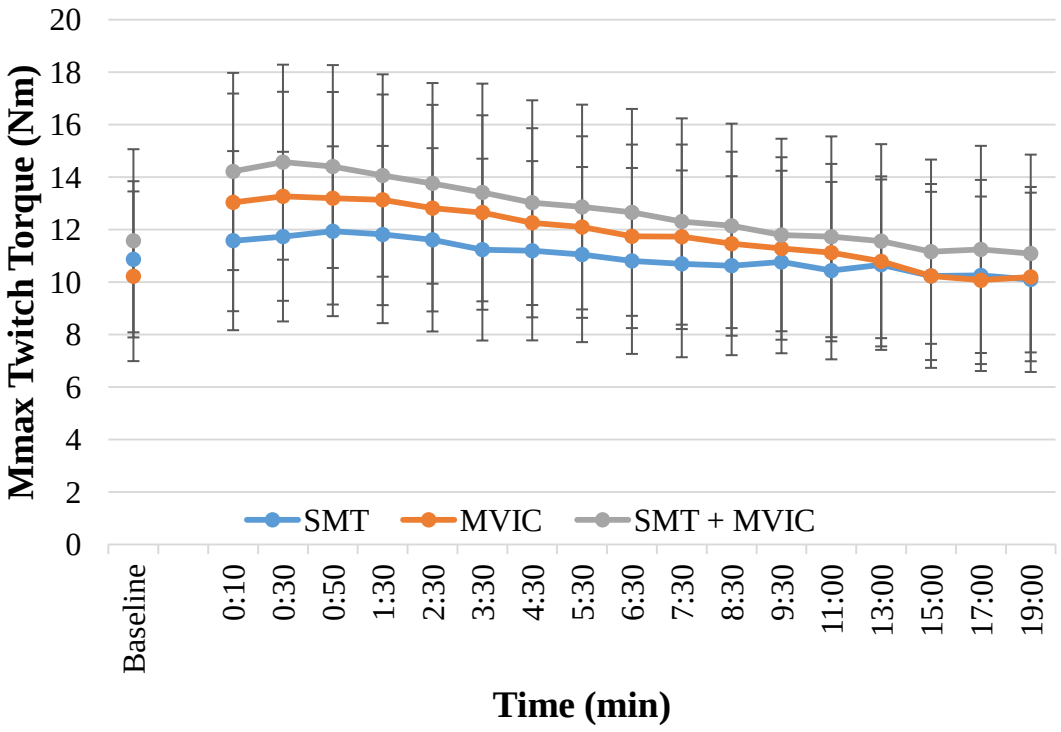

Figure 15. *Changes in the M_{max} isometric twitch torque post-treatment. Mean ± SD.*

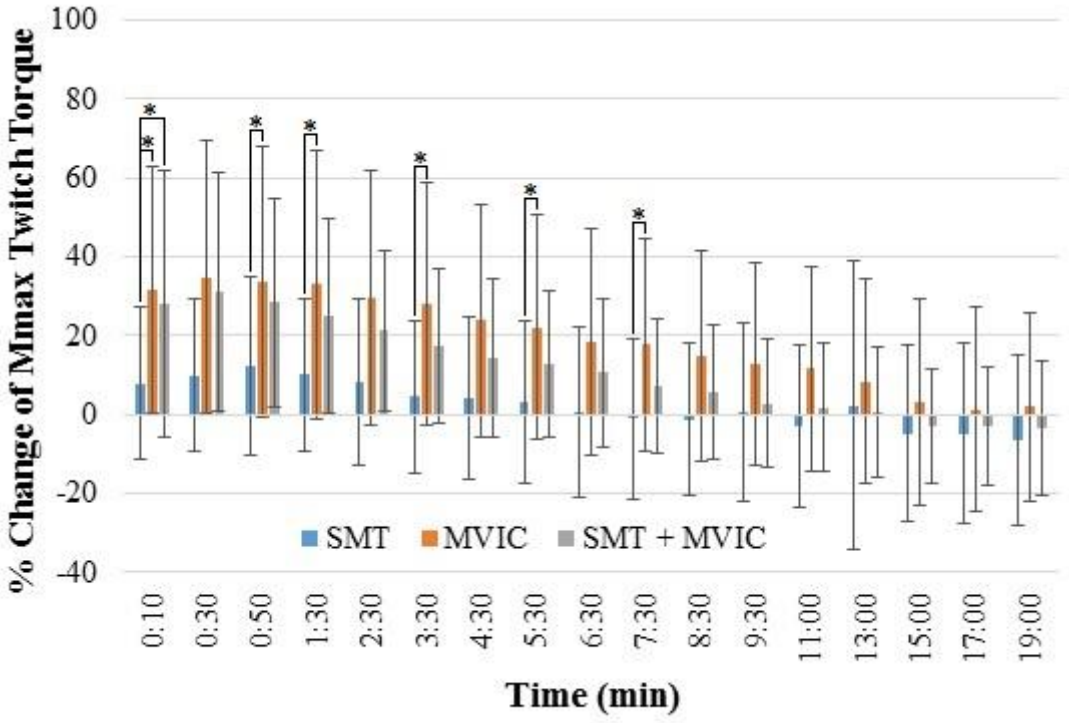

Figure 16. *Percent change of M_{max} isometric twitch torque from baseline following each of the experimental conditions. Mean ± SD. *p < 0.05.*

Control group

Temporal changes in all four dependent variables measured in the five control group subjects during both sessions of H-reflex electrical stimulation protocol recordings on two separate days are displayed below in Figures 17 – 20. The gastrocnemius H_{max}/M_{max} ratios are depicted in Figure 17. The mean H_{max}/M_{max} ratios from day one were 7.6 ± 3.8 during session 1 and 8.2 ± 3.6 during session two. The mean H_{max}/M_{max} ratios from day two were 9.9 ± 5.3 in session one and 9.3 ± 4.1 in session two.

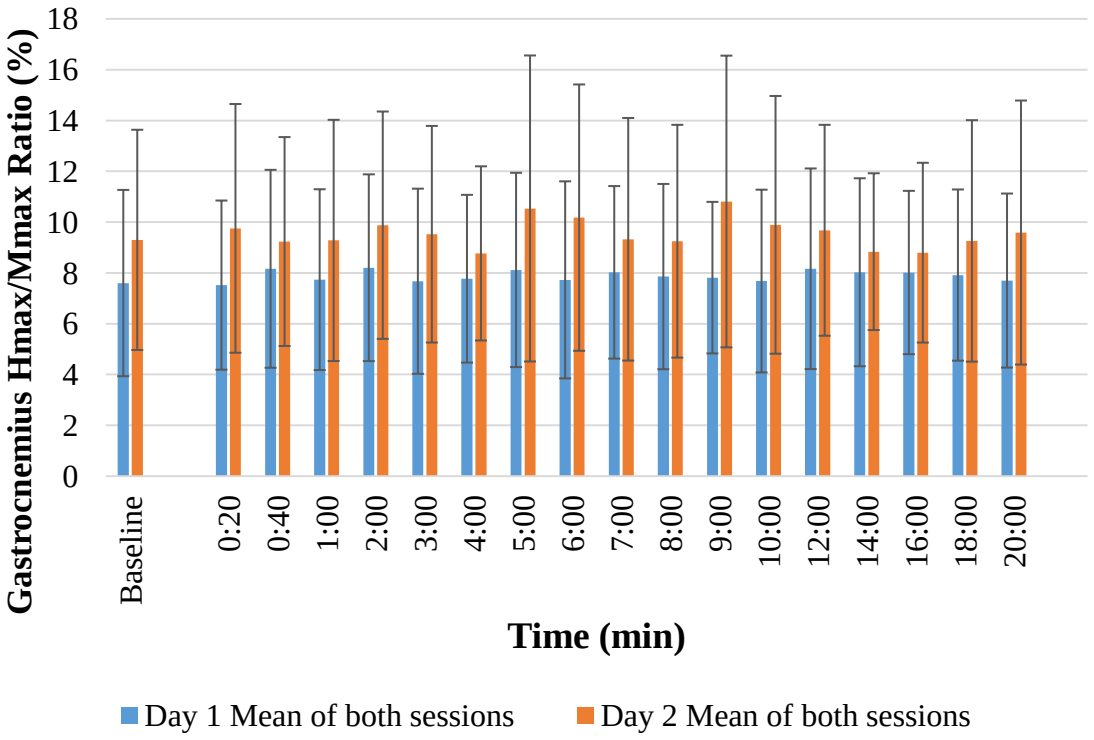

Figure 17. *Temporal changes in the control group gastrocnemius H_{max}/M_{max} ratios.*

The soleus H_{max}/M_{max} ratios are illustrated below in Figure 18. The mean H_{max}/M_{max} ratios from day one were 42.5 ± 19.9 during session 1 and 43.4 ± 17.6 during session two. The mean H_{max}/M_{max} ratios from day two were 50.8 ± 20.8 in session 1 and 48.8 ± 19.6 in session two.

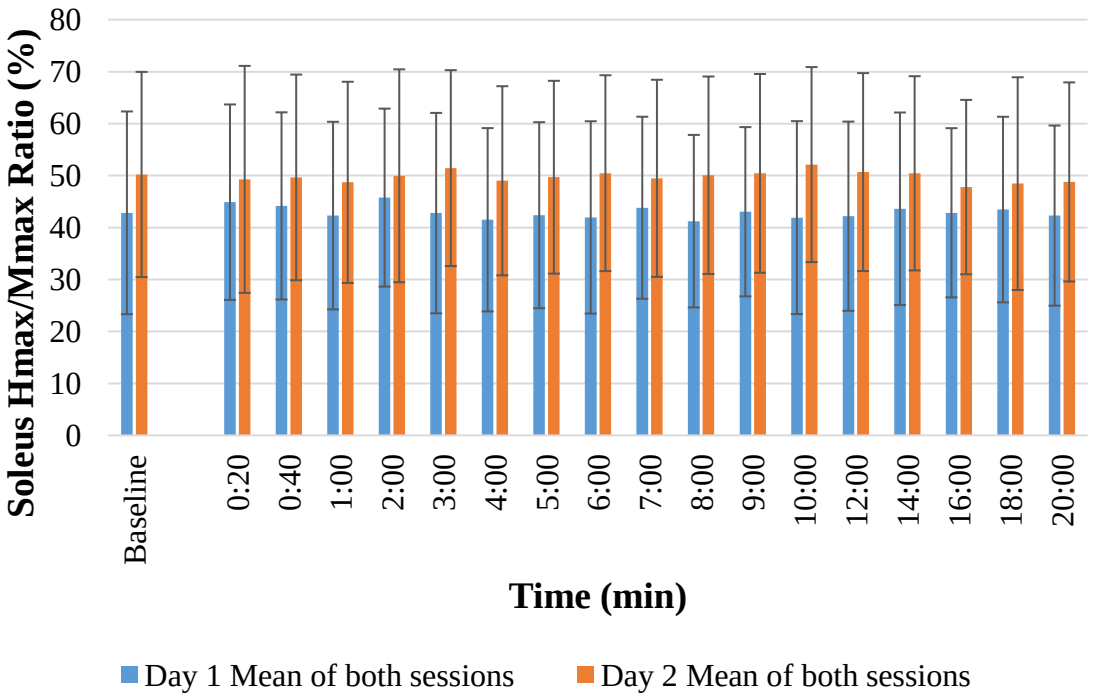

Figure 18. *Temporal changes in the control group soleus H_{max}/M_{max} ratios.*

The isometric twitch torques at H_{max} are shown below in Figure 19. The mean twitch torques from day one were 7.1 ± 3.0 from session 1 and 6.6 ± 3.6 from session two. The mean twitch torques from day two were 5.9 ± 3.8 in session 1 and 6.0 ± 4.4 in session two.

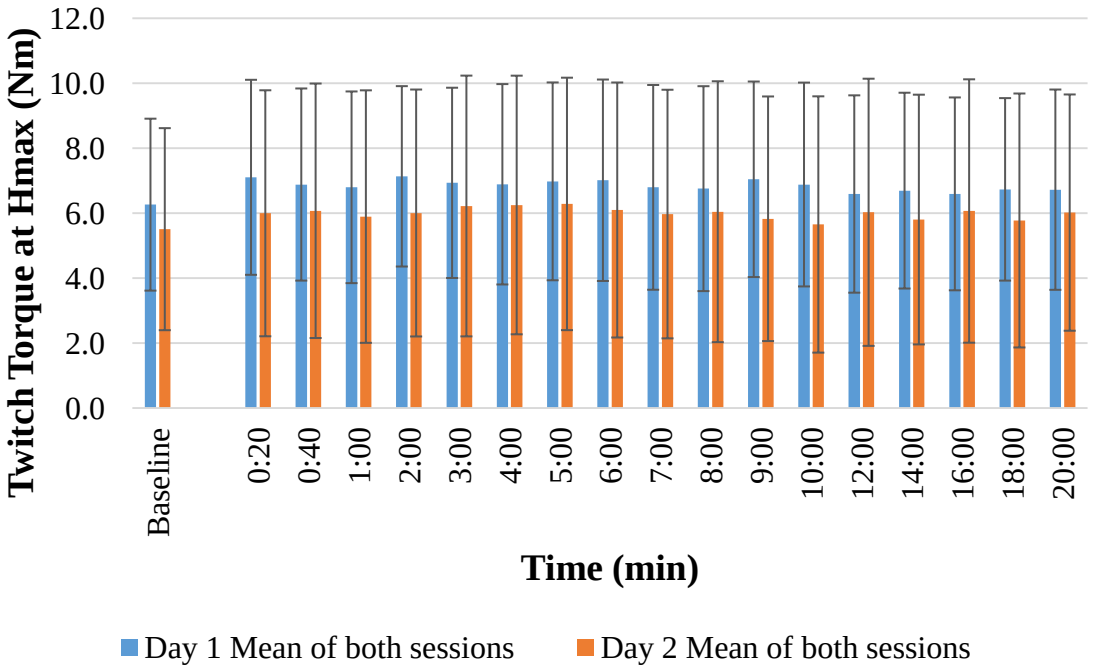

Figure 19. *Temporal changes in the control group H_{max} twitch torques.*

The isometric twitch torques at M_{max} are displayed below in Figure 20. The mean twitch torques from day one were 12.2 ± 2.7 during session 1 and 11.0 ± 2.4 during session two. The mean twitch torques from day two were 10.2 ± 4.1 in session 1 and 10.2 ± 4.9 in session two.

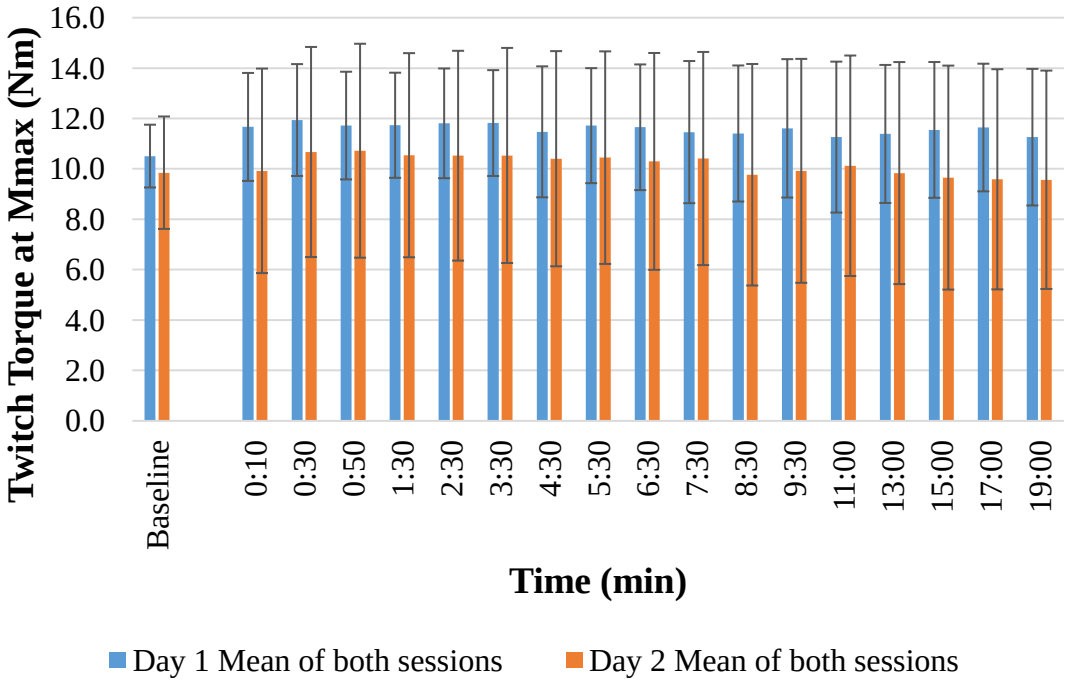

Figure 20. *Temporal changes in the control group M_{max} twitch torques.*

Table 4 below depicts the intra-rater reliability (ICC, [2,1]) of the four dependent variables measured during the H-reflex electrical stimulation protocol with the five control subjects. Expressed as qualitative ratings of agreement,[239] 7 of the 16 measurements demonstrated excellent intra-rater reliability (values between 0.75 and 1.0) and 6 exhibited good reliability (values between 0.60 and 0.74). Poor reliability (values less than 0.40) was revealed in three measurements: the between-day comparison of session one gastrocnemius H_{max}/M_{max} ratios; the day one within-session comparison of twitch torque at M_{max} and the between-day comparison of session one gastrocnemius H_{max}/M_{max} ratios.

Table 4. *Intrasession and intersession reliability of the H-reflex stimulation protocol.*

Dependent Variable	Measurement	ICC (95% CI)	F (*P* value)
Gastrocnemius Hmax/Mmax Ratio (%)	Day 1 Within-session	0.772 (0.664, 0.847)	8.152 (<0.001)
	Day 2 Within-session	0.756 (0.648, 0.834)	7.349 (<0.001)
	Session 1 Between-day	0.329 (0.113, 0.512)	2.186 (<0.001)
	Session 2 Between-day	0.684 (0.520, 0.793)	5.947 (<0.001)
Soleus Hmax/Mmax Ratio (%)	Day 1 Within-session	0.863 (0.797, 0.909)	13.586 (<0.001)
	Day 2 Within-session	0.909 (0.860, 0.940)	21.919 (<0.001)
	Session 1 Between-day	0.627 (0.369, 0.775)	5.387 (<0.001)
	Session 2 Between-day	0.721 (0.541, 0.827)	7.215 (<0.001)
Twitch Torque at Hmax (Nm)	Day 1 Within-session	0.716 (0.588, 0.808)	6.356 (<0.001)
	Day 2 Within-session	0.936 (0.903, 0.958)	29.917 (<0.001)
	Session 1 Between-day	0.633 (0.431, 0.764)	5.142 (<0.001)
	Session 2 Between-day	0.831 (0.746, 0.889)	11.498 (<0.001)
Twitch Torque at Mmax (Nm)	Day 1 Within-session	0.037 (-0.150, 0.229)	1.086 (0.353)
	Day 2 Within-session	0.905 (0.858, 0.937)	19.842 (<0.001)
	Session 1 Between-day	0.106 (-0.075, 0.290)	1.288 (0.124)
	Session 2 Between-day	0.651 (0.501, 0.761)	5.013 (<0.001)

Abbreviation: ICC = Intraclass correlation coefficient.

Discussion

The results did not support the first research hypothesis that significantly greater potentiation would be stimulated by the 10 second plantar flexion MVIC with SMT delivered immediately beforehand versus the potentiation arising from the MVIC only. Instead, the only significant within-subjects effects occurred in the M_{max} twitch torque, identified in the post-hoc analyses as between SMT and MVIC and between SMT and SMT + MVIC. The immediate increase in Mmax twitch torque post-MVIC (Figures 15 and 16) was consistent with other reports.[61,89] As the mechanical component of PAP, the CMAP induced at the Mmax stimulation intensity is a purely efferent response and thus any changes in force are due to enhancement of tension production directly within the myofilaments.[89] Specifically, it has been theorized that there is increased phosphorylation of myosin regulatory light chains, catalyzed by the enzyme myosin light chain kinase.[206] This state is thought to contribute to the enhancement of subsequent contractions by the positioning of the myosin heads closer to the actin filaments, as well as prompting greater myoplasmic calcium sensitivity during the actin-myosin interaction.[60]

While this form of mechanical potentiation occurred following the MVIC both with and without SMT, the fact that these twitch torques were not significantly higher than those following SMT after 7:30 suggests a possible shortcoming with the conditioning activity (Figure 16). It is likely that the single 10 second MVIC did not induce enough potentiation and concurrent fatigue to reach the second "window" of enhanced neuromuscular performance described by Sale[231] and expanded on by Tillin

and Bishop.[196] While potentiation can occur in the first window, resulting performance is not augmented to the same degree as when fatigue subsides in the second window from a conditioning activity of greater volume and intensity. This concept is illustrated below in Figure 21, reprinted from Sports Medicine, Volume 39, Tillin N and Bishop D, Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities, pp. 147-66, Copyright 2009, with permission from Springer publishing company (license # 3683330377460).

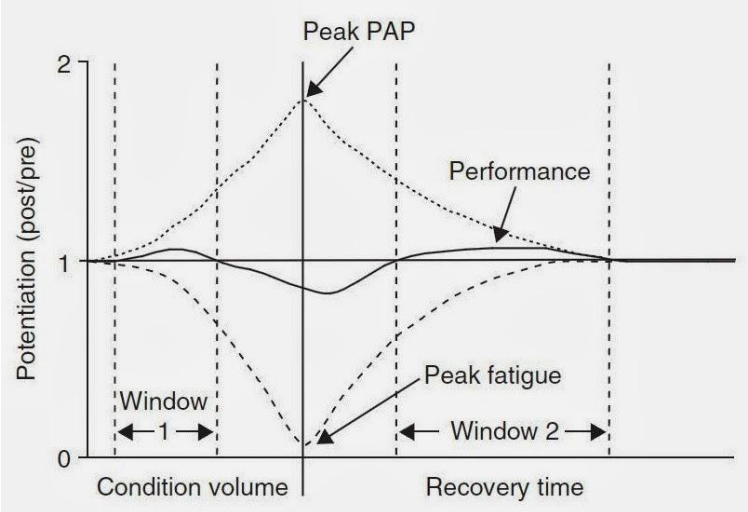

Figure 21. A model of the hypothetical relationship between postactivation potentiation (PAP) and fatigue following a pre-conditioning contraction protocol (condition).[196]

The likelihood of the MVIC not inducing enough fatigue might also explain why the duration of PAD was relatively shorter than what is reported in the literature. For resistance-trained subjects, a rest time of at least seven minutes post-conditioning activity has been shown to result in enhanced subsequent performance of explosive.[56] However, these results were also reached from studies in which the majority of the experimental designs incorporated multiple sets of multi-joint exercises as the conditioning activity. PAP did occur nonetheless, as Figures 14 and 16 show the twitch torques at H_{max} and M_{max} exceeded baseline recordings immediately post-MVIC with and without SMT. This time course of potentiation is also similar to the results of Folland, Wakamatsu and Fimland,[89] whose methodology (including the single 10 second MVIC) served as the basis for this experiment.

It is also possible that the shorter delay in potentiation compared to other studies may be related to the second research hypothesis, that SMT with the MVIC would decrease the time span of PAD, and trigger an earlier onset of PAP compared to the MVIC only. While decreased durations of PAD did not occur in the H_{max}/M_{max} ratios of both muscles and their percent changes from baseline (Figures 9 – 12), it did transpire in the H_{max} twitch torque. Figure 13 shows that the twitch torque rose above baseline immediately post-SMT + MVIC, compared to at 40 seconds post-MVIC.

It has been found that a conditioning activity of multiple sets at moderate intensities (60-84% of 1RM) produce the greatest potentiation.[199] However, a single 10 second MVIC was chosen for three reasons. The first reason is it was thought by the PI that a maximal intensity contraction would compensate for only one set in view of the recommended moderate intensity with several sets. Second, the single plantar flexion MVIC of the same duration was what Folland, Wakamatsu and Fimland[89] employed, which resulted in much a greater potentiated response in only recreationally active participants. PAP has also been documented following five second plantar flexion MVICs employed in two other studies.[109,195] The third reason in support of using the single MVIC is because it is important to minimize subject movement with H-reflex testing. An isometric contraction helps ensure that the data are minimally influenced by subject movement and accurately reflect the effects of the treatments as much as possible. Furthermore, it has been reported that a significant difference does not exist in potentiation resulting from static compared with dynamic activities.[199]

The third hypothesis was that the gastrocnemius muscles would yield much greater potentiation than the soleus, in line with several authors' conclusions that a potentiated response post-conditioning activity is much more likely in muscles with a high proportion of Type II muscle fibers.[59-61,63,64] The results of this study support this concept, evident in the contrast between the percent change from baseline of the gastrocnemius and soleus H_{max}/M_{max} ratios in Figures 10 and 12, respectively. In addition to greater phosphorylation of myosin regulatory light chains and increased calcium sensitivity of the myofilaments,[60,61,64,206] it has been hypothesized that stimulation of sodium-potassium active transport also may occur.[61,206] This effect would also be more pronounced in Type II fibers, which have a greater density of sodium-potassium pumps within the sarcolemma.[61] Likewise, the inclusion criteria of this study were chosen in consideration of these factors, to ensure that subjects possessed a sufficient percentage of Type II fibers for a potentiated response to be recorded. The final research hypotheses was that SMT only would result in PAD for less than one minute, followed by the return of EMG amplitudes and isometric twitch torques to baseline levels. This prediction was consistent with findings in the manual therapy literature.[80-83,85-87] The temporal profiles of the H_{max}/M_{max} ratios of the gastrocnemius and soleus, however, reveal that the peak-to-peak amplitudes of both muscles did not return to baseline until 2:00 post-SMT (Figures 9 – 12). Perhaps a greater relaxation response was initiated in this sample population than in the subjects of other studies.

According to the sub-classifications of potentiation from Folland, Wakamatsu and Fimland,[89] SMT paired with the MVIC did not augment electrical potentiation as per the results of the temporal and percent changes in the H_{max}/M_{max} ratios of the gastrocnemius and soleus (Figures 9 - 12). The twitch torque at M_{max} following SMT + MVIC revealed no significant mechanical potentiation of SMT + MVIC (Figures 15 and 16), and the twitch torque at H_{max} also indicated no significant increase in the combination of electrical and mechanical potentiation following SMT + MVIC (Figures 13 and 14). In light of this information, neither CNS excitability nor phosphorylation of myosin regulatory light chains was significantly increased when HVLA SMT was delivered immediately before contractile activity to induce PAP.

The lack of overall significant differences between the effects of MVIC versus SMT + MVIC do not support the premise that SMT enhances PAP. This lack of statistical significance was also due to the substantial inter-subject variability in the means at each time point. The wide spread in the data occurred even with the use of a common normalization procedure of Hmax (the H_{max}/M_{max} ratio)[65] However, another consideration is the reliability of the H-reflex recordings during the electrical stimulation protocol as revealed by the within and between-session reliability of the control group. The most likely explanation for the poor reliability of three of the 16 measurement comparisons is because the first subject produced the widest range of data. These data were not outliers, but their presence created greater overall variability considering that responses from only four other subjects were recorded. It is unable to be determined from the literature reviewed for this investigation why ICC values or other analyses of instrumentation reliability were not reported. A number of different contributing factors may apply to this scenario. This lack of reporting may be due to the fact that, as was the case in the current investigation, these results were not anticipated. In addition to reliability studies, future research efforts incorporating the H-reflex need to include the results of reliability analyses of the instrumentation/control group. Exercise science research may introduce more factors which may increase the likelihood of greater variability in responses to H-reflex stimulation protocols than in clinical uses of the H-reflex. It is established in the literature that with the H_{max}/M_{max} normalization procedure, the soleus H-reflex has high reliability, widely reported as an ICC (2,1) of 0.975 or higher.[65,240]

Clinical studies of the effect of SMT on H-reflex amplitudes[80-83,85-87] and of PAP on the H-reflex in exercise science journals[89,90,209-211] include comparable variability in EMG peak-to-peak amplitudes and/or isometric twitch torque. For example, Fryer and Pearce reported mean H_{max}/M_{max} ratios (%) of 17.32 ± 9.92 (Mean ± SD) following lumbosacral HVLA SMT via tibial nerve stimulation of the lateral gastrocnemius in subjects who were asymptomatic with regard to low back pain.[86] Similarly, in their investigation of neuromechanical mechanisms of PAP, Folland, Wakamatsu and Fimland reported H_{max}/M_{max} ratios (%) of 23.6 ± 11.1 at one minute post-MVIC and 31.5 ± 15.4 at five minutes; their results were drawn from femoral nerve stimulation of the quadriceps femoris.[89] By comparison, the means of the H_{max}/M_{max} ratios (%) measured in this study at one minute post-treatment were 6.5 ± 3.5 after SMT, 6.3 ± 3.4 following the MVIC and 5.4 ± 3.1 after SMT + MVIC. At five minutes post-treatment, the H_{max}/M_{max} ratios were 7.5 ± 3.9 after SMT, 7.0 ± 4.2 following the MVIC and 5.8 ± 3.6 after SMT + MVIC.

A final consideration is that the most active subjects and also the closest to the top tier of PAP responders (high level athletes)[78] were subjects 10, 16 and 22 (Figures 18 – 21). The percent changes from baseline in the H_{max}/M_{max} ratio of the gastrocnemius are shown in Figure 18 and in the soleus in Figure 19. Both figures reveal that electrical potentiation was induced in these three NAIA Division I baseball players only following the MVIC. Figure 20 illustrates their H_{max} twitch torque percent change from baseline, which is similar to the means of the rest of the subjects following SMT + MVIC (Figure 14). The M_{max} twitch torque percent change from baseline is displayed in Figure 21.

Compared to the means of all 20 subjects (Figure 16), a greater amount of mechanical potentiation was recorded in these three subjects following SMT + MVIC.

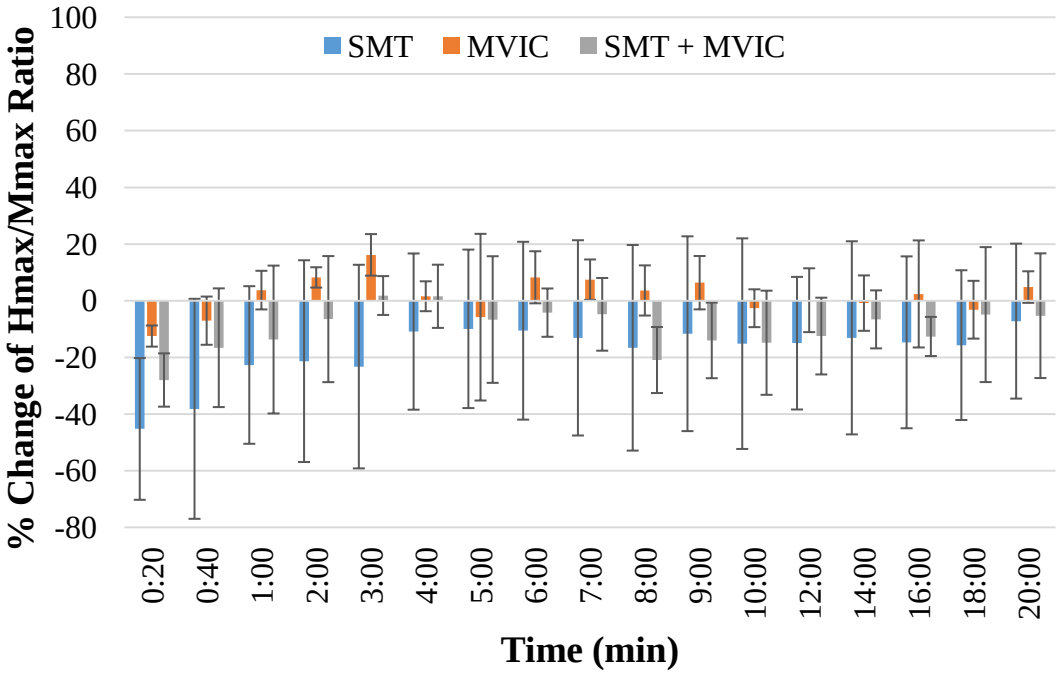

Figure 22. *Temporal changes in the gastrocnemius H_{max}/M_{max} ratio relative to baseline amplitudes following each of the experimental conditions in subjects 10, 16 and 22. Mean ± SD.*

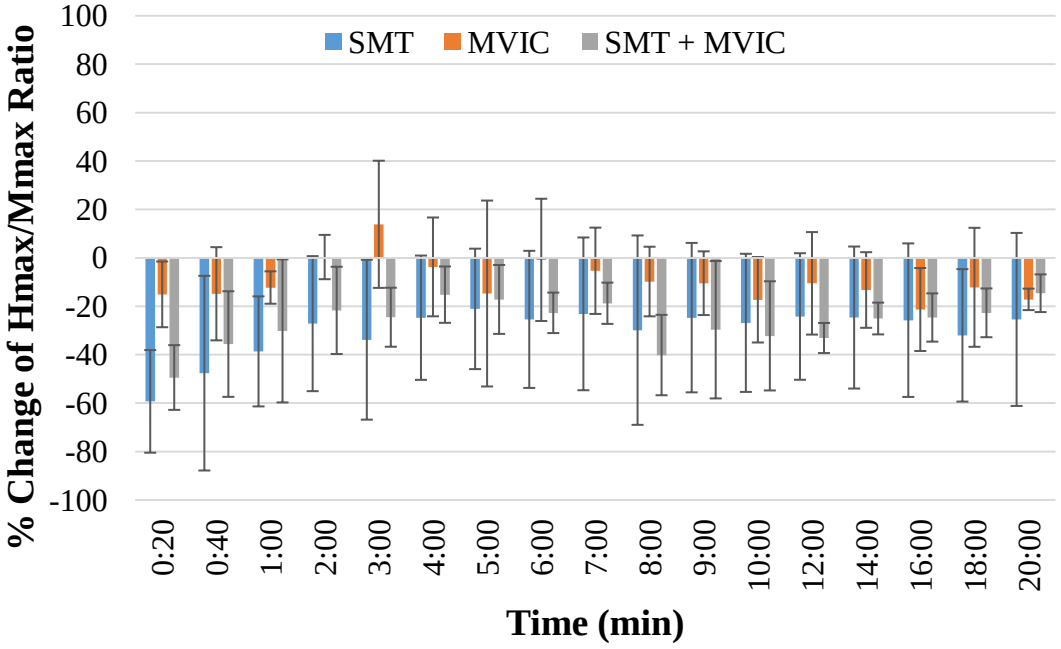

Figure 23. *Temporal changes in the soleus H_{max}/M_{max} ratio relative to baseline amplitudes following each of the experimental conditions in subjects 10, 16 and 22. Mean ± SD.*

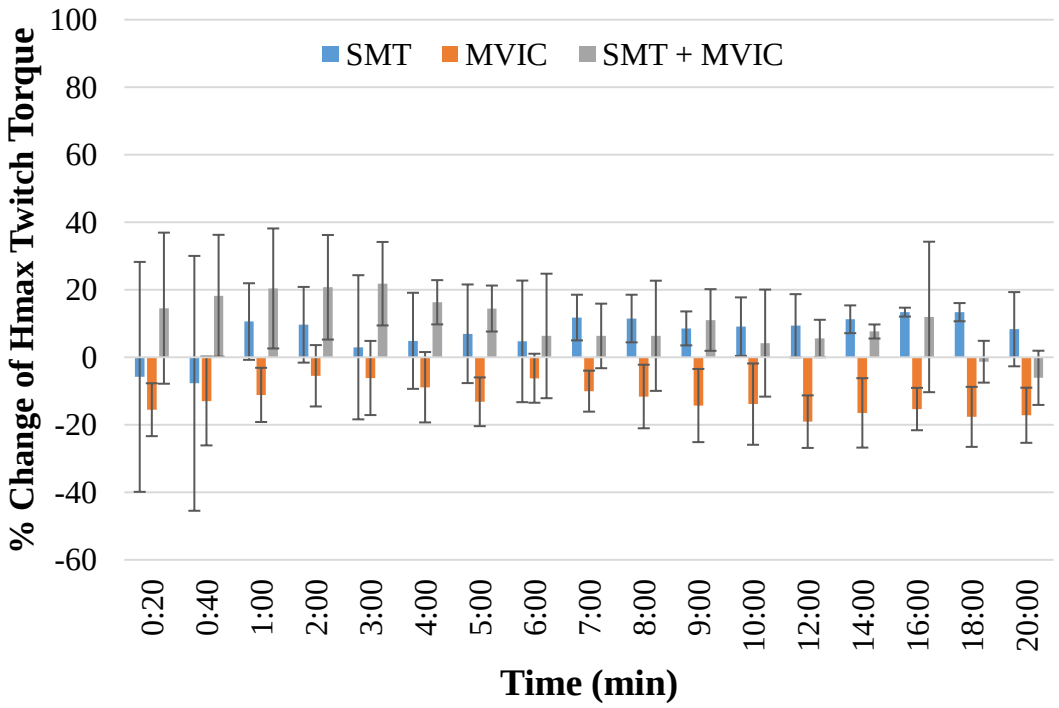

Figure 24. *Temporal changes in the H_{max} isometric twitch torque relative to baseline twitch torques following each of the experimental conditions in subjects 10, 16 and 22. Mean ± SD.*

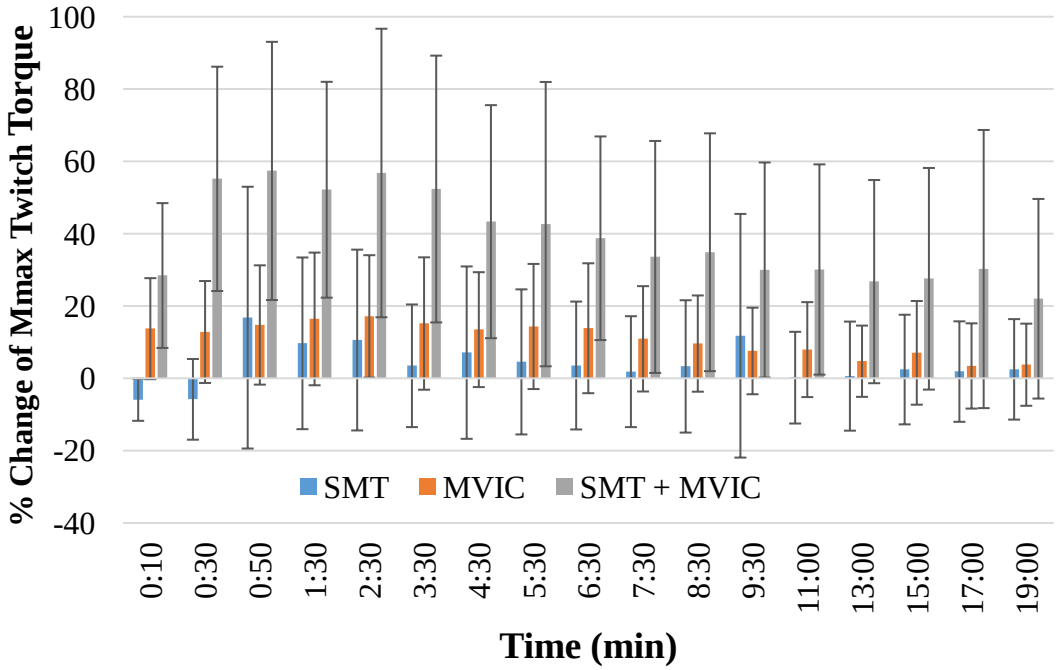

Figure 25. *Temporal changes in the M_{max} isometric twitch* torque *relative to baseline twitch* torques *following each of the experimental conditions in subjects 10, 16 and 22. Mean ± SD.*

The data from subjects 10, 16 and 22 hint that a greater sample size of subjects who are all college athletes might have produced more significant differences in the overall effects of the treatment means. A post-hoc power analysis depicted below in Table 5 reveals that for adequate power (0.80), 10 more subjects were needed for the gastrocnemius H_{max}/M_{max} ratio percent change from baseline, 19 more subjects for the soleus H_{max}/M_{max} ratio percent change from baseline and one more subject for the H_{max} twitch torque percent change from baseline. Conclusions cannot be drawn from this post-hoc analysis as to a potential difference in the efficacy of any of the three treatments; rather, these data are provided due to the greater than expected variability in the results.

Table 5. *Within-subjects effects and post-hoc power analysis.*

Result		Gastrocnemius H/M ratio %Δ from baseline	Soleus H/M ratio %Δ from baseline	Hmax Torque %Δ from baseline	Mmax Torque %Δ from baseline
Significance ($\alpha = 0.05$)	Sphericity assumed	0.420	0.692	0.088	0.000
	Greenhouse-Geisser correction	0.393	0.548	0.181	0.005
Effect size	partial η^2	0.052	0.041	0.073	0.168
Observed power	Sphericity assumed	0.735	0.594	0.910	1.000
	Greenhouse-Geisser correction	0.304	0.281	0.582	0.905
Post-hoc minimum sample size	Power = 0.80	30	39	21	12
	Power = 0.95	45	57	33	15

It is also interesting to note that subjects 10, 16 and 22 were among the 13 subjects who denied any form of supplement consumption on the health history questionnaire, so hypothetically might have had yielded even greater PAP with supplement use. Among the 12 other subjects, supplement usage included multivitamins, protein powder, branched chain amino acids (BCAAs), pre-workout supplement, creatine and fish oil. These other 12 subjects still participated in the study because the only supplement that would have directly impacted the testing would have been the pre-workout ergogenic aid, and subjects claimed that any caffeine intake was not within several hours of testing. All subjects also denied anabolic steroid use.

Limitations

Although the connection between Ia afferents and αMNs in the ventral horn of the spinal cord is monosynaptic, the H-reflex is not a pure measure of CNS excitability.[60,65,66] Modification within the CNS occurs in the form of presynaptic inhibition descending from supraspinal influences and in the periphery from inhibitory actions of the Golgi tendon organs along Ib afferents as well as cutaneous afferents[67] (hence the need to minimize subject movement during data collection). If rigorous methodology is not exercised, these inhibitory inputs can significantly alter the monosynaptic neurotransmitter release. As a result, the amplitude of the H-reflex would be decreased, irrespective of actual changes in αMN activity and possibly leading to false negative results regarding the efficacy of the treatment.[60,65]

A consequence of the filtering needed to convert the raw EMG signals and torque data into quantifiable signals was the resulting partially incomplete depiction of the total electrical activity and torque production occurring in the gastrocnemius and soleus muscles during the electrical stimulations. The SEMG recordings also included the potential for crosstalk, most notably from the peroneal muscles with the collection of the lateral gastrocnemius EMG amplitudes. The effect of adipose tissue detracting from the EMG amplitudes also cannot be discounted, even though most of the sample population exhibited low body fat percentages.[187] Intersession variability in the placement of the stimulating and recording electrodes was another limiting factor. Since the Sharpie pen "x" marks underlying each site faded between sessions, these exact points had to be re-measured during subject preparation at the beginning of each session. In addition, despite the best efforts of the PI, other measurement errors were likely due to factors such as inducing inexact H_{max} and M_{max} stimulation intensities with the turn dial on the Digitimer muscle stimulator. Also, despite the measures taken to prevent the heel from lifting off of the foot plate of the ankle attachment, the two padded straps cinched around the subject's upside femoroacetabular joint and downside thigh and visual observance by the PI, a slight amount of cephalad axial translation inevitably occurred during the electrical stimulations, detracting from the full isometric twitch torques.

Subject heterogeneity was another limiting factor to extrapolation of the results, specifically regarding age, anthropometric measures, supplementation use, relative and absolute strength and also the neural recruitment patterns of the subjects,[59] despite all meeting the inclusion criteria. Ideally, the entire sample population would engage in the same training regimen and explosive athletic activity/sport to display less variability in neural recruitment factors and possibly a greater proliferation of Type IIx fibers. Furthermore, the CMAPs induced by electrical stimulation under controlled laboratory conditions have limited applicability to training or competition. The electrical stimulations to invoke the H-reflex bypass the muscle spindle, which are essential in the coordination of muscle fiber recruitment during physical activity. Nonetheless, the results are intended supplement what is currently known regarding the neurophysiological effects of SMT, with specific application to PAP in a resistance-trained sample population. More studies are needed which include multiple sets of compound exercises like the majority of the conditioning activities implemented to induce PAP in the exercise science literature for more direct inferences on performance enhancement.

Conclusions

The delivery of side-posture, lumbosacral HVLA SMT immediately preceding the 10 second plantar flexion MVIC did not produce a significantly greater amount of potentiation than that following the MVIC alone. However, given the substantial variability present in all of the measurements, different results might have been yielded with the recruitment of a larger number of subjects. The effects of SMT alone were similar to those reported in the manual therapy literature, with a slightly longer duration of EMG amplitude attenuation.

Chapter 5: Summary discussion

Introduction

Chronic intervertebral joint hypomobility, referred to by many synonyms, such as a manipulable lesion by chiropractors and somatic dysfunction by osteopaths, is believed to precipitate several clinical consequences. In addition to decreased range of motion and a predisposition to an earlier onset of degenerative changes and pain, other factors are thought to occur due to associated neural dysfunction. These factors stem from the alteration of afferent input from mechoreceptive structures in the peripheral nervous system.[108,120] This hyperactive state is thought to lead to altered somatosensory integration within the CNS with increased nociception and decreased mechanoreception.[2,108] The purported clinical result is a facilitated state of hypertonicity of the segmentally innervated musculature,[104,122] which perpetuates a cycle of faulty movement patterns, postural distortions, myofascial trigger points and pain.[94]

SMT, in addition to improving joint kinematics, is thought to positively affect neural functioning.[119,120,128,136,138] It has been postulated that the facilitated state is silenced with the barrage of afferent signals from each of the mechanoreceptive structures of the intervertebral joint complex triggered by HVLA SMT (such as the facet joint capsule, dorsal root ganglion, intervertebral disc and muscle spindles and golgi tendon organs of the instrinsic muscles of the spine).[126] As a result, the gamma gain of the muscle spindles would be decreased, leading to a relaxation response.[98,105,120,165] This immediate resulting improvement in joint ROM and decreased muscle hypertonicity and pain is thought to create a window for increased effectiveness of other forms of therapy; these procedures typically include corrective exercises and postural retraining to address any muscle imbalances or other factors contributing to the spinal joint fixations. Related home care recommendations often include holistic factors such as ergonomic corrections, stress management techniques and nutritional advice.

Research investigations of these purported neurophysiological effects in the manual therapy literature have revealed various changes in CNS activity in response to SMT in both symptomatic (back pain) and asymptomatic subjects. Various forms of instrumentation has been employed for this purpose, such as transcranial magnetic stimulation (TMS), twitch interpolation, various pain sensitivity measures, surface and indwelling EMG and the H-reflex. However, inconsistent results have been reported with each of these measures. For example, increases in motor neuron excitability[113,114,116-118] as well as unchanged MEP amplitudes[188,189] have been documented during TMS measurements post-SMT. Similar variance has been reported in the peripheral nervous system with analyses of changes in SEMG amplitudes subsequent to SMT.[177-182] These results include no change or a decrease in amplitudes in resting muscle activity, which was correlated with muscle hypertonicity pre and post-manipulation. Conversely, significant increases in EMG amplitudes have also been reported during MVICs in both symptomatic and asymptomatic participants.[34,37,44,46] Several authors[104,119,120,130,131] have attributed the changes in neural activity post-SMT to altered CNS processing of afferent input from the segmentally-innervated structures of the restricted intervertebal joint. It has been further proposed that the perpetual aberrant afferent signals of the fixated

motion segment are ameliorated by the dynamic stimulus during HVLA SMT. This event occurs in response to the afferent bombardment generated from mechanoreceptive structures of the joint complex and concomitant neuroplastic changes in CNS processing of the mechanoreceptive input.[113,114]

Apart from these chiropractic and osteopathic theories, however, the significance of the reported neurological measures post-SMT are not understood. The physiological response with inclusion of contractile activity following SMT is also unknown. It was thought that since increased neural activity in back pain patients as well as in asymptomatic subjects has been documented at rest, the neuromuscular effects of SMT would work synergistically with CNS mechanisms of PAP in healthy participants. This hypothesized augmented neural functioning was hypothesized to occur due to factors such as decreased αMN inhibition within the ventral horn of the spinal cord.[255] The removal of restrictions in neural signal propagation also was considered, such as in one example of reported increases in H-reflex EMG amplitudes immediately post-SMT in patients diagnosed with a lumbar disc herniation.[79] The first study therefore investigated if these effects would occur in healthy, college-aged subjects, thereby enhancing strength. As the efficacy of both SMT and PAP has been attributed in part to changes in CNS, the second study included physiological measurements of PAP in resistance-trained participants.

Research questions and hypotheses

The first study was completed to determine if gross muscle strength can be enhanced following the delivery of SMT. The findings were also used for comparison with reported strength increases during MVICs post-SMT in other studies, as well as to add to these results with the inclusion of dynamic contractions. These objectives were accomplished by measuring the effect of HVLA SMT delivered to the lumbar spine and/or sacroiliac joint on peak torque production measured during isometric and concentric isokinetic MVCs of knee extension and flexion. Based on previous studies, it was hypothesized that significant differences would be found between the peak torques following SMT and the sham manipulation at five minutes post-treatment, but not at 20 minutes. It was also estimated that the significant increase in peak torque generation would be most notable during the isometric contractions.

The second study delved further into the neurophysiological effects of SMT by investigating if the same form of lumbosacral HVLA SMT affects spinal reflex excitability. This was assessed using PAP as a measurement tool, indicated by changes in peak-to-peak EMG amplitudes and twitch torques of the gastrocnemius and soleus during tibial nerve H-reflex electrical stimulations. These data were associated with a commonly cited contributing factor to PAP, in which increased CNS drive post-contractile activity results in increased motor unit recruitment and force production. It was hypothesized that SMT delivered immediately before a 10 second plantar flexion MVIC would result in greater PAP than from the MVIC only. In addition, it was thought that the addition of SMT would induce a faster onset of PAP, which would be revealed to a much greater extent within the gastrocnemius than the soleus. Additionally, it was presumed that SMT would not generate a potentiated response, but rather decrease spinal reflex excitability

for less than one minute, followed by a return of EMG amplitudes and twitch torques to baseline levels.

The rationale underlying the hypotheses of both studies was based on several of the effects of SMT reported in the manual therapy literature. These effects include the amelioration of possible hampered impulse-based mechanisms of nerve conduction arising from nerve root compression and inflammation, a decrease in muscle inhibition which was reported in healthy subjects[34] in addition to those with anterior knee pain[35-37] and the generation of a massive influx of mechanoreceptive afferent input within the CNS from the mechanoreceptors of the intervertebral motion segment during the HVLA thrust. It has been proposed within chiropractic and osteopathy literature that this bombardment of afferent information may silence facilitated gamma motor neuron activity and restore normal muscle tone,[98,105,120,165] thus possibly improving ROM and the length tension-relationship of the intrinsic muscles of the spine. The results of both studies would therefore occur because of enhanced PAP with a synergistic increase in CNS excitability and neural drive, thereby increasing αMN recruitment, firing rate and resulting force generation.

Discussion

It was found in the first study that a statistically significant difference did not occur between the effects of lumbosacral SMT or the sham manipulation in the percent changes of knee extension and flexion peak torques at 5 and 20 minutes post-treatment. In the second study, an overall significant difference did not occur in the potentiation that was induced by the delivery of SMT immediately preceding the MVIC compared to the MVIC alone. Considering only the significance levels of the within-subjects effects from the repeated measures ANOVAs of these two investigations, the inclusion of HVLA SMT pre-training or pre-competition is not supported. This is because the results of the repeated measures ANOVAs did not indicate significant differences between the effects of the treatments with and without SMT. These results are in contrast to previously published studies using SMT,[34-54,55] which used poor experimental designs and inadequate strength testing methods. Specifically, these limitations include small sample sizes, lack of a control group and/or not utilizing the most reliable strength measurement methods of isokinetic dynamometry or a load cell. Moreover, less than half of the studies implemented a randomized, controlled experimental design. This unfortunately is also the case with four of five studies which have investigated the direct effects of SMT on sports performance, which included dancers, female distance runners, sprinters and jumpers, baseball players and golfers.[232-235]

The studies included in this work were designed to overcome the limitations of these other investigations while analyzing the effects of SMT on performance and neural excitability. However, based on the results, athletes' utilization of spinal manipulation may only yield clinical benefits, such as a relaxation response, and possibly improving joint kinematics. As such, anecdotal claims of performance enhancement post-SMT could be due to a placebo effect[236] as a consequence of therapeutic touch.[29,237] A final consideration is a possible publication bias, as only 2 of the 22 studies on strength modulation post-SMT[34-55] (20 of which reporting a significant effect of SMT[34-44,46,48-55])

were published in non-chiropractic or manual therapy-related journals.[40,46] Moreover, many of these authors reported funding by chiropractic organizations. While this situation certainly does not guarantee such a bias, it hints at a greater likelihood of its occurrence.

While the data presented here do not support the use of SMT, it cannot be definitively concluded that SMT does not enhance strength and/or PAP. In both experiments, a large amount of variability was present in all of the dependent variable measurements, thereby reducing the likelihood of detectable significant differences between the effects of each treatment. Another consideration is that in the first study, only about half of the subjects required by the power analysis were recruited due to time constraints. In the second study, more subjects were needed for analysis of all time points. In both cases, a significant difference might have been revealed with a greater number of participants. This is especially evident in the second study, in which a difference in the means at each time point following each of the three treatments was evident with each dependent variable. Thus, it is plausible that significant differences between each treatment could have been detected with a larger sample size and greater subject homogeneity, such as with all collegiate or professional athletes on the same team to ensure the same training regimen (with slight variations for each position but the same overall). This possibility is evidenced by the results of subjects 10, 16 and 22, who were the most active of all 25 participants. However, in view of elite athletes, the subject category shown to exhibit the greatest potentiated response to conditioning activities,[78] they are still within the second tier subject classification of resistance-trained.

An additional consideration is that although all subjects met the inclusion criteria, they participated in an eclectic mix of physical activities which resulted in a wide variety of training goals, such as strength, power, hypertrophy and endurance. This resulting heterogeneity in subjects' training regimens and muscle fiber type distributions most likely created a wide range of motor unit recruitment patterns, as evidenced by the sizeable variability in the means of each dependent variable. It is interesting to note that during data collection, Subjects 10, 16 and 22 completed only one to two days per week of cardiovascular endurance training. The rest of their time was spent completing resistance training and position-specific training. Consequently, these three subjects likely presented with a high proportion of Type IIx muscle fibers and higher rate coding acquired from the incorporation of Olympic lifts in their training programs. These characteristics likely contributed to their more pronounced potentiated response, particularly revealed as a greater increase in mechanical potentiation (Figure 21).

The question of whether HVLA SMT changes CNS excitability in the second study was resolved with both decreases as well as increases in H-reflex amplitudes. Consistent with the manual therapy literature,[80-83,85-87] the decrease in EMG amplitudes and peak twitch torque following SMT could be due to a relaxation response possibly from silencing facilitated gamma gain of the musculature of the restricted SI joint. The increase in the means of these dependent variables was induced by the CNS stimulation from the MVIC, as per the decreased PAD revealed in the temporal profile of H_{max} twitch torque in Figure 13. If a greater proportion of the MN pool was activated, it would correspond with reports of increased CNS excitability in healthy subjects following

SMT. These changes in neural activity have been recorded at the cortical level with increased MEPs measured during TMS[117,118] as well as at the spinal level with decreased muscle inhibition as revealed by twitch interpolation.[34] However, the changes in excitability observed in this investigation are not in support of the research hypothesis that SMT may enhance PAP. Since significant differences in the treatment effects were not present, it cannot be stated that a greater increase in synaptic transmission occurred between Ia afferents and αMNs with the inclusion of SMT. This occurrence is theorized to be triggered by several factors, including increased neurotransmitter released by the afferent terminals, greater frequency of firing and recruitment of more Type IIx fibers and/or less inhibition from the cortical level or from peripheral afferents such as Golgi tendon organs along Ib fibers. Motor unit recruitment evoked by submaximal electrical stimulation via the Ia afferent pathway transpires according to the size principle.[56,57,65,216] Consequently, if the reflexive EMG amplitude at Hmax is increased post-contraction, then it is presumed in light of this standard that the next units to be recruited would be the larger, high-threshold, fast-twitch motor units. The direct activation of αMNs, which progresses with increasing stimulation intensities higher than H_{max}, theoretically reaches full muscle activation, and thus recruitment of all motor neurons at M_{max}.

It has been reported that subjects with back pain as well as asymptomatic subjects of various fitness levels have all shown increases in strength post-SMT.[34-44,46,48-50,52-55] When the clinical effects of SMT were assessed with the H-reflex, it was found that the depression in peak-to-peak EMG amplitudes returned to baseline within one minute of the manipulation in most cases. In the exercise science literature, it has been concluded that PAP is induced in high level athletes and to a lesser degree in resistance-trained subjects, but not recreationally active.[78] Considering the sample populations of both experiments within this manuscript, the results parallel those of the journals in both fields. In the first experiment, a significant difference was not evident in isometric or isokinetic peak torque production of knee extension and flexion in recreationally active participants. However, to some degree these data may also reflect the general differences between novice and experienced weightlifters, such as in motor unit recruitment and synchronization and muscle cross-sectional area.[165] Hypothetically, the greater the presence of these factors, the greater likelihood that improvement in their function will be shown following the treatments. A similar result occurred in the second experiment with resistance-trained subjects, in which the pairing of SMT with the MVIC did not produce a significant difference in PAP compared to the MVIC only. Despite a difference evident in the effects of each of the three treatments on the dependent variables, which may have been statistically significant with a greater *n*, SMT did not enhance PAP in resistance-trained subjects. Again considering the first study, the inclusion of SMT also did not modulate isometric or isokinetic strength in recreationally active or sedentary subjects. Because of these results, inferences cannot be made regarding the implementation of SMT pre-training or pre-competition in any cycle of periodized resistance training. Such extrapolation must also be withheld because only three longitudinal studies of the effects of SMT on athletic performance have been completed.[234,235,238]

Conclusions

The results of the first study (Chapter 3) suggest that spinal manipulation does not yield a strength-enhancing effect in healthy, recreationally active college-aged subjects. The second study results (Chapter 4) imply that anecdotal claims of enhanced athletic performance following SMT may only be due to placebo effect. However, extensive further research incorporating larger sample sizes must be conducted on SMT to develop a central defining paradigm of the neurophysiological effects of the treatment. This information must have equal application to the fields of healthcare and exercise science to allow for hypothesis testing of strength and/or PAP modulation post-treatment. Until the results of these investigations are established, it cannot be definitively implied that the treatment is not effective in enhancing the performance of explosive athletes, especially given the factors considered in Chapter 2 in support of this possible enhancement.

Future Research

Concerning the first study, future related research is needed involving a larger sample size and with a sample population of a more narrow age range and that is physically more homogenous and highly motivated to generate maximal contractions in the absence of verbal encouragement. Fatiguing contractions should also be measured post-manipulation to generate an idea of the effect on recruitment of Type I fibers for comparison to what has been found involving MVC/MVICs. Also, more experiments must also be designed to compare the strength-modulating effect of SMT in symptomatic and asymptomatic groups of subjects. Regarding the second study, a larger sample size of elite athletes is necessary, as well as a conditioning activity of higher volume and intensity to result in enough fatigue that the second window of PAP is reached. In addition, this conditioning activity should be a closed chain exercise (such as back squats) in order to allow for more direct comparison with the conditioning activities employed in PAP studies in the exercise science literature.

Research is also needed incorporating several forms of instrumentation to further investigate the neurophysiological effects of SMT (such as EMG, MEPs, SEPs, TI and the H-reflex) in a repeated measures design. Ideally, these measurements would be taken at rest as well as pre and post-conditioning activity to induce PAP to compare general changes in CNS excitability post-SMT and generate a complete picture of CNS effects. This experimental design would allow for identification of changes in PAP to be localized to the cortical, spinal, and peripheral levels under conditions of both rest and PAP. A different H-reflex set-up should also be used, possibly prone with the inclusion of Thompson technique (drop table manipulation) or mechanically-assisted SMT, such as with the Activator Instrument.

Measures of the effects of SMT of PAP also need to be taken in addition to the neurophysiological effects, and instead related to the most commonly cited theory of PAP being attributed to increased myofilament sensitivity to calcium, in consideration of the mechanical potentiation evident in the M_{max} twitch torques of subjects 10, 16 and 22. Finally, studies involving longitudinal data collection must take place in order to elucidate the optimal timing for the inclusion of SMT in the pre-training and pre-competition settings, should future evidence of the efficacy of SMT in enhancing PAP

and athletic performance be established. These investigations should also account for clinical factors such as the presence of myofascial trigger points, Upper Crossed/Lower Crossed Syndrome and muscle imbalances, with possible relation to functional training assessment and recommendations. The effect of the full complement of in-office procedures on changes in peak torque and/or PAP provided by all healthcare practitioners who employ manual therapy should also be investigated. These procedures include the use of modalities such as the application of heat packs, interferential current, cold laser and therapeutic ultrasound, as well as different forms of stretching such as passive, active assisted, dynamic and proprioceptive neuromuscular facilitation (PNF). Athletes rarely receive SMT alone, but in conjunction with these listed modalities; therefore, the analysis of these additional factors may provide insight for manual therapists with the secondary goal of optimizing an explosive athlete's training and performance and further promote collaboration with strength and conditioning professionals.

Appendix A: Study #1 subject recruitment flyer

Chiropractic and Strength Research Study

The purpose is to determine if adjusting the lower back can be correlated with lower extremity strength gains. Measurements will be taken during different types of muscle contractions with an instrument called an isokinetic dynamometer.

Please reply if you:

- *Are between the ages of 20-35*
- *Do not have low back, pelvic or leg pain*
- *Have never received chiropractic treatment*
- *Are interested in knowing the strength of your quadriceps and hamstrings*

Contact:
Grant Sanders, D.C.
Principal Investigator
grantdsanders@gmail.com
216-509-3231

UK UNIVERSITY OF KENTUCKY

Appendix B: Study #1 medical history intake form

INTAKE FORM

Subject #_____ **Today's Date:_____**

PAST MEDICAL HISTORY

YES	NO	CHECK YES OR NO FOR EACH QUESTION	DATE AND DESCRIPTION
☐	☐	Have you ever been treated by a chiropractor?	
☐	☐	Do you currently have pain in your lower back, abdomen or legs?	
☐	☐	Any previous injuries to these areas?	
☐	☐	Any surgeries performed in these areas?	
☐	☐	Any previous illness, infection or disease involving your: abdomen, digestion, liver, kidney, autoimmune system, nerves, skin, muscles, collages, blood, connective tissue, joints, brain, spinal cord or spine?	
☐	☐	Recent and unusual problems with balance, walking, talking, vision, ringing in the ears, light headed, dizziness, fainting, swallowing, seizures, sudden onset of severe headache or neck pain/ stiffness, arm/leg weakness or vomiting?	
☐	☐	Women only: Is there any chance that you are pregnant?	

YES	NO	HAVE YOU EVER BEEN DIAGNOSED WITH:	DATE OF DIAGNOSIS
☐	☐	Cardiovascular disease	
☐	☐	Blood clotting disorder	
☐	☐	Stroke	
☐	☐	Aneurysm	
☐	☐	Thromboembolism	
☐	☐	Vascular/neurogenic claudication	
☐	☐	Lumbar disc herniation	
☐	☐	Cauda equina syndrome	
☐	☐	Spondylolisthesis	
☐	☐	Scoliosis	
☐	☐	Diabetes	
☐	☐	Any type of bone disease (such as osteoporosis)	
☐	☐	Any type of joint disease (such as arthritis)	

OTHER INFORMATION

☐ **YES** ☐ **NO** Have you exercised during the past few days?
If so, what type of exercise?
☐ **YES** ☐ **NO** Have you consumed caffeine today?
☐ **YES** ☐ **NO** Are you on any pain medication right now?
☐ **YES** ☐ **NO** Any recent dietary changes?

Appendix C: Study #1 informed consent

IRB Approval
12-0280
THIS FORM VALID
4/29/12 – 4/1/13

Consent to Participate in a Research Study

Pilot Study: Effects of Lumbar Spine Manipulation on Isokinetic Strength of the Knee Extensors and Flexors.

WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?

You are being invited to take part in a research study to help determine how low back adjustments impact the muscles of the lower extremities. You are being invited to take part in this research study because you are between 20 and 35 years of age, have no problems or pain in your lower back or legs and also have never received chiropractic treatment. If you volunteer to take part in this study, you will be one of about 50 people to do so.

WHO IS DOING THE STUDY?

The person in charge of this study is Grant Sanders, who is a licensed chiropractor in the state of Kentucky and a doctoral student in the Kinesiology and Health Promotion Department of the University of Kentucky. He is being guided in this research by J.W. Yates, PhD. There may be other people on the research team assisting at different times during the study.

WHAT IS THE PURPOSE OF THIS STUDY?

By doing this study, we hope to learn if adjusting the lower back impacts the performance of different types of muscle contractions with an instrument called a dynamometer (a device that allows us to measure muscle performance).

ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?

You will not be eligible to participate if you:

1. Have any pain in your lower back, abdomen or legs.
2. Have ever had any of your joints or your back adjusted by a manual therapist (chiropractor, osteopath, physical therapist).
3. Have a history of vertigo (dizziness with standing).
4. Experience dizziness, nausea, vomiting or fainting with certain head movements.
5. Have recently experienced a sudden onset of severe headache or neck pain/stiffness.

6. Have ever been diagnosed with:
    a. cardiovascular disease
    b. blood clotting disorder
    c. stroke
    d. aneurysm (bulge of a major blood vessel)
    e. thromboembolism (blood clot that blocked blood flow)
    f. vascular/neurogenic claudication (pain and discoloration in the lower legs with walking)
    g. lumbar disc herniation
    h. cauda equina syndrome
    i. spondylolisthesis (displacement of spinal structures)
    j. scoliosis (curvature of the spine to the side)
    k. diabetes
    l. any type of bone disease (such as osteoporosis)
    m. any type of joint disease (such as arthritis)
7. Have ever undergone any surgical procedures in your lower back, abdomen, pelvis or thigh/leg.
8. Are pregnant.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?

The research procedures will be conducted at the Biodynamics Laboratory located in the Wenner-Gren Center for Biomedical Engineering. You will need to come to the Biodynamics Laboratory 3 times during the study. Each of those visits will take about 1 hour. The total amount of time you will be asked to volunteer for this study is 3 hours over the course of 3 days.

WHAT WILL YOU BE ASKED TO DO?

You will be asked to report to the Wenner-Gren Center for Biomedical Engineering at three previously scheduled dates and times. All procedures will take place in the Biodynamics Laboratory.

1. Brief medical history
    a. Fill out a short form during your first visit to confirm that you are eligible to be in the study.
2. Physical Exam
    a. After the medical history, a basic neurological assessment will be performed. It will include:
        i. Vitals (body temperature, respiratory rate, heart rate and blood pressure)
        ii. Range of motion of your neck, upper back and low back
        iii. Neurologic evaluation (muscle strength, reflexes and sensory assessment) of your upper and lower extremities.
        iv. Orthopedic tests
        v. Motion palpation of your lower back
3. Treatment
    a. Two therapies will be performed by the same researcher, Grant Sanders. Both will be focused on your low back and performed on the same table on which the physical exam was conducted. During one type of therapy, you will be asked to lie on your side with your upside knee bent, your downside leg straight, and your arms crossed. The researcher will contact the

lower part of your spine with one hand, and place the other hand on your shoulder to stabilize your upper body. The researcher will then slightly drop his weight and deliver a quick, short impulse with his hand through your lower back. During the other therapy, you will be asked to lie face down with your head comfortably in the headrest. A part of the table that utilizes a spring-loaded mechanism will be used to deliver the impulse. It is set by an adjustable tension to hold the your lower back in a half-inch "up" position before the impulse is given by one of the researcher's hands, supported by the other.

b. A random number generator in Microsoft Excel will determine which treatment will be delivered on the second day, and consequently the other treatment will be performed on the third day.

4. Strength Testing
   a. Prior to strength testing, you will warm up for 5 minutes on a stationary bike pedaling at a comfortable rate. Then you will be assessed for the maximum amount of force that your leg (thigh) muscles can generate on a Biodex strength testing machine.
   b. Muscle strength will then be determined in your dominant leg in a seated position on the Biodex. To minimize the use of muscles other than your leg muscles, you will be stabilized with two shoulder straps, a waist strap, an upper leg strap and an ankle strap. Your muscle strength will be the highest force generated during 6 trials of isometric knee contractions (3 pushing your ankle away and 3 pulling it in toward you) held for 5 seconds each at a knee angle of 60°. A one minute rest period will be given between each knee contraction.
   c. Your muscle strength will also be determined by pushing and pulling your ankle in the same way at two controlled movement speeds (one fast and one slow). A one-minute rest period will be given between each contraction.
   d. Testing will occur during the 2nd and 3rd days of your participation, and will be conducted 3 times during each day: after the warm-up, within 5 minutes after the treatment and again after a 20 minute rest.

Schedule

1st visit	Short history	Physical exam	Fill out informed consent form	Warm-up	Become familiar with the Biodex	
wait at least two days in-between						
2nd visit	Warm-up	Strength testing	1st type of treatment	Strength testing	20 minute rest	Strength testing
wait at least three days in-between						
3rd visit	Warm-up	Strength testing	2nd type of treatment	Strength testing	20 minute rest	Strength testing

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WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

Some potential risks are associated with the testing and treatment procedures presented in this protocol. As with any therapeutic procedure there are possible side effects and risks involved in adjusting the spine. Complications of low back adjustments are rare and may include strain or sprain of spinal joints and muscles, fractures, or injury to the discs between the bones of the spine or nerves exiting the spinal cord. Recent estimates of the risk of lumbar spine manipulation causing a disc herniation or neurological complication range from 1 in 1,000,000 to 1 in over 100,000,000. On the other hand, about half of all subjects will experience mild adverse effects after treatment, such as soreness and local discomfort. Although common, these events are usually mild, and go away within 24 to 48 hours after treatment.

Muscle strength testing may be associated with some risk. These risks include, but are not limited to: muscle soreness, fatigue, tightness and possible muscle strain. However, these symptoms are no different from what would normally result as part of any strength testing or resistance exercise procedures and are both temporary and recoverable. In addition, there is always a chance that any therapeutic treatment can harm you, and the investigational treatment in this study is no different. In addition to the risks listed above, you may experience a previously unknown risk or side effect.

WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?

There is no guarantee that you will get any benefit from taking part in this study. However, some people have experienced an increase in range of motion, sense of relaxation and/or energy and vitality after being adjusted. In addition, you will receive a copy of your strength measurements at the conclusion of the study. As a result, knowing the quantified force-generating capacity of the muscles in your thigh may assist you in any of your athletic endeavors. Additionally, imbalances between the muscles in the front and back of your thigh can be identified. This information could serve to increase your awareness of the potential for future related muscle strains.

DO YOU HAVE TO TAKE PART IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?

If you do not want to be in the study, there are no other choices except not to take part in the study.

WHAT WILL IT COST YOU TO PARTICIPATE?

There will be no costs to you for participating in this research.

WHO WILL SEE THE INFORMATION THAT YOU GIVE?

Officials of the University of Kentucky may look at or copy pertinent portions of records that identify you. Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be personally identified in these written materials. We may

publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. You will be assigned a number whenever identified throughout the study using a crosswalk table. The crosswalk table will be kept in a separate locked cabinet from the other paper records in the Biodynamics Laboratory. Your recorded data obtained from the intake form, focused physical exam form as well as strength testing results printed from the computer attached to the Biodex will be put into a file and stored in a locked file cabinet. The file will be identified using only your assigned participant number. The locked file cabinet is kept inside the Biodynamics Laboratory (which is locked with a padlock when not in use), inside the Wenner-Gren Center for Biomedical Engineering, which itself is locked after business hours.

The electronic data from your strength testing will be saved in the password-protected computer attached to the Biodex under your assigned number, not your name. In addition, this electronic data will be backed using a dedicated encrypted flash drive that will also be password-protected. At the completion of the study, your data will be entered into an encrypted spreadsheet file to be analyzed, again using only your participant number and not your name. All paper and computer data records will be kept for seven years following the completion of the study and then destroyed.

CAN YOUR TAKING PART IN THE STUDY END EARLY?

If you decide to take part in this study, you have the right to decide at any time that you no longer want to continue. You will not be treated any differently if you decide to stop taking part in this study. The investigator conducting the study may need to take you out of the study. This may occur if you are not able to follow the directions given or if it is found that being in the study causes you more risk than benefit.

ARE YOU PARTICIPATING OR CAN YOU PARTICIPATE IN ANOTHER RESEARCH STUDY AT THE SAME TIME AS PARTICIPATING IN THIS ONE?

You may take part in this study if you are currently involved in another research study as long as there are no medications or physical activity as part of the protocol that would affect the outcome of this study. It is important to let the investigator know if you are in an additional research study. You should also discuss with the investigator before you agree to participate in another research study while you are enrolled in this study.

WHAT HAPPENS IF YOU GET HURT OR SICK DURING THE STUDY?

If you believe you are hurt or if you get sick because of something that is due to the study, you should call Grant Sanders at 216-509-3231 immediately. If what you are experiencing can be treated under the chiropractic scope of practice (such as soreness/stiffness in your lower back), Grant Sanders will provide treatment and recommend home care activities (such as stretches or ice/heat application). If you are experiencing more serious signs/symptoms, you will be referred to your primary care physician. In addition, you can also contact Grant Sanders' supervisor, J.W. Yates, Ph.D. at 257-5879 to help answer any questions you might have.

It is important for you to understand that the University of Kentucky does not have funds set aside to pay for the cost of any care or treatment that might be necessary because you get hurt or sick while

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taking part in this study. Also, the University of Kentucky will not pay for any wages you may lose if you are harmed by this study.

The medical costs related to your care and treatment because of research related harm will be your responsibility. You do not give up your legal rights by signing this form.

WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?

You will not receive any payment for taking part in the study but will receive the results of your strength measurements at the conclusion of the experiment.

WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Grant Sanders at 216-509-3231. If you have any questions about your rights as a volunteer in this research, contact the staff in the Office of Research Integrity at the University of Kentucky at 859-257-9428 or toll free at 1-866-400-9428. You will be given a signed copy of this consent form to take with you.

WHAT IF NEW INFORMATION IS LEARNED DURING THE STUDY THAT MIGHT AFFECT YOUR DECISION TO PARTICIPATE?

If the researcher learns of new information in regard to this study, and it might change your willingness to stay in this study, the information will be provided to you. You may be asked to sign a new informed consent form if the information is provided to you after you have joined the study.

WHAT ELSE DO YOU NEED TO KNOW?

There is no external funding source for this research study.

_____ _____

Signature of person agreeing to take part in the study Date

_____

Printed name of person agreeing to take part in the study

_____ _____

Name of [authorized] person obtaining informed consent Date

_____

Signature of Investigator

Appendix D: Study #1 physical examination form

FOCUSED PHYSICAL EXAM

Subject #_____ **Today's Date:_____**

Blood Pressure_____mmHg

RANGE OF MOTION

Cervical

Motion	Active	Passive	Pain
Flex			
Ext			
RLF			
LLF			
R Rot			
L Rot			

Thoracic

Motion	Active	Passive	Pain
Flex			
Ext			
RLF			
LLF			
R Rot			
L Rot			

Lumbar

Motion	Active	Passive	Pain
Flex			
Ext			
RLF			
LLF			
R Rot			
L Rot			

Notes:_____
_____
_____
_____

SENSORY EVALUATION (WARTENBERG WHEEL)

	Left	Right
UE		
LE		

REFLEXES	Left	Right
Biceps		
Brachioradialis		
Triceps		
Patellar		
Achilles		
Hoffmann's		
Plantar/Babinski		

MOTOR EVALUATION	Left	Right
Deltoids C5 C6 Axillary N.		
Wrist Extension C6 C7 C8 radial N.		
Wrist Flexion C6 **C7** C8 Median N. Ulnar N.		
Finger Flexion C7 C8 Median N. Ulnar N.		
Finger Abduction C8 **T1** Ulnar N.		
Finger Adduction C8 **T1** Ulnar N.		
Hip Flexion L1 L2 L3 Femoral N./L1-L3 nerve roots		
Hip Adduction L2 L3 L4 Obturator N.		
Hip Abduction L4 L5 S1 Superior Gluteal N.		
Ankle Dorsiflexion w/ Inversion L4 Tibial N.		
Extensor Hallicus Longus L4 **L5** S1 Deep Peroneal N.		
Ankle Plantarflexion w/ Eversion S1 Sup. Peron N.		

ORTHOPEDIC TESTS FOR LUMBAR/SI/HIP REGION

Test	Left	Right
Kemp's		
Bechterew's		
Patrick's/Fabere		
Yeoman's		

SPINAL EVALUATION

Left	Level	Right
	L1-L2	
	L2-L3	
	L3-L4	
	L4-L5	
	L5-S1	
	SI	

Additional Notes:_____
_____
_____
_____
_____

Appendix E: Study #1 raw data

Subject	Baseline isometric extension SM (Nm)	5 min isometric extension SM (Nm)	20 min isometric extension SM (Nm)	Baseline isometric flexion SM (Nm)	5 min isometric flexion SM (Nm)	20 min isometric flexion SM (Nm)
1	264.8	252.7	252.3	136.1	136.5	120.8
2	177.2	176.1	175.2	96.9	94.4	98.8
3	238.8	238.8	208.5	101.3	102.6	95.7
4	140.5	169.5	167.6	32.3	79.0	82.6
5	159.2	165.4	158.1	78.2	85.6	80.9
6	174.6	193.3	185.2	114.7	115.0	113.1
7	203.6	249.2	255.3	158.1	164.3	164.3
8	204.1	221.9	213.0	112.1	120.3	126.4
9	187.1	187.0	179.9	120.3	150.1	147.6
10	152.3	182.2	191.0	126.8	125.8	123.9
11	247.4	252.3	250.3	111.2	141.1	130.3
12	246.3	258.3	230.4	161.4	164.0	157.9
13	191.9	200.0	216.1	150.1	147.5	163.8
14	162.9	158.2	147.3	107.3	109.8	104.2
15	161.9	176.3	152.6	91.8	84.6	85.2
16	65.8	67.7	70.2	68.1	71.8	72.4
17	171.8	160.9	161.6	88.0	87.6	82.0
18	144.4	164.1	164.3	102.2	107.8	106.5
19	176.8	186.6	168.5	96.3	95.2	97.4
20	139.7	145.0	125.0	73.1	82.9	73.3
21	116.7	124.5	118.8	67.1	60.8	62.2
Mean	190.2	203.6	198.6	107.7	117.4	115.4
SD	38.9	33.8	33.6	34.4	27.8	27.1

Subject	Baseline isokinetic 60°/s extension SM (Nm)	5 min isokinetic 60°/s extension SM (Nm)	20 min isokinetic 60°/s extension SM (Nm)	Baseline isokinetic 60°/s flexion SM (Nm)	5 min isokinetic 60°/s flexion SM (Nm)	20 min isokinetic 60°/s flexion SM (Nm)
1	325.3	301.3	300.4	142.1	142.8	142.1
2	185.3	169.3	184.7	102.5	95.6	93.0
3	223.6	216.1	178.2	95.7	100.7	88.5
4	129.1	139.6	128.9	58.7	64.1	71.0
5	147.0	142.8	139.8	65.9	68.6	85.6
6	190.4	200.9	189.0	91.4	102.8	98.8
7	203.9	127.3	158.1	153.1	101.3	121.6
8	205.5	206.8	198.9	136.8	133.0	122.2
9	171.2	186.0	176.9	121.8	138.8	147.2
10	123.0	115.8	134.4	96.4	99.0	108.6
11	179.0	204.3	177.2	135.9	114.7	122.0
12	271.6	270.5	267.9	132.2	150.1	130.5
13	141.1	168.6	181.5	141.0	137.1	166.0
14	176.0	142.5	140.2	61.0	35.9	63.1
15	172.8	171.1	164.6	101.5	97.4	105.9
16	60.4	74.6	85.8	59.0	63.8	67.9
17	166.2	167.1	148.6	81.3	67.7	72.3
18	116.3	125.6	126.1	90.3	90.8	93.0
19	142.0	139.5	140.7	96.1	76.5	76.0
20	116.3	76.1	88.4	72.1	66.9	68.9
21	112.7	115.3	95.9	65.1	62.6	61.6
Mean	190.4	180.6	178.9	106.4	104.7	107.9
SD	58.0	55.0	49.2	31.6	26.9	25.0

Subject	Baseline isokinetic 180°/s extension SM (Nm)	5 min isokinetic 180°/s extension SM (Nm)	20 min isokinetic 180°/s extension SM (Nm)	Baseline isokinetic 180°/s flexion SM (Nm)	5 min isokinetic 180°/s flexion SM (Nm)	20 min isokinetic 180°/s flexion SM (Nm)
1	222.4	205.0	206.5	104.8	99.9	104.7
2	118.8	124.6	130.3	60.1	52.3	65.9
3	177.9	173.0	167.2	81.3	84.5	78.8
4	75.7	84.5	76.2	40.1	52.7	48.4
5	100.9	93.6	94.0	52.1	52.7	52.1
6	112.5	122.7	122.3	87.9	97.6	79.3
7	37.3	26.4	28.1	54.5	39.2	47.7
8	115.0	119.9	106.4	78.2	87.7	79.5
9	154.4	141.3	139.6	110.0	113.2	115.7
10	80.3	105.5	106.7	62.8	72.7	70.2
11	161.9	166.1	144.0	92.5	110.0	105.1
12	183.7	178.6	180.2	124.1	128.6	120.7
13	99.7	98.8	122.8	112.9	126.0	131.9
14	129.4	125.0	102.4	17.8	18.5	19.5
15	109.1	100.4	107.1	78.8	74.6	81.0
16	61.7	77.5	69.5	51.5	53.1	49.2
17	86.7	60.3	44.8	54.3	47.7	42.2
18	74.4	79.2	77.2	59.9	64.3	61.3
19	81.2	86.9	89.1	82.0	81.8	84.9
20	55.5	53.6	59.3	51.6	53.7	52.8
21	72.9	69.8	64.8	44.5	43.1	47.0
Mean	119.5	119.6	117.7	73.2	75.3	74.2
SD	53.6	48.8	48.9	23.2	25.0	22.8

Subject	Baseline isometric extension Sham (Nm)	5 min isometric extension Sham (Nm)	20 min isometric extension Sham (Nm)	Baseline isometric flexion Sham (Nm)	5 min isometric flexion Sham (Nm)	20 min isometric flexion Sham (Nm)
1	279.7	296.8	296.7	128.4	119.2	127.2
2	208.5	186.7	158.6	112.5	113.1	108.7
3	237.7	235.8	242.4	110.6	111.4	105.5
4	133.3	152.5	156.2	61.1	79.2	73.5
5	131.7	125.4	138.7	86.9	86.9	78.1
6	172.3	188.6	172.3	108.1	108.1	100.5
7	252.0	255.7	270.9	154.7	158.5	211.9
8	189.8	200.1	203.1	102.8	123.5	123.2
9	197.4	219.5	221.8	149.3	147.4	142.2
10	168.0	193.5	202.6	131.9	130.2	141.0
11	238.9	229.1	294.5	118.5	110.8	122.7
12	267.1	302.3	263.5	165.4	176.3	169.9
13	187.0	157.5	206.9	151.3	162.2	143.9
14	154.1	145.8	150.6	115.8	110.0	117.9
15	129.3	120.6	117.0	88.5	87.5	86.1
16	68.6	61.4	67.4	59.6	66.6	63.1
17	153.8	179.1	145.5	89.6	84.2	87.5
18	158.8	159.8	172.6	109.7	107.9	92.4
19	181.7	176.9	182.2	90.9	101.6	89.3
20	113.0	113.1	104.3	82.3	82.7	78.1
21	120.7	132.1	125.3	73.6	72.5	58.6
Mean	197.0	205.5	206.3	114.6	117.7	121.2
SD	48.9	49.4	52.1	28.1	24.3	39.5

Subject	Baseline isokinetic 60°/s extension Sham (Nm)	5 min isokinetic 60°/s extension Sham (Nm)	20 min isokinetic 60°/s extension Sham (Nm)	Baseline isokinetic 60°/s flexion Sham (Nm)	5 min isokinetic 60°/s flexion Sham (Nm)	20 min isokinetic 60°/s flexion Sham (Nm)
1	278.5	294.3	296.2	130.6	142.1	142.9
2	196.7	195.8	193.6	99.7	101.4	95.9
3	218.2	230.8	219.4	107.1	107.4	91.7
4	131.1	133.0	123.9	62.4	63.3	63.3
5	136.1	137.2	145.8	85.8	86.4	69.8
6	163.8	181.8	180.9	83.4	89.9	89.8
7	168.8	155.3	136.7	98.2	111.0	132.7
8	214.8	201.1	203.1	135.7	108.1	123.5
9	207.0	203.1	178.2	152.8	143.4	123.8
10	134.0	130.4	141.7	99.7	108.1	115.9
11	155.8	178.6	194.3	94.5	118.4	121.1
12	261.7	267.5	259.9	152.4	155.8	153.9
13	184.9	189.2	176.6	156.4	166.3	160.4
14	159.3	140.0	136.5	83.2	85.1	97.9
15	174.5	166.0	172.4	101.3	111.3	108.7
16	77.7	62.5	61.9	66.9	62.3	64.9
17	150.7	152.3	130.2	82.7	87.3	77.7
18	113.8	129.9	129.5	89.9	98.5	84.1
19	124.8	126.8	136.2	97.9	89.4	84.9
20	72.9	100.6	77.0	68.2	71.1	66.8
21	119.4	113.4	81.4	61.7	67.3	61.6
Mean	184.9	186.3	181.9	105.5	106.1	104.9
SD	47.1	51.2	51.0	27.2	24.1	26.8

Subject	Baseline isokinetic 180°/s extension Sham (Nm)	5 min isokinetic 180°/s extension Sham (Nm)	20 min isokinetic 180°/s extension Sham (Nm)	Baseline isokinetic 180°/s flexion Sham (Nm)	5 min isokinetic 180°/s flexion Sham (Nm)	20 min isokinetic 180°/s flexion Sham (Nm)
1	201.6	190.9	185.2	110.4	114.6	98.3
2	131.9	131.5	130.8	61.7	50.2	50.0
3	172.5	168.4	179.4	86.2	82.0	76.2
4	83.4	88.9	78.5	41.4	45.8	40.1
5	67.5	90.4	94.9	33.6	42.2	54.1
6	119.9	114.3	122.4	69.6	84.7	76.6
7	83.8	62.9	39.9	82.7	63.2	44.8
8	125.4	110.4	109.4	87.7	73.8	82.6
9	140.1	142.0	153.2	119.0	120.0	112.8
10	87.5	97.2	89.5	73.5	70.1	68.7
11	136.0	148.5	158.2	92.1	99.9	91.1
12	180.8	188.6	189.3	123.2	123.4	132.5
13	111.1	106.5	114.6	120.5	126.4	137.0
14	124.4	118.4	120.8	46.4	58.9	34.3
15	109.7	113.6	108.0	85.5	87.4	85.9
16	76.9	56.6	63.1	55.3	50.3	51.2
17	56.8	40.0	37.5	50.1	28.3	38.8
18	90.9	85.6	76.6	64.8	64.8	63.5
19	70.1	70.2	75.7	61.7	82.3	81.1
20	49.2	51.8	47.4	50.8	51.6	49.6
21	77.5	77.0	71.4	47.4	48.9	46.3
Mean	121.3	119.7	118.3	76.6	74.7	70.4
SD	42.7	39.1	45.7	27.0	26.8	23.7

Appendix F: Study #2 subject recruitment flyer

Weightlifters Needed

Researchers at the University of Kentucky Department of Kinesiology and Health Promotion are conducting a study to investigate the effects of lower back adjustments on postactivation potentiation (an enhanced neuromuscular response following resistance training). Subjects will attend three separate sessions in which potentiation will be measured by electromyographic responses of the calf muscles during low-intensity electrical stimulations.

You may be eligible to participate if you:

- are between 20 to 35 years of age
- have been consistently lifting weights for a minimum of two days per week for at least one year
- can maximally back squat your body weight (women) or 1.5 times your body weight (men)
- do not have pain or a past history of surgery in your lower back, abdomen or legs

Individuals who qualify for this study will have the option of a free, full-body DXA scan to measure body composition (fat and muscle percentages) and bone density.

For more information, please contact:
Grant Sanders, DC, CSCS
grant.sanders@uky.edu
216-509-3231

UK UNIVERSITY OF KENTUCKY

Muscle Research Study
Grant Sanders
216-509-3231
grant.sanders@uky.edu

Appendix G: Study #2 health history questionnaire

HEALTH HISTORY QUESTIONNAIRE

Subject #_____ **Date:**_____

PAST MEDICAL HISTORY

YES	NO	CHECK YES OR NO FOR EACH QUESTION	DATE AND DESCRIPTION
☐	☐	Do you currently have pain in your lower back, hip, abdomen or legs?	
☐	☐	Any previous injuries to these areas?	
☐	☐	Any surgeries performed in these areas?	
☐	☐	Any previous illness, infection or disease involving your: abdomen, digestion, liver, kidney, autoimmune system, nerves, skin, muscles, collages, blood, connective tissue, joints, brain, spinal cord or spine?	
☐	☐	Recent and unusual problems with balance, walking, talking, vision, ringing in the ears, light headed, dizziness, fainting, swallowing, seizures, sudden onset of severe headache or neck pain/ stiffness, arm/leg weakness or vomiting?	
☐	☐	Any implanted electronic devices, such as cardiac pacemakers, electric infusion pumps or implanted stimulators?	
☐	☐	Female subjects: Is there any chance that you are pregnant?	

YES	NO	HAVE YOU EVER BEEN DIAGNOSED WITH:	DATE OF DIAGNOSIS
☐	☐	Cardiovascular disease	
☐	☐	Blood clotting disorder	
☐	☐	Stroke	
☐	☐	Aneurysm	
☐	☐	Thromboembolism	
☐	☐	Vascular/neurogenic claudication	
☐	☐	Lumbar disc herniation	
☐	☐	Cauda equina syndrome	
☐	☐	Spondylolisthesis	
☐	☐	Scoliosis	
☐	☐	Diabetes	
☐	☐	Any type of bone disease (such as osteoporosis)	
☐	☐	Any type of joint disease (such as arthritis)	

OTHER INFORMATION

YES	NO	CHECK YES OR NO FOR EACH QUESTION
☐	☐	Have you ever been treated with spinal manipulation by a licensed health care
☐	☐	Have you exercised during the past few days? If so, please list when and which type of exercise _____
☐	☐	Are you currently being prescribed medications and/or taking supplements? If so, please list (e.g., protein powder, multivitamin) _____
☐	☐	Have you consumed caffeine within the past few hours?
☐	☐	Any recent dietary changes?
☐	☐	Are you allergic to silver?

Appendix H: Study #2 informed consent

IRB Approval
14-0507-F6A
THIS FORM VALID
7/22/14 – 7/15/15

Consent to Participate in a Research Study

THE EFFECTS OF SPINAL MANIPULATIVE THERAPY ON POSTACTIVATION POTENTIATION

WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?
You are being invited to take part in a research study to help determine if spinal manipulative therapy (also referred to as a low back adjustment) impacts the performance of your calf muscles measured immediately after a maximal force contraction. You are being invited to take part in this research study because you are between 20 to 35 years of age, have been consistently lifting weights 2 days or more per week for at least a year and are able to back squat your weight if you are a female or 1.5 times your weight if you are a male. If you volunteer to take part in this study, you will be one of about 35 people to do so at the University of Kentucky.

WHO IS DOING THE STUDY?
The person in charge of this study is Grant Sanders, a doctoral candidate in the Department of Kinesiology and Health Promotion at the University of Kentucky. He is being guided in this research by J.W. Yates, PhD. There may be other people on the research team assisting at different times during the study.

WHAT IS THE PURPOSE OF THIS STUDY?
By conducting this study, we hope to learn if spinal manipulative therapy impacts the electrical activity, amount of force and rate of force development of your calf muscles. This will be determined by changes in postactivation potentiation (enhanced force generation following prior muscular contractions), measured with a response called the Hoffmann reflex (a muscle or nerve twitch that we can measure). It is hoped that this study will expand the current knowledge regarding enhanced power production after exercise, and the possible physiological influence of spinal manipulation in the creation of this effect.

ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?
You will not be eligible to participate if you:

1. Have any pain in your lower back, abdomen or legs.
2. Have a history of vertigo (dizziness with standing).
3. Experience nausea, dizziness, vomiting or fainting with certain head movements.
4. Have recently experienced a sudden onset of severe headache or neck pain/stiffness
5. Have ever been diagnosed with:
    a. cardiovascular disease
    b. blood clotting disorder
    c. stroke
    d. aneurysm (bulge of a major blood vessel)
    e. thromboembolism (blood clot that blocked blood flow)
    f. vascular/neurogenic claudication (pain and discoloration in the lower legs with walking)
    g. lumbar disc herniation
    h. cauda equina syndrome (compression of the bundle of nerves in the lower end of the spine)

i. spondylolisthesis (displacement of spinal structures)
j. scoliosis (curvature of the spine to the side)
k. diabetes
l. any type of bone disease (such as osteoporosis)
m. any type of joint disease (such as arthritis)

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6. Have ever undergone any surgical procedures in your lower back, abdomen, pelvis or thigh/leg
7. Are allergic to silver
8. Are pregnant

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?
The research procedures will be conducted at the Biodynamics Laboratory located in the Multidisciplinary Science Building. You will need to come to the Biodynamics Laboratory three times during the study. Each of those visits will take about two hours. The total amount of time you will be asked to volunteer for this study is six hours over the next two weeks.

WHAT WILL YOU BE ASKED TO DO?
You will be asked to report to the Multidisciplinary Science Building at three scheduled dates and times. All procedures will take place in the Biodynamics Laboratory, and are depicted in Table 1.

1. Brief medical history
    a. Fill out a short form during your first visit to confirm that you are eligible to be in the study
2. Physical exam
    a. After the medical history, a basic neurological assessment will be performed. It will include:
        i. Heart rate and blood pressure
        ii. Range of motion of your neck, upper back and low back
        iii. Neurologic evaluation (muscle strength, tendon reflexes and sensory assessment) of your upper and lower extremities
        iv. Orthopedic tests
        v. Motion palpation of your lower back
        vi. Female subjects: because pregnancy is an exclusionary factor, a urine pregnancy test will be necessary before proceeding with the study
3. Tibial nerve stimulation
    a. You will be asked to lie on your side on the treatment table with your upside foot strapped into the isokinetic dynamometer (machine to assess muscle strength) ankle attachment.
        i. Padded straps will be placed over your hip and downside thigh. These will be tightened to minimize movement during the Hmax/Mmax recruitment curve, strength testing and stimulation protocol and loosened the rest of the time.
        ii. Your comfort will be maintained as much as possible with an elevated headrest and pillows to support your head, foam pads placed between your knees and padding for your heel and the top of your foot while strapped into the ankle attachment.
        iii. You will have the opportunity to sit up and move around during both of the 20 minute rest periods, or if you request to do so at any other time.
    b. Electrodes that deliver the stimulations will be placed in the back of your knee and above your kneecap
        i. These locations will be shaved if necessary and then wiped with an alcohol pad
        ii. Conductive gel will be applied to the skin under the electrode
        iii. The electrodes will then be held in place with surgical tape
    c. Electrodes which record muscle activity will be placed on the outside of your calf muscle, below the bottom of the muscle and on the kneecap of your downside leg.

i. These locations will also be shaved if needed and then wiped with an alcohol pad
ii. The electrodes will be affixed with special two-sided tape between the skin and the electrodes and surgical tape over the top

d. Familiarization
   i. During the first session, the intensity of the electrical stimulations will gradually be increased every ten seconds in small increments from zero for you to become used to the sensation. If you experience unusual pain at these low intensities, the investigator will end the session.

e. Recruitment Curve
   i. The intensity of the stimulations will again be increased every ten seconds, but in larger increments. The investigator will monitor your status and ask for feedback. The point of this procedure is to obtain two values from your muscles' responses. These values will then be used at the conclusion of the session, during the Hmax/Mmax stimulation protocol.
   ii. The recruitment curve will occur after the first 20 minute rest (Table 1).

f. Hmax/Mmax stimulation protocol
   i. Only the two values obtained from the recruitment curve, one at a low intensity and the other at a high intensity, will be used during these final stimulations of the session. For 20 minutes, the investigator will alternate the intensity between high and low.
      1. Stimulations will occur every 10 seconds for the first minute, every 30 seconds until the 10th minute, and every 60 seconds until the 20th minute.
      2. If at any time the stimulations become unusually painful, the investigator will stop the stimulations and end the session.
   ii. This protocol will be the final procedure of all three sessions.

4. Strength testing
   a. You will be assessed for the maximum amount of force that your calf muscles can generate with the Biodex strength testing machine.
   b. Muscle strength will be determined in the upside leg that will be strapped into the ankle attachment. This value will be the highest force generated while pushing your foot against the non-moving plate for 5 seconds. You will be asked to perform only 2 sets of this maximal contraction.
   c. Testing will occur after the recruitment curve and possibly again as the second-to-last procedure, according the randomized protocol of the particular session (Table 1).
5. Treatment
   a. Toward the end of each session, one of three randomly determined treatment combinations will be delivered. This will be spinal manipulation or rest, followed by a 10 second maximal contraction or rest and then the Hmax/Mmax stimulation protocol.
   b. Spinal manipulation or 60 second rest
      i. The manipulation will be performed by Grant Sanders (the same researcher who conducted the rest of the procedures, who is a licensed chiropractor), and will specifically target your low back. First, your foot will be unfastened from the ankle attachment and you will be asked to bend your upside knee and cross your arms. Then the researcher will contact the lower part of your spine with one hand, and place the other hand on your shoulder to stabilize your upper body. The researcher will then slightly drop his weight and deliver a quick, short impulse with his hand

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through your lower back. During the 60 second rest, you will be asked to remain lying on your side in the same position as the rest of the procedures.

c. 10 second maximal contraction or 10 second rest
    i. The contraction will be exactly the same as what you did earlier in the session. You will be asked to push your foot as hard as you can onto the non-moving plate of the ankle attachment once for 10 seconds. If the protocol for that day calls for a brief rest instead, you will be asked to relax without changing your position on the treatment table.
d. Stimulation protocol
    i. The alternating sequence of low and higher intensity stimulations will be implemented as described in #3 (Tibial nerve stimulation).
e. A random number generator in Microsoft Excel will determine which combination of treatments will be delivered at the end of each of the three sessions.

Table 1. *Summary of experimental procedures.*

1st Visit	Health history questionnaire, informed consent and physical exam	Biodex familiarization and electrode placement	Tibial nerve stimulation familiarization	Rest 20 minutes	Hmax and Mmax recruitment curve	Determine Hmax and Mmax stimulation intensities	Confirm Hmax	2 sets of 5 second plantar flexion MVICs	Rest 20 minutes	SMT or 60 second rest	10 second MVIC or 10 second rest	Hmax/Mmax stimulation protocol
2nd Visit	Subject positioning on table and dynamometer, electrode placement	Rest 20 minutes	Hmax and Mmax recruitment curve	Determine Hmax and Mmax stimulation intensities	Confirm Hmax	2 sets of 5 second plantar flexion MVICs	Rest 20 minutes	SMT or 60 second rest	10 second MVIC or 10 second rest	Hmax/Mmax stimulation protocol		
3rd Visit	Subject positioning on table and dynamometer, electrode placement	Rest 20 minutes	Hmax and Mmax recruitment curve	Determine Hmax and Mmax stimulation intensities	Confirm Hmax	2 sets of 5 second plantar flexion MVICs	Rest 20 minutes	SMT or 60 second rest	10 second MVIC or 10 second rest	Hmax/Mmax stimulation protocol		

Red = Data collection

Bold = Treatment (randomized order)

3 randomized treatments: SMT only, MVIC only or SMT+MVIC			
1)	SMT	no MVIC	Hmax/Mmax protocol
2)	60 s rest	MVIC	Hmax/Mmax protocol
3)	SMT	MVIC	Hmax/Mmax protocol

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WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?
Some potential risks are associated with the testing and treatment procedures presented in this protocol. As with any therapeutic procedure there are possible side effects and risks involved in adjusting the spine. Complications of low back adjustments are rare and may include strain or sprain of spinal joints and muscles, fractures, or injury to the discs between the bones of the spine or nerves exiting the spinal cord. Recent estimates of the risk of lumbar spine manipulation causing a disc herniation or neurological complication range from 1 in 1,000,000 to 1 in over 100,000,000. On the other hand, about half of all subjects will experience mild adverse effects after treatment, such as soreness and local discomfort. Although common, these events are usually mild, and go away within 24 to 48 hours after treatment.

Muscle strength testing may be associated with some risk. These risks include, but are not limited to: muscle soreness, fatigue, tightness and possible muscle strain. However, these symptoms are no different from what would normally result as part of any strength testing or resistance exercise procedures and are both temporary and recoverable. Electrical stimulation may cause slight discomfort, pain, a tingling sensation and could cause your calf muscles to spasm or tighten. However, the stimulations only last for a fraction of a second, and will not cause any harm to the body systems. In addition, the surface electrodes used may cause temporary and minor skin irritation following placement and removal. There is always a chance that any therapeutic treatment can harm you, and the investigational treatment in this study is no different. In addition to the risks listed above, you may experience a previously unknown risk or side effect.

WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?
There is no guarantee that you will derive any personal benefit from taking part in this study. Your willingness to take part, however, may help researchers, practitioners, and athletes better understand this topic.

DO YOU HAVE TO TAKE PART IN THE STUDY?
If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. As a student, if you decide not to take part in this study, your choice will have no effect on your academic status or grade in the class.

IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?
If you do not want to be in the study, there are no other choices except not to take part in the study.

WHAT WILL IT COST YOU TO PARTICIPATE?
There will be no costs to you for participating in this research.

WHO WILL SEE THE INFORMATION THAT YOU GIVE?
Officials of the University of Kentucky may look at or copy pertinent portions of records that identify you. Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be personally identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.
We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. You will be assigned a number whenever identified throughout the study. Your information obtained from the health history questionnaire and physical exam will be put into a file and stored in a locked file cabinet. The file will be identified using only your assigned participant number. The locked file cabinet is kept inside the Biodynamics Laboratory, which is locked when not in use.

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The electronic data from your strength testing will be saved on a password-protected computer under your assigned number, not your name. In addition, these data will be backed using your participant number with a dedicated encrypted flash drive that will also be password-protected. All paper and computer data records will be kept for six years following the completion of the study and then destroyed.

CAN YOUR TAKING PART IN THE STUDY END EARLY?
If you decide to take part in this study, you have the right to decide at any time that you no longer want to continue. You will not be treated any differently if you decide to stop taking part in this study. The investigator conducting the study may need to take you out of the study. This may occur if you are not able to follow the directions given or if it is found that being in the study causes you more risk than benefit.

ARE YOU PARTICIPATING OR CAN YOU PARTICIPATE IN ANOTHER RESEARCH STUDY AT THE SAME TIME AS PARTICIPATING IN THIS ONE?
You may take part in this study if you are currently involved in another research study as long as there are no medications or physical activity as part of the protocol that would affect the outcome of this study. It is important to let the investigator know if you are in an additional research study. You should also discuss with the investigator before you agree to participate in another research study while you are enrolled in this study.

WHAT HAPPENS IF YOU GET HURT OR SICK DURING THE STUDY?
If you believe you are hurt or if you get sick because of something that is due to the study, you should call Grant Sanders at 216-509-3231 immediately. If you are experiencing signs/symptoms that require medical attention, you will be referred to your primary care physician. In addition, you can also contact Grant Sanders' supervisor, J.W. Yates, Ph.D. at 859-321-1296 to help answer any questions you might have.

It is important for you to understand that the University of Kentucky does not have funds set aside to pay for the cost of any care or treatment that might be necessary because you get hurt or sick while taking part in this study. Also, the University of Kentucky will not pay for any wages you may lose if you are harmed by this study. The medical costs related to your care and treatment because of research-related harm will be your responsibility. You do not give up your legal rights by signing this form.

WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?
You will not be given monetary compensation for participating. However, you will have the option of a free Dual-Energy X-ray Absorptiometry (DXA) scan at the Body Composition Core Laboratory, located inside the Seaton Building. If interested, the measurements acquired from the scan are for your information only, and will not be collected by the PI or included in the results of the study.

DXA Scan
The scan will be performed to determine the bone mineral content and density of your bones, and your body composition (how much muscle and fat you have). This will involve lying on a table for approximately 10 minutes while wearing a t-shirt and shorts containing no metal during the scanning procedure. During this time the director of the laboratory, Jody Clasey, Ph.D., will take a scan of your total body. The DXA is a relatively new procedure and has advantages over traditional x-rays because it will expose you to much less radiation.

Possible Risk
The radiation dose from a typical DXA bone scan procedure produces approximately 1/300th of the natural background radiation dose we receive each year. This radiation dose would not be considered a risk of producing any harmful effects.

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Pregnancy Testing

If you are a woman participating in this study, prior to having your body composition testing by the DXA scanner you will be required to take a urine pregnancy test. You will be given a urine collection cup and asked to provide a small amount of urine in a bathroom located in the Seaton Building. The urine sample you provide will only be used to determine if you are pregnant or not. Once you provide the urine sample, it will only take a few minutes for an investigator to test this sample. If this test determines that you are pregnant, you will not be allowed to have a DXA scan. The pregnancy testing is performed because the machine used to measure your body composition and skeleton uses a very small amount of X-ray. We do not want to expose an unborn child to any radiation, no matter how small the amount.

WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Grant Sanders at 216-509-3231. If you have any questions about your rights as a volunteer in this research, contact the staff in the Office of Research Integrity at the University of Kentucky at 859-257-9428 or toll free at 1-866-400-9428. You will be given a signed copy of this consent form to take with you.

WHAT IF NEW INFORMATION IS LEARNED DURING THE STUDY THAT MIGHT AFFECT YOUR DECISION TO PARTICIPATE?

If the researcher learns of new information in regards to this study, and it might change your willingness to stay in this study, the information will be provided to you. You may be asked to sign a new informed consent form if the information is provided to you after you have joined the study.

WHAT ELSE DO YOU NEED TO KNOW?

There is no external funding source for this research study.

_____ _____

Signature of person agreeing to take part in the study Date

_____

Printed name of person agreeing to take part in the study

_____ _____

Name of [authorized] person obtaining informed consent Date

_____

Signature of Principal Investigator or Sub/Co-Investigator

Appendix I: Study #2 physical examination form

PHYSICAL EXAM

Subject #_____ **Date:**_____

Blood Pressure_____mmHg

RANGE OF MOTION

Cervical

Motion	Active	Passive	Pain
Flex			
Ext			
RLF			
LLF			
R Rot			
L Rot			

Thoracic

Motion	Active	Passive	Pain
Flex			
Ext			
RLF			
LLF			
R Rot			
L Rot			

Lumbar

Motion	Active	Passive	Pain
Flex			
Ext			
RLF			
LLF			
R Rot			
L Rot			

Notes:_____
_____
_____
_____

SENSORY EVALUATION (WARTENBERG WHEEL)

	Left	Right
UE		
LE		

REFLEXES	Left	Right
Biceps		
Brachioradialis		
Triceps		
Patellar		
Achilles		
Hoffmann's		
Plantar/Babinski		

MOTOR EVALUATION	Left	Right
Deltoids C5 C6 Axillary N.		
Wrist Extension C6 C7 C8 Radial N.		
Wrist Flexion C6 **C7** C8 Median N. Ulnar N.		
Finger Flexion C7 C8 Median N. Ulnar N.		
Finger Abduction C8 **T1** Ulnar N.		
Finger Adduction C8 **T1** Ulnar N.		
Hip Flexion L1 L2 L3 Femoral N./L1-L3 nerve roots		
Hip Adduction L2 L3 L4 Obturator N.		
Hip Abduction L4 L5 S1 Superior Gluteal N.		
Ankle Dorsiflexion w/ Inversion L4 Tibial N.		
Extensor Hallicus Longus L4 **L5** S1 Deep Peroneal N.		
Ankle Plantarflexion w/ Eversion S1 Sup. Peron N.		

ORTHOPEDIC TESTS FOR LUMBAR/SI/HIP REGION

Test	Left	Right
Kemp's		
Bechterew's		
Patrick's/Fabere		
Yeoman's		

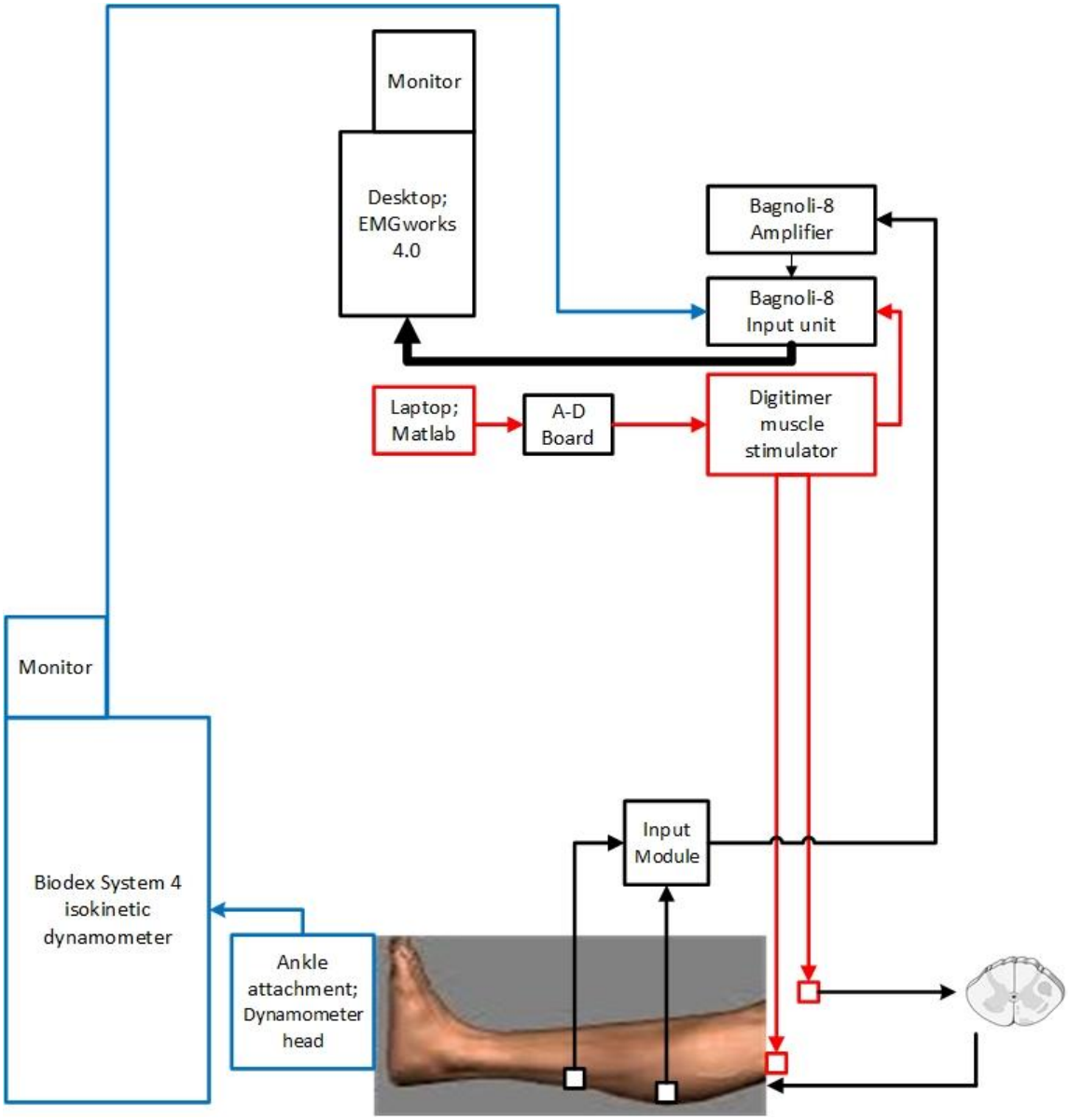
SPINAL EVALUATION (Motion Palpation)

Left	Level	Right
	L1-L2	
	L2-L3	
	L3-L4	
	L4-L5	
	L5-S1	
	SI	

Female subjects: Urine pregnancy test result
Negative _____ Positive _____

Additional Notes:_____
_____
_____
_____
_____

Appendix J: Study #2 instrumentation schematic



Appendix K: Study #2 raw data

Subject 1 Session 1 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	4.9%	9.894	13.1%	11.426	15.491
0:20	H	0.483		1.292		8.757	11.873
0:30	**M**	9.895	5.3%	9.894	22.6%	10.189	13.814
0:40	H	0.526		2.235		8.059	10.926
0:50	**M**	9.894	6.7%	9.895	22.6%	10.030	13.599
1:00	H	0.660		2.238		8.134	11.028
1:30	**M**	9.894	6.4%	9.894	22.1%	10.013	13.576
2:00	H	0.638		2.187		8.247	11.181
2:30	**M**	9.895	7.7%	9.894	23.2%	9.805	13.294
3:00	H	0.757		2.298		7.873	10.674
3:30	**M**	9.894	7.7%	9.894	24.7%	9.627	13.052
4:00	H	0.765		2.448		7.754	10.513
4:30	**M**	9.894	7.8%	9.894	24.9%	9.509	12.892
5:00	H	0.770		2.460		7.672	10.402
5:30	**M**	9.894	7.7%	9.894	24.8%	9.416	12.766
6:00	H	0.759		2.458		7.713	10.457
6:30	**M**	9.894	8.0%	9.893	23.9%	9.194	12.465
7:00	H	0.792		2.365		7.563	10.254
7:30	**M**	9.894	7.8%	9.894	24.2%	8.957	12.144
8:00	H	0.769		2.390		7.570	10.263
8:30	**M**	9.894	6.7%	9.894	21.6%	9.074	12.303
9:00	H	0.662		2.142		7.492	10.158
9:30	**M**	9.895	7.7%	9.895	23.9%	9.738	13.203
10:00	H	0.759		2.365		7.123	9.657
11:00	**M**	9.894	7.9%	9.894	24.1%	8.828	11.969
12:00	H	0.779		2.389		7.371	9.994
13:00	**M**	9.894	8.6%	9.894	25.0%	8.511	11.539
14:00	H	0.846		2.470		7.066	9.580
15:00	**M**	9.894	8.7%	9.894	26.3%	8.196	11.112
16:00	H	0.858		2.603		6.898	9.352
17:00	**M**	9.894	6.7%	9.894	24.6%	8.318	11.278
18:00	H	0.660		2.431		7.081	9.600
19:00	**M**	9.894	8.8%	9.894	25.5%	8.045	10.907
20:00	H	0.869		2.526		7.046	9.553

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.788		Hmax Amplitude (mV):	2.586
Hmax Torque (ft lbs, Nm)	5.861	7.946344	Hmax Torque (Nm)	7.946344
Mmax Stim Intensity (mA):	100		Mmax Stim Intensity (mA):	100
Mmax Amplitude (mV):	9.894		Mmax Amplitude (mV):	8.242
Mmax Torque (ft lbs, Nm)	8.729	11.83478	Mmax Torque (Nm)	11.83478
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.909		Hmax Amplitude (mV):	2.885
Hmax Torque (ft lbs, Nm)	6.530	8.853374	Hmax Torque (Nm)	8.853374
Gastroc H/M	9.2%		Solues H/M	35.0%

Subject 1 Session 2 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	5.3%	8.217	20.4%	8.337	11.303
0:20	H	0.522		1.679		5.655	7.667
0:30	**M**	9.895	6.4%	8.156	24.1%	7.545	10.230
0:40	H	0.629		1.969		6.241	8.462
0:50	**M**	9.895	6.5%	8.139	23.7%	6.795	9.213
1:00	H	0.645		1.926		5.140	6.969
1:30	**M**	9.894	7.2%	8.922	25.1%	6.816	9.241
2:00	H	0.713		2.240		5.310	7.199
2:30	**M**	9.895	6.8%	8.670	26.4%	6.663	9.034
3:00	H	0.675		2.291		5.082	6.890
3:30	**M**	9.895	7.7%	9.049	24.9%	6.344	8.601
4:00	H	0.765		2.256		4.468	6.058
4:30	**M**	9.895	8.5%	9.401	27.8%	5.848	7.929
5:00	H	0.839		2.616		4.189	5.679
5:30	**M**	9.895	10.0%	9.895	23.4%	5.586	7.573
6:00	H	0.992		2.311		3.815	5.172
6:30	**M**	9.895	9.6%	9.895	19.9%	4.748	6.437
7:00	H	0.949		1.971		3.252	4.409
7:30	**M**	9.894	9.3%	9.895	17.5%	4.744	6.432
8:00	H	0.919		1.728		3.305	4.481
8:30	**M**	9.895	9.5%	9.894	16.0%	4.404	5.971
9:00	H	0.944		1.584		2.993	4.058
9:30	**M**	9.895	9.5%	9.895	18.1%	4.128	5.597
10:00	H	0.943		1.792		2.322	3.148
11:00	**M**	9.895	10.7%	9.895	14.8%	3.606	4.889
12:00	H	1.056		1.460		2.176	2.950
13:00	**M**	9.895	11.3%	9.895	16.5%	3.514	4.764
14:00	H	1.114		1.637		2.296	3.113
15:00	**M**	9.896	10.9%	9.896	16.8%	3.702	5.019
16:00	H	1.079		1.667		2.101	2.849
17:00	**M**	9.895	10.5%	9.895	20.1%	3.218	4.363
18:00	H	1.042		1.987		1.706	2.313
19:00	**M**	9.896	10.6%	9.896	17.8%	3.301	4.475
20:00	H	1.047		1.764		1.846	2.503

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	1.066		Hmax Amplitude (mV):	2.753
Hmax Torque (Nm)	4.971	6.739682	Hmax Torque (Nm)	6.739682
Mmax Stim Intensity (mA):	85		Mmax Stim Intensity (mA):	85
Mmax Amlitude (mV):	9.894		Mmax Amplitude (mV):	6.658
Mmax Torque (Nm)	6.237	8.456125	Mmax Torque (Nm)	8.456125
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.891		Hmax Amplitude (mV):	2.523
Hmax Torque (Nm)	4.961	6.726124	Hmax Torque (Nm)	6.726124
Gastroc H/M	9.0%		Soleus H/M	37.9%

Subject 1 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	9.4%	9.894	20.7%	7.402	10.036
0:20	H	0.928		2.046		4.339	5.883
0:30	**M**	9.895	9.6%	9.895	20.6%	8.212	11.134
0:40	H	0.947		2.037		4.457	6.043
0:50	**M**	9.896	10.7%	9.894	17.5%	8.191	11.105
1:00	H	1.055		1.729		4.796	6.502
1:30	**M**	9.895	11.2%	9.894	18.2%	7.927	10.747
2:00	H	1.106		1.804		4.770	6.467
2:30	**M**	9.895	12.2%	9.894	16.6%	7.236	9.811
3:00	H	1.207		1.645		4.803	6.512
3:30	**M**	9.894	12.4%	9.894	18.4%	6.923	9.386
4:00	H	1.231		1.822		4.654	6.310
4:30	**M**	9.894	12.7%	9.895	17.2%	6.668	9.040
5:00	H	1.258		1.706		4.386	5.947
5:30	**M**	9.895	12.6%	9.894	16.4%	6.409	8.689
6:00	H	1.247		1.623		4.329	5.869
6:30	**M**	9.894	13.3%	9.894	19.5%	6.454	8.750
7:00	H	1.320		1.930		3.933	5.332
7:30	**M**	9.894	12.2%	9.895	16.5%	6.033	8.180
8:00	H	1.212		1.637		3.959	5.368
8:30	**M**	9.894	13.1%	9.894	17.2%	5.793	7.854
9:00	H	1.301		1.698		3.733	5.061
9:30	**M**	9.894	13.0%	9.894	17.3%	5.625	7.626
10:00	H	1.285		1.708		3.587	4.863
11:00	**M**	9.894	10.7%	9.895	12.9%	5.127	6.951
12:00	H	1.059		1.276		3.700	5.016
13:00	**M**	9.895	11.6%	9.895	14.8%	5.372	7.283
14:00	H	1.151		1.464		3.114	4.222
15:00	**M**	9.894	11.9%	9.894	12.8%	4.883	6.620
16:00	H	1.180		1.270		3.162	4.287
17:00	**M**	9.895	11.3%	9.895	13.9%	5.181	7.024
18:00	H	1.115		1.373		3.602	4.884
19:00	**M**	9.894	9.7%	9.894	15.5%	5.645	7.653
20:00	H	0.958		1.530		3.227	4.375

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.789		Hmax Amplitude (mV):	2.363
Hmax Torque (Nm)	2.772	3.758278	Hmax Torque (Nm)	3.758278
Mmax Stim Intensity (mA):	90		Mmax Stim Intensity (mA):	90
Mmax Amlitude (mV):	9.894		Mmax Amplitude (mV):	5.159
Mmax Torque (Nm)	4.187	5.676735	Mmax Torque (Nm)	5.676735
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.680		Hmax Amplitude (mV):	1.907
Hmax Torque (Nm)	3.386	4.590739	Hmax Torque (Nm)	4.590739
Gastroc H/M	6.9%		Soleus H/M	37.0%

Subject 2 Session 1 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	6.8%	9.894	24.5%	7.214	9.781
0:20	H	0.675		2.425		5.054	6.852
0:30	**M**	9.894	6.9%	9.894	25.5%	7.787	10.558
0:40	H	0.678		2.524		5.005	6.786
0:50	**M**	9.896	7.9%	9.897	26.7%	7.661	10.387
1:00	H	0.777		2.64		5.042	6.836
1:30	**M**	9.894	7.2%	9.896	27.8%	7.509	10.181
2:00	H	0.709		2.755		4.777	6.477
2:30	**M**	9.894	8.4%	9.895	27.1%	7.414	10.052
3:00	H	0.831		2.684		5.014	6.798
3:30	**M**	9.894	7.7%	9.894	26.3%	7.184	9.740
4:00	H	0.758		2.607		4.738	6.424
4:30	**M**	9.894	8.5%	9.896	25.9%	7.278	9.868
5:00	H	0.837		2.565		4.779	6.479
5:30	**M**	9.894	10.2%	9.894	25.1%	7.023	9.522
6:00	H	1.007		2.488		5.001	6.780
6:30	**M**	9.894	7.5%	9.894	26.0%	7.088	9.610
7:00	H	0.743		2.575		4.746	6.435
7:30	**M**	9.896	8.5%	9.897	26.4%	7.151	9.695
8:00	H	0.837		2.613		4.979	6.751
8:30	**M**	9.894	7.5%	9.896	27.5%	7.219	9.788
9:00	H	0.738		2.725		4.569	6.195
9:30	**M**	9.894	7.8%	9.895	26.8%	6.821	9.248
10:00	H	0.772		2.65		4.565	6.189
11:00	**M**	9.895	6.7%	9.895	27.8%	6.790	9.206
12:00	H	0.659		2.755		4.592	6.226
13:00	**M**	9.894	7.7%	9.895	27.4%	6.906	9.363
14:00	H	0.760		2.713		4.502	6.104
15:00	**M**	9.894	7.0%	9.896	30.2%	6.081	8.245
16:00	H	0.691		2.993		4.239	5.747
17:00	**M**	9.897	7.4%	9.897	30.8%	6.464	8.764
18:00	H	0.730		3.045		4.151	5.628
19:00	**M**	9.894	7.5%	9.895	30.8%	6.547	8.876
20:00	H	0.741		3.045		4.334	5.876

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.787		Hmax Amplitude (mV):	2.991
Hmax Torque (Nm)	5.770	7.822966	Hmax Torque (Nm)	7.822966
Mmax Stim Intensity (mA):	85		Mmax Stim Intensity (mA):	85
Mmax Amplitude (mV):	9.893		Mmax Amplitude (mV):	9.894
Mmax Torque (Nm)	8.146	11.04435	Mmax Torque (Nm)	11.04435
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.738		Hmax Amplitude (mV):	3.041
Hmax Torque (Nm)	4.325	5.863835	Hmax Torque (Nm)	5.863835
Gastroc H/M	7.5%		Soleus H/M	30.7%

Subject 2 Session 2 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	4.3%	9.893	25.7%	11.669	15.821
0:20	H	0.421		2.546		6.099	8.269
0:30	**M**	9.892	4.9%	9.893	27.0%	12.283	16.653
0:40	H	0.484		2.668		6.751	9.153
0:50	**M**	9.892	3.9%	9.893	25.3%	11.928	16.172
1:00	H	0.390		2.502		6.323	8.573
1:30	**M**	9.892	4.1%	9.895	27.9%	11.966	16.224
2:00	H	0.410		2.764		6.445	8.738
2:30	**M**	9.893	4.8%	9.893	27.7%	11.221	15.213
3:00	H	0.472		2.744		6.106	8.279
3:30	**M**	9.893	4.4%	9.893	28.3%	10.940	14.832
4:00	H	0.440		2.801		6.117	8.293
4:30	**M**	9.894	4.6%	8.816	30.3%	10.454	14.174
5:00	H	0.455		2.675		5.972	8.097
5:30	**M**	9.893	5.0%	9.893	28.9%	10.067	13.649
6:00	H	0.494		2.858		5.702	7.731
6:30	**M**	9.893	5.8%	9.606	31.6%	9.517	12.903
7:00	H	0.575		3.032		6.072	8.232
7:30	**M**	9.894	5.8%	9.895	29.8%	9.427	12.781
8:00	H	0.570		2.944		6.057	8.212
8:30	**M**	9.895	7.7%	9.893	28.6%	9.166	12.427
9:00	H	0.758		2.833		4.942	6.700
9:30	**M**	9.893	6.1%	9.893	31.5%	8.732	11.839
10:00	H	0.604		3.114		6.002	8.138
11:00	**M**	9.894	5.9%	9.894	30.3%	8.631	11.702
12:00	H	0.582		2.999		5.892	7.988
13:00	**M**	9.893	4.9%	9.893	32.2%	8.812	11.947
14:00	H	0.482		3.182		5.017	6.802
15:00	**M**	9.894	4.4%	9.894	29.1%	8.238	11.169
16:00	H	0.436		2.875		5.351	7.255
17:00	**M**	9.894	4.7%	9.895	30.1%	8.101	10.983
18:00	H	0.463		2.978		4.824	6.540
19:00	**M**	9.893	5.4%	9.894	30.6%	7.627	10.341
20:00	H	0.531		3.026		5.359	7.266

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.356		Hmax Amplitude (mV):	2.054
Hmax Torque (Nm)	4.779	6.479368	Hmax Torque (Nm)	6.479368
Mmax Stim Intensity (mA):	85		Mmax Stim Intensity (mA):	85
Mmax Amlitude (mV):	9.892		Mmax Amlitude (mV):	9.894
Mmax Torque (Nm)	5.589	7.577566	Mmax Torque (Nm)	7.577566
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.305		Hmax Amplitude (mV):	2.783
Hmax Torque (Nm)	4.264	5.781131	Hmax Torque (Nm)	5.781131
Gastroc H/M	3.1%		Soleus H/M	28.1%

Subject 2 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	3.7%	7.865	36.5%	14.256	19.328
0:20	H	0.364		2.873		5.935	8.047
0:30	**M**	9.895	4.7%	8.138	37.8%	12.644	17.143
0:40	H	0.466		3.074		6.238	8.457
0:50	**M**	9.894	4.2%	7.855	40.2%	12.218	16.565
1:00	H	0.412		3.161		5.917	8.022
1:30	**M**	9.894	3.9%	7.802	41.1%	11.449	15.523
2:00	H	0.385		3.203		5.688	7.712
2:30	**M**	9.894	5.7%	8.153	40.3%	10.594	14.363
3:00	H	0.565		3.286		5.867	7.954
3:30	**M**	9.895	7.2%	8.092	41.6%	10.013	13.576
4:00	H	0.715		3.363		5.931	8.041
4:30	**M**	9.895	5.1%	8.136	42.3%	9.864	13.374
5:00	H	0.505		3.439		5.716	7.750
5:30	**M**	9.894	3.4%	8.051	39.6%	9.267	12.564
6:00	H	0.341		3.189		5.116	6.936
6:30	**M**	9.894	3.7%	8.153	38.7%	9.299	12.608
7:00	H	0.364		3.155		5.381	7.296
7:30	**M**	9.894	8.1%	7.854	44.0%	8.821	11.960
8:00	H	0.797		3.455		6.043	8.193
8:30	**M**	9.895	4.9%	7.882	40.9%	9.089	12.323
9:00	H	0.488		3.223		5.901	8.001
9:30	**M**	9.894	7.1%	8.038	41.7%	8.621	11.688
10:00	H	0.704		3.348		5.096	6.909
11:00	**M**	9.895	4.9%	7.873	42.2%	8.732	11.839
12:00	H	0.483		3.323		5.045	6.840
13:00	**M**	9.895	4.8%	8.187	39.5%	8.104	10.987
14:00	H	0.478		3.231		4.944	6.703
15:00	**M**	9.894	5.7%	8.243	41.0%	7.972	10.808
16:00	H	0.567		3.381		4.504	6.107
17:00	**M**	9.894	7.0%	8.211	41.3%	7.332	9.941
18:00	H	0.694		3.394		5.097	6.911
19:00	**M**	9.894	6.8%	7.839	42.3%	7.752	10.510
20:00	H	0.677		3.316		5.037	6.829

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.532		Hmax Amplitude (mV):	3.158
Hmax Torque (Nm)	4.307	5.839431	Hmax Torque (Nm)	5.839431
Mmax Stim Intensity (mA):	80		Mmax Stim Intensity (mA):	80
Mmax Amlitude (mV):	9.893		Mmax Amlitude (mV):	7.300
Mmax Torque (Nm)	6.852	9.289942	Mmax Torque (Nm)	9.289942
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.22		Hmax Amplitude (mV):	2.821
Hmax Torque (Nm)	3.808	5.162886	Hmax Torque (Nm)	5.162886
Gastroc H/M	2.2%		Soleus H/M	38.6%

Subject 3 Session 1 Control

1st

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	5.9%	8.736	45.5%	6.069	8.228
0:20	H	0.585		3.973		2.854	3.869
0:30	**M**	9.895	6.4%	8.685	42.3%	6.333	8.586
0:40	H	0.635		3.674		2.958	4.010
0:50	**M**	9.894	7.0%	8.830	37.1%	5.825	7.898
1:00	H	0.689		3.280		2.424	3.286
1:30	**M**	9.894	6.9%	8.422	47.2%	6.248	8.471
2:00	H	0.687		3.979		3.006	4.076
2:30	**M**	9.894	6.3%	8.722	45.3%	6.310	8.555
3:00	H	0.622		3.950		3.131	4.245
3:30	**M**	9.894	7.7%	8.426	44.9%	5.705	7.735
4:00	H	0.762		3.787		3.357	4.551
4:30	**M**	9.894	6.4%	8.449	43.7%	5.868	7.956
5:00	H	0.637		3.692		3.364	4.561
5:30	**M**	9.894	5.6%	8.402	44.9%	5.785	7.843
6:00	H	0.557		3.770		3.322	4.504
6:30	**M**	9.894	5.9%	8.644	43.8%	5.952	8.070
7:00	H	0.581		3.788		3.206	4.347
7:30	**M**	9.894	6.9%	8.536	44.8%	5.846	7.926
8:00	H	0.682		3.820		3.176	4.306
8:30	**M**	9.894	7.3%	8.540	46.4%	5.686	7.709
9:00	H	0.725		3.961		2.888	3.916
9:30	**M**	9.894	7.0%	8.401	44.3%	5.584	7.571
10:00	H	0.692		3.720		3.148	4.268
11:00	**M**	9.894	5.0%	8.392	41.1%	5.528	7.495
12:00	H	0.496		3.445		3.105	4.210
13:00	**M**	9.894	6.1%	8.275	46.8%	5.403	7.325
14:00	H	0.606		3.873		2.954	4.005
15:00	**M**	9.894	6.4%	8.205	46.3%	5.488	7.441
16:00	H	0.631		3.795		2.915	3.952
17:00	**M**	9.895	6.9%	8.259	47.1%	5.358	7.264
18:00	H	0.685		3.888		2.854	3.869
19:00	**M**	9.894	6.1%	8.134	42.9%	5.308	7.197
20:00	H	0.608		3.489		2.921	3.960

2nd

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	6.0%	8.560	47.2%	6.275	8.508
0:20	H	0.595		4.038		3.793	5.143
0:30	**M**	9.894	6.1%	8.701	44.8%	6.950	9.423
0:40	H	0.603		3.899		3.923	5.319
0:50	**M**	9.894	5.5%	8.661	44.7%	6.881	9.329
1:00	H	0.540		3.873		3.708	5.027
1:30	**M**	9.894	5.3%	8.874	45.4%	6.887	9.337
2:00	H	0.527		4.031		3.930	5.328
2:30	**M**	9.894	5.9%	8.700	44.9%	6.726	9.119
3:00	H	0.583		3.906		3.842	5.209
3:30	**M**	9.894	6.0%	8.831	44.0%	6.983	9.468
4:00	H	0.598		3.888		3.583	4.858
4:30	**M**	9.894	6.8%	8.745	43.5%	7.021	9.519
5:00	H	0.669		3.804		3.806	5.160
5:30	**M**	9.894	10.0%	8.789	46.4%	7.058	9.569
6:00	H	0.990		4.081		3.484	4.724
6:30	**M**	9.894	8.0%	8.862	44.5%	7.139	9.679
7:00	H	0.796		3.946		3.828	5.190
7:30	**M**	9.895	8.2%	8.701	43.5%	7.387	10.015
8:00	H	0.812		3.782		4.059	5.503
8:30	**M**	9.893	6.7%	8.799	47.3%	7.518	10.193
9:00	H	0.659		4.162		3.914	5.307
9:30	**M**	9.894	6.8%	8.900	43.1%	6.940	9.409
10:00	H	0.676		3.837		4.007	5.433
11:00	**M**	9.894	10.5%	8.851	44.1%	7.217	9.785
12:00	H	1.043		3.902		3.493	4.736
13:00	**M**	9.894	9.4%	8.915	44.6%	7.139	9.679
14:00	H	0.927		3.976		2.795	3.789
15:00	**M**	9.894	9.7%	8.901	42.6%	7.148	9.691
16:00	H	0.960		3.795		2.754	3.734
17:00	**M**	9.894	8.0%	8.741	45.1%	6.847	9.283
18:00	H	0.787		3.946		3.265	4.427
19:00	**M**	9.894	9.4%	8.678	44.6%	6.577	8.917
20:00	H	0.927		3.874		2.675	3.627

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.789		Hmax Amplitude (mV):	3.466
Hmax Torque (Nm)	3.691	5.004258	Hmax Torque (Nm)	5.004258
Mmax Stim Intensity (mA):	100		Mmax Stim Intensity (mA):	100
Mmax Amplitude (mV):	9.894		Mmax Amlitude (mV):	8.587
Mmax Torque (Nm)	6.987	9.472975	Mmax Torque (Nm)	9.472975
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.723		Hmax Amplitude (mV):	3.591
Hmax Torque (Nm)	3.250	4.40635	Hmax Torque (Nm)	4.40635
Gastroc H/M	7.3%		Soleus H/M	41.8%

Subject 3 Session 2 Control

#1

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	9.2%	8.723	42.0%	6.139	8.323
0:20	H	0.907		3.665		2.854	3.869
0:30	**M**	9.894	10.7%	8.647	45.3%	6.333	8.586
0:40	H	1.058		3.919		3.016	4.089
0:50	**M**	9.894	8.2%	8.672	45.5%	5.898	7.997
1:00	H	0.807		3.942		2.404	3.259
1:30	**M**	9.894	9.2%	8.672	44.3%	6.248	8.471
2:00	H	0.907		3.841		3.018	4.092
2:30	**M**	9.895	7.2%	8.491	45.9%	6.310	8.555
3:00	H	0.708		3.898		3.131	4.245
3:30	**M**	9.894	6.2%	8.570	47.0%	5.935	8.047
4:00	H	0.614		4.028		3.373	4.573
4:30	**M**	9.894	6.4%	8.717	41.7%	5.868	7.956
5:00	H	0.634		3.631		3.364	4.561
5:30	**M**	9.894	9.2%	8.672	42.9%	5.869	7.957
6:00	H	0.912		3.720		3.322	4.504
6:30	**M**	9.894	8.6%	8.446	45.9%	5.952	8.070
7:00	H	0.851		3.877		3.206	4.347
7:30	**M**	9.894	7.7%	8.390	45.2%	5.883	7.976
8:00	H	0.761		3.794		3.138	4.255
8:30	**M**	9.894	10.9%	8.618	44.4%	5.743	7.786
9:00	H	1.081		3.826		2.888	3.916
9:30	**M**	9.894	8.8%	8.584	44.4%	5.584	7.571
10:00	H	0.873		3.815		2.377	3.223
11:00	**M**	9.895	8.4%	8.538	43.5%	5.558	7.536
12:00	H	0.832		3.711		2.180	2.956
13:00	**M**	9.894	8.7%	8.742	44.8%	5.484	7.435
14:00	H	0.863		3.916		2.954	4.005
15:00	**M**	9.894	8.5%	8.617	43.4%	5.517	7.480
16:00	H	0.837		3.739		2.915	3.952
17:00	**M**	9.894	10.3%	8.630	44.5%	5.358	7.264
18:00	H	1.017		3.839		2.844	3.856
19:00	**M**	9.894	7.5%	8.781	42.6%	5.308	7.197
20:00	H	0.740		3.740		1.899	2.575

#2

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	10.3%	8.574	45.1%	4.555	6.176
0:20	H	1.021		3.866		2.188	2.966
0:30	**M**	9.898	8.1%	8.368	45.9%	4.689	6.357
0:40	H	0.797		3.837		2.306	3.126
0:50	**M**	9.894	9.2%	8.701	43.5%	4.697	6.368
1:00	H	0.908		3.783		2.110	2.861
1:30	**M**	9.894	9.7%	8.613	42.3%	4.912	6.660
2:00	H	0.960		3.639		2.183	2.960
2:30	**M**	9.894	9.3%	8.343	41.2%	5.191	7.038
3:00	H	0.921		3.439		1.820	2.468
3:30	**M**	9.894	9.3%	8.287	44.5%	4.916	6.665
4:00	H	0.921		3.688		2.157	2.924
4:30	**M**	9.894	10.4%	8.345	43.9%	4.570	6.196
5:00	H	1.028		3.662		1.983	2.689
5:30	**M**	9.894	9.7%	8.438	44.7%	4.194	5.686
6:00	H	0.959		3.770		2.037	2.762
6:30	**M**	9.894	9.9%	8.254	43.6%	3.940	5.342
7:00	H	0.980		3.597		2.045	2.773
7:30	**M**	9.894	9.2%	8.327	44.1%	4.675	6.338
8:00	H	0.915		3.674		1.914	2.595
8:30	**M**	9.895	10.1%	8.261	44.4%	4.058	5.502
9:00	H	1.004		3.665		1.945	2.637
9:30	**M**	9.894	10.1%	8.268	47.3%	3.876	5.255
10:00	H	0.995		3.912		1.968	2.668
11:00	**M**	9.894	11.6%	8.245	43.4%	3.932	5.331
12:00	H	1.144		3.582		1.903	2.580
13:00	**M**	9.895	9.6%	8.103	43.9%	3.651	4.950
14:00	H	0.952		3.561		1.869	2.534
15:00	**M**	9.894	10.1%	8.233	41.5%	3.446	4.672
16:00	H	1.001		3.415		1.997	2.708
17:00	**M**	9.894	7.0%	8.353	40.7%	4.222	5.724
18:00	H	0.688		3.396		2.061	2.794
19:00	**M**	9.894	6.0%	8.348	41.2%	4.071	5.519
20:00	H	0.597		3.439		1.979	2.683

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.791		Hmax Amplitude (mV):	3.34
Hmax Torque (Nm)	2.098	2.844468	Hmax Torque (Nm)	2.844468
Mmax Stim Intensity (mA):	45		Mmax Stim Intensity (mA):	45
Mmax Amlitude (mV):	9.892		Mmax Amlitude (mV):	7.732
Mmax Torque (Nm)	5.536	7.505709	Mmax Torque (Nm)	7.505709
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.909		Hmax Amplitude (mV):	3.683
Hmax Torque (Nm)	1.844	2.500095	Hmax Torque (Nm)	2.500095
Gastroc H/M	9.2%		Soleus H/M	47.6%

Subject 4 Session 1 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	2.5%	2.957	33.2%	7.082	9.602
0:20	H	0.245		0.982		2.373	3.217
0:30	**M**	9.894	3.3%	2.980	39.2%	7.045	9.552
0:40	H	0.324		1.167		2.573	3.488
0:50	**M**	9.894	2.9%	3.040	40.9%	6.744	9.144
1:00	H	0.289		1.244		2.576	3.493
1:30	**M**	9.894	3.3%	3.020	42.6%	6.574	8.913
2:00	H	0.331		1.287		2.555	3.464
2:30	**M**	9.894	3.7%	3.120	44.5%	6.157	8.348
3:00	H	0.369		1.388		2.687	3.643
3:30	**M**	9.894	3.8%	3.170	41.4%	6.093	8.261
4:00	H	0.379		1.312		2.550	3.457
4:30	**M**	9.894	3.6%	3.090	42.8%	5.779	7.835
5:00	H	0.358		1.322		2.514	3.408
5:30	**M**	9.894	3.9%	3.110	42.1%	5.634	7.639
6:00	H	0.385		1.310		2.570	3.484
6:30	**M**	9.894	3.8%	3.190	41.6%	5.535	7.504
7:00	H	0.373		1.328		2.637	3.575
7:30	**M**	9.895	3.9%	2.900	42.0%	5.365	7.274
8:00	H	0.388		1.218		2.370	3.213
8:30	**M**	9.894	3.5%	3.010	41.3%	5.183	7.027
9:00	H	0.343		1.243		2.386	3.235
9:30	**M**	9.894	3.4%	3.240	38.2%	5.139	6.967
10:00	H	0.336		1.238		2.439	3.307
11:00	**M**	9.894	3.3%	3.300	37.5%	4.991	6.767
12:00	H	0.322		1.236		2.046	2.774
13:00	**M**	9.894	3.1%	3.250	37.3%	4.732	6.416
14:00	H	0.311		1.213		2.134	2.893
15:00	**M**	9.894	3.1%	3.010	36.6%	4.520	6.128
16:00	H	0.308		1.101		1.858	2.519
17:00	**M**	9.894	3.0%	3.160	35.4%	4.415	5.986
18:00	H	0.300		1.119		1.981	2.686
19:00	**M**	9.894	3.0%	3.110	40.5%	4.442	6.022
20:00	H	0.292		1.259		2.081	2.821

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.186		Hmax Amplitude (mV):	1.287
Hmax Torque (Nm)	2.008	2.722446	Hmax Torque (Nm)	2.722446
Mmax Stim Intensity (mA):	90		Mmax Stim Intensity (mA):	90
Mmax Amplitude (mV):	9.893		Mmax Amplitude (mV):	4.140
Mmax Torque (Nm)	6.335	8.588993	Mmax Torque (Nm)	8.588993
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.280		Hmax Amplitude (mV):	1.275
Hmax Torque (Nm)	2.495	3.382721	Hmax Torque (Nm)	3.382721
Gastroc H/M	2.8%		Soleus H/M	30.8%

Subject 4 Session 2 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	3.2%	4.545	16.6%	7.034	9.537
0:20	H	0.319		0.755		3.232	4.382
0:30	**M**	9.894	3.3%	4.197	25.0%	6.896	9.350
0:40	H	0.323		1.048		3.111	4.218
0:50	**M**	9.894	4.2%	4.457	22.0%	6.407	8.687
1:00	H	0.411		0.981		3.381	4.584
1:30	**M**	9.894	4.0%	5.010	25.0%	6.131	8.312
2:00	H	0.394		1.250		3.551	4.814
2:30	**M**	9.894	3.9%	4.705	31.3%	5.773	7.827
3:00	H	0.387		1.474		3.442	4.667
3:30	**M**	9.894	3.6%	4.674	24.8%	5.927	8.036
4:00	H	0.357		1.159		3.257	4.416
4:30	**M**	9.894	3.5%	4.846	20.6%	5.818	7.888
5:00	H	0.347		0.996		3.162	4.287
5:30	**M**	9.894	2.9%	4.828	18.4%	5.763	7.813
6:00	H	0.287		0.889		3.006	4.076
6:30	**M**	9.894	3.5%	4.791	23.8%	5.500	7.457
7:00	H	0.348		1.142		2.960	4.013
7:30	**M**	9.894	4.3%	4.801	22.3%	5.369	7.279
8:00	H	0.429		1.072		2.697	3.657
8:30	**M**	9.894	3.6%	4.644	24.1%	5.405	7.328
9:00	H	0.359		1.119		2.828	3.834
9:30	**M**	9.894	4.1%	4.374	27.3%	5.205	7.057
10:00	H	0.410		1.192		3.083	4.180
11:00	**M**	9.894	4.0%	4.402	27.2%	5.294	7.178
12:00	H	0.391		1.199		3.104	4.208
13:00	**M**	9.894	3.1%	4.807	21.8%	5.275	7.152
14:00	H	0.309		1.050		2.682	3.636
15:00	**M**	9.894	3.3%	4.761	26.1%	5.121	6.943
16:00	H	0.324		1.242		2.670	3.620
17:00	**M**	9.894	2.8%	4.812	18.8%	4.887	6.626
18:00	H	0.280		0.905		2.750	3.728
19:00	**M**	9.895	3.6%	4.329	26.2%	5.028	6.817
20:00	H	0.355		1.136		2.706	3.669

Gastroc

Recruitment Curve

Hmax Stim Intensity (mA):	16	
Hmax Amplitude (mV):	0.376	
Hmax Torque (Nm)	2.120	2.874296
Mmax Stim Intensity (mA):	100	
Mmax Amlitude (mV):	9.894	
Mmax Torque (Nm)	5.184	7.028467

Confirm Hmax

Hmax Stim Intensity (mA):	16	
Hmax Amplitude (mV):	0.410	
Hmax Torque (Nm)	2.386	3.234939
Gastroc H/M	4.1%	

Soleus

Recruitment Curve

Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	1.485
Hmax Torque (Nm)	2.874296
Mmax Stim Intensity (mA):	100
Mmax Amplitude (mV):	4.613
Mmax Torque (Nm)	7.028467

Confirm Hmax

Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	1.289
Hmax Torque (Nm)	3.234939
Soleus H/M	27.9%

Subject 4 Session 3 Treatment oder: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	3.1%	4.332	14.6%	6.972	9.453
0:20	H	0.304		0.633		1.621	2.198
0:30	**M**	9.894	3.4%	4.468	18.4%	7.439	10.086
0:40	H	0.340		0.824		1.675	2.271
0:50	**M**	9.894	3.8%	4.625	16.9%	6.566	8.902
1:00	H	0.373		0.780		1.652	2.240
1:30	**M**	9.894	4.4%	4.382	18.6%	6.421	8.706
2:00	H	0.432		0.814		1.859	2.520
2:30	**M**	8.911	4.8%	4.815	19.9%	5.799	7.862
3:00	H	0.432		0.958		2.048	2.777
3:30	**M**	6.895	6.8%	4.870	20.6%	5.618	7.617
4:00	H	0.471		1.005		2.065	2.800
4:30	**M**	7.574	6.6%	4.915	18.0%	5.607	7.602
5:00	H	0.503		0.883		2.078	2.817
5:30	**M**	8.094	6.4%	4.922	18.3%	5.627	7.629
6:00	H	0.514		0.903		1.884	2.554
6:30	**M**	7.872	4.8%	4.923	22.4%	5.378	7.291
7:00	H	0.381		1.105		1.793	2.431
7:30	**M**	7.925	4.6%	4.888	16.6%	5.193	7.041
8:00	H	0.363		0.809		1.839	2.493
8:30	**M**	7.845	5.7%	4.971	18.3%	5.129	6.954
9:00	H	0.444		0.910		1.869	2.534
9:30	**M**	9.113	4.9%	4.701	21.1%	4.961	6.726
10:00	H	0.450		0.990		1.849	2.507
11:00	**M**	9.232	4.5%	4.857	21.8%	5.003	6.783
12:00	H	0.411		1.057		1.894	2.568
13:00	**M**	9.894	4.0%	4.895	20.0%	4.949	6.710
14:00	H	0.396		0.980		1.856	2.516
15:00	**M**	9.895	4.1%	4.827	13.1%	5.089	6.900
16:00	H	0.402		0.631		1.864	2.527
17:00	**M**	9.894	3.5%	4.703	20.6%	5.122	6.944
18:00	H	0.349		0.970		1.365	1.851
19:00	**M**	9.895	4.3%	4.700	20.4%	4.866	6.597
20:00	H	0.425		0.959		1.610	2.183

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	16		Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	0.386		Hmax Amplitude (mV):	0.946
Hmax Torque (Nm)	2.875	3.897925	Hmax Torque (Nm)	3.897925
Mmax Stim Intensity (mA):	85		Mmax Stim Intensity (mA):	85
Mmax Amlitude (mV):	9.894		Mmax Amplitude (mV):	5.304
Mmax Torque (Nm)	5.142	6.971524	Mmax Torque (Nm)	6.971524
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.389		Hmax Amplitude (mV):	1.098
Hmax Torque (Nm)	2.107	2.856671	Hmax Torque (Nm)	2.856671
Gastroc H/M	3.9%		Soleus H/M	20.7%

Subject 5 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	7.534	1.7%	6.970	12.5%	6.554	8.886
0:20	H	0.125		0.871		5.041	6.835
0:30	**M**	8.261	1.5%	6.885	15.1%	7.478	10.139
0:40	H	0.120		1.043		5.089	6.900
0:50	**M**	8.628	1.3%	7.028	10.7%	7.329	9.937
1:00	H	0.112		0.753		5.327	7.222
1:30	**M**	8.229	1.3%	7.162	12.9%	7.127	9.663
2:00	H	0.108		0.925		4.967	6.734
2:30	**M**	8.815	2.1%	7.062	12.7%	7.078	9.596
3:00	H	0.184		0.896		4.987	6.761
3:30	**M**	8.598	2.2%	6.978	12.9%	7.060	9.572
4:00	H	0.190		0.902		5.009	6.791
4:30	**M**	8.909	2.1%	7.040	14.2%	6.704	9.089
5:00	H	0.183		0.999		4.548	6.166
5:30	**M**	8.709	2.3%	7.075	14.6%	6.685	9.064
6:00	H	0.199		1.033		4.246	5.757
6:30	**M**	9.011	2.1%	6.872	9.2%	6.747	9.148
7:00	H	0.192		0.635		4.246	5.757
7:30	**M**	8.956	2.1%	7.236	10.2%	6.274	8.506
8:00	H	0.192		0.741		4.029	5.463
8:30	**M**	9.090	1.9%	7.254	14.5%	6.138	8.322
9:00	H	0.175		1.052		4.131	5.601
9:30	**M**	9.121	1.6%	7.350	9.4%	5.871	7.960
10:00	H	0.150		0.693		4.166	5.648
11:00	**M**	8.875	1.7%	7.452	12.3%	5.586	7.573
12:00	H	0.152		0.917		4.164	5.646
13:00	**M**	8.675	1.7%	7.441	8.6%	5.939	8.052
14:00	H	0.150		0.643		4.057	5.500
15:00	**M**	9.024	1.7%	7.156	8.7%	5.658	7.671
16:00	H	0.152		0.620		4.055	5.498
17:00	**M**	9.049	1.9%	7.030	8.7%	5.572	7.555
18:00	H	0.175		0.611		4.011	5.438
19:00	**M**	8.855	1.6%	7.187	7.7%	5.442	7.378
20:00	H	0.142		0.553		4.204	5.700

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	8		Hmax Stim Intensity (mA):	8
Hmax Amplitude (mV):	0.961		Hmax Amplitude (mV):	2.723
Hmax Torque (Nm)	1.795	2.433661	Hmax Torque (Nm)	
Mmax Stim Intensity (mA):	100		Mmax Stim Intensity (mA):	100
Mmax Amplitude (mV):	6.296		Mmax Amplitude (mV):	6.871
Mmax Torque (Nm)	3.897	5.283553	Mmax Torque (Nm)	
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.166		Hmax Amplitude (mV):	0.698
Hmax Torque (Nm)	3.776	5.119501	Hmax Torque (Nm)	
Gastroc H/M	2.6%		Soleus H/M	10.2%

Subject 5 Session 2 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.786	2.3%	9.895	8.4%	4.370	5.925
0:20	H	0.222		0.831		1.837	2.491
0:30	**M**	8.768	4.2%	9.895	14.9%	5.050	6.847
0:40	H	0.372		1.477		1.626	2.205
0:50	**M**	9.092	2.6%	9.894	11.3%	5.197	7.046
1:00	H	0.235		1.114		1.568	2.126
1:30	**M**	9.733	6.9%	9.895	18.9%	4.144	5.618
2:00	H	0.673		1.868		1.336	1.811
2:30	**M**	9.700	5.4%	9.894	17.3%	4.270	5.789
3:00	H	0.522		1.707		1.373	1.862
3:30	**M**	9.894	7.2%	9.894	22.0%	4.003	5.427
4:00	H	0.711		2.181		1.205	1.634
4:30	**M**	9.894	2.3%	9.894	15.0%	3.810	5.166
5:00	H	0.223		1.485		0.661	0.896
5:30	**M**	9.894	6.7%	9.894	18.2%	4.553	6.173
6:00	H	0.660		1.802		1.270	1.722
6:30	**M**	9.894	6.9%	9.894	17.9%	3.647	4.945
7:00	H	0.680		1.77		0.892	1.209
7:30	**M**	9.894	6.5%	9.894	15.7%	3.517	4.768
8:00	H	0.644		1.556		2.542	3.446
8:30	**M**	9.894	6.1%	9.894	17.4%	3.762	5.101
9:00	H	0.602		1.722		0.887	1.203
9:30	**M**	9.894	2.2%	9.895	14.7%	4.090	5.545
10:00	H	0.215		1.457		1.034	1.402
11:00	**M**	9.895	7.6%	9.895	22.0%	3.896	5.282
12:00	H	0.751		2.175		1.146	1.554
13:00	**M**	9.894	5.7%	9.894	13.4%	7.866	10.665
14:00	H	0.567		1.327		3.769	5.110
15:00	**M**	9.894	5.6%	9.895	16.0%	4.163	5.644
16:00	H	0.556		1.586		1.071	1.452
17:00	**M**	9.894	6.4%	9.895	19.7%	4.108	5.570
18:00	H	0.635		1.953		1.222	1.657
19:00	**M**	9.895	3.3%	9.895	12.7%	3.688	5.000
20:00	H	0.323		1.254		0.945	1.281

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.733		Hmax Amplitude (mV):	1.751
Hmax Torque (Nm)	0.747	1.012783	Hmax Torque (Nm)	1.012783
Mmax Stim Intensity (mA):	100		Mmax Stim Intensity (mA):	100
Mmax Amlitude (mV):	9.893		Mmax Amplitude (mV):	9.893
Mmax Torque (Nm)	3.449	4.676154	Mmax Torque (Nm)	4.676154
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.716		Hmax Amplitude (mV):	1.905
Hmax Torque (Nm)	1.643	2.227579	Hmax Torque (Nm)	2.227579
Gastroc H/M	7.2%		Soleus H/M	19.3%

Subject 5 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	3.7%	6.747	2.3%	7.906	10.719
0:20	H	0.368		0.156		7.227	9.798
0:30	**M**	9.894	3.6%	6.869	2.4%	7.878	10.681
0:40	H	0.357		0.165		6.423	8.708
0:50	**M**	9.894	3.1%	7.062	2.2%	7.392	10.022
1:00	H	0.305		0.158		6.172	8.368
1:30	**M**	9.894	2.8%	6.764	2.3%	6.790	9.206
2:00	H	0.279		0.153		5.856	7.940
2:30	**M**	9.894	2.7%	6.402	2.8%	6.612	8.965
3:00	H	0.263		0.177		6.175	8.372
3:30	**M**	9.894	3.6%	6.793	2.3%	6.071	8.231
4:00	H	0.352		0.156		5.238	7.102
4:30	**M**	9.894	2.9%	6.737	2.4%	5.174	7.015
5:00	H	0.286		0.162		4.472	6.063
5:30	**M**	9.894	2.9%	6.829	2.4%	5.451	7.390
6:00	H	0.283		0.166		4.590	6.223
6:30	**M**	9.894	2.8%	6.651	2.6%	5.110	6.928
7:00	H	0.279		0.176		5.100	6.915
7:30	**M**	9.894	3.0%	6.798	2.2%	4.845	6.569
8:00	H	0.295		0.148		4.461	6.048
8:30	**M**	9.894	3.0%	6.801	2.3%	4.924	6.676
9:00	H	0.301		0.155		4.628	6.275
9:30	**M**	9.894	3.3%	6.882	2.3%	4.912	6.660
10:00	H	0.325		0.158		4.857	6.585
11:00	**M**	9.894	3.3%	6.477	2.5%	4.931	6.685
12:00	H	0.322		0.162		4.427	6.002
13:00	**M**	9.895	3.3%	6.894	2.4%	4.486	6.082
14:00	H	0.328		0.163		4.327	5.867
15:00	**M**	9.895	3.2%	6.677	2.5%	4.817	6.531
16:00	H	0.320		0.167		4.567	6.192
17:00	**M**	9.894	3.3%	6.305	2.6%	4.977	6.748
18:00	H	0.323		0.166		3.900	5.288
19:00	**M**	9.872	3.4%	6.500	2.5%	4.906	6.652
20:00	H	0.332		0.161		4.809	6.520

Gastroc

Recruitment Curve

Hmax Stim Intensity (mA):	14	
Hmax Amplitude (mV):	0.359	
Hmax Torque (Nm)	5.714	7.747041
Mmax Stim Intensity (mA):	50	
Mmax Amlitude (mV):	9.892	
Mmax Torque (Nm)	6.387	8.659495

Confirm Hmax

Hmax Stim Intensity (mA):	12	
Hmax Amplitude (mV):	0.317	
Hmax Torque (Nm)	5.089	6.899666
Gastroc H/M	3.2%	

Soleus

Recruitment Curve

Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.159
Hmax Torque (Nm)	
Mmax Stim Intensity (mA):	50
Mmax Amplitude (mV):	4.784
Mmax Torque (Nm)	

Confirm Hmax

Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.164
Soleus H/M	3.4%

Subject 6 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	8.918	11.1%	5.573	56.9%	12.439	16.865
0:20	H	0.990		3.171		4.689	6.357
0:30	**M**	9.012	10.5%	4.796	62.4%	13.402	18.170
0:40	H	0.946		2.991		5.249	7.117
0:50	**M**	9.085	11.2%	5.135	55.8%	13.192	17.886
1:00	H	1.020		2.863		5.678	7.698
1:30	**M**	9.184	11.3%	4.893	58.3%	12.943	17.548
2:00	H	1.040		2.851		5.902	8.002
2:30	**M**	9.142	11.3%	4.317	55.7%	12.315	16.697
3:00	H	1.030		2.404		6.014	8.154
3:30	**M**	9.374	10.9%	4.669	52.8%	12.053	16.341
4:00	H	1.020		2.467		5.708	7.739
4:30	**M**	9.408	15.3%	3.837	18.1%	11.856	16.074
5:00	H	1.440		0.696		9.225	12.507
5:30	**M**	9.392	10.6%	4.379	52.2%	11.673	15.826
6:00	H	0.993		2.288		6.043	8.193
6:30	**M**	9.432	10.3%	4.607	47.0%	11.306	15.329
7:00	H	0.972		2.166		5.784	7.842
7:30	**M**	9.269	9.3%	4.011	47.1%	11.069	15.007
8:00	H	0.865		1.891		6.717	9.107
8:30	**M**	9.355	10.3%	4.135	56.2%	10.997	14.910
9:00	H	0.964		2.324		5.352	7.256
9:30	**M**	9.409	10.0%	3.993	51.7%	10.553	14.308
10:00	H	0.938		2.066		5.435	7.369
11:00	**M**	9.357	10.2%	3.673	59.4%	10.423	14.132
12:00	H	0.958		2.181		5.156	6.991
13:00	**M**	9.348	10.6%	3.957	58.7%	10.182	13.805
14:00	H	0.992		2.323		5.063	6.864
15:00	**M**	9.379	10.0%	3.788	55.8%	9.781	13.261
16:00	H	0.935		2.114		4.864	6.595
17:00	**M**	9.422	10.4%	3.853	55.8%	9.673	13.115
18:00	H	0.977		2.150		5.016	6.801
19:00	**M**	9.419	10.1%	3.988	51.5%	9.662	13.100
20:00	H	0.948		2.054		5.243	7.108

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.897		Hmax Amplitude (mV):	4.315
Hmax Torque (Nm)	2.875	3.898	Hmax Torque (Nm)	3.897925
Mmax Stim Intensity (mA):	55		Mmax Stim Intensity (mA):	55
Mmax Amplitude (mV):	9.303		Mmax Amplitude (mV):	9.893
Mmax Torque (Nm)	6.520	8.840	Mmax Torque (Nm)	8.839816
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.963		Hmax Amplitude (mV):	3.661
Hmax Torque (Nm)	2.955	4.006	Hmax Torque (Nm)	4.006389
Gastroc H/M	10.4%		Soleus H/M	37.0%

Subject 6 Session 2 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	3.7%	5.517	32.6%	11.509	15.604
0:20	H	0.368		1.801		6.069	8.228
0:30	**M**	9.894	3.5%	5.330	31.3%	11.766	15.952
0:40	H	0.347		1.670		6.381	8.651
0:50	**M**	9.894	2.7%	5.344	27.6%	11.452	15.527
1:00	H	0.270		1.475		6.708	9.095
1:30	**M**	9.894	3.0%	5.238	29.2%	11.429	15.495
2:00	H	0.292		1.532		7.148	9.691
2:30	**M**	9.894	4.0%	5.360	32.6%	11.523	15.623
3:00	H	0.398		1.748		6.838	9.271
3:30	**M**	9.894	4.8%	5.301	32.9%	11.171	15.146
4:00	H	0.475		1.746		6.697	9.080
4:30	**M**	9.894	4.5%	5.333	34.7%	10.798	14.640
5:00	H	0.441		1.849		6.493	8.803
5:30	**M**	9.895	4.3%	5.374	35.3%	10.449	14.167
6:00	H	0.425		1.898		6.240	8.460
6:30	**M**	9.894	4.2%	5.329	33.4%	10.673	14.470
7:00	H	0.411		1.779		6.481	8.787
7:30	**M**	9.894	4.3%	5.484	36.5%	10.382	14.076
8:00	H	0.425		1.999		5.998	8.132
8:30	**M**	9.895	4.4%	5.543	41.8%	9.972	13.520
9:00	H	0.438		2.315		6.010	8.148
9:30	**M**	9.894	4.6%	5.358	42.3%	9.904	13.428
10:00	H	0.451		2.267		5.768	7.820
11:00	**M**	9.894	3.9%	5.233	39.6%	9.676	13.119
12:00	H	0.389		2.074		5.602	7.595
13:00	**M**	9.894	3.3%	5.567	35.5%	9.260	12.555
14:00	H	0.327		1.976		5.838	7.915
15:00	**M**	9.894	2.7%	5.679	29.3%	9.142	12.395
16:00	H	0.271		1.665		5.788	7.847
17:00	**M**	9.894	3.0%	5.944	34.9%	9.023	12.233
18:00	H	0.296		2.073		5.098	6.912
19:00	**M**	9.894	3.8%	6.243	38.9%	8.884	12.045
20:00	H	0.378		2.429		4.663	6.322

Gastroc

Recruitment Curve

Hmax Stim Intensity (mA):	12	
Hmax Amplitude (mV):	0.771	
Hmax Torque (Nm)	4.605	6.243459
Mmax Stim Intensity (mA):	80	
Mmax Amlitude (mV):	9.893	
Mmax Torque (Nm)	10.366	14.05422

Confirm Hmax

Hmax Stim Intensity (mA):	12	
Hmax Amplitude (mV):	0.398	
Hmax Torque (Nm)	6.608	8.959126
Gastroc H/M	4.0%	

Soleus

Recruitment Curve

Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	2.811
Hmax Torque (Nm)	6.243459
Mmax Stim Intensity (mA):	80
Mmax Amlitude (mV):	5.036
Mmax Torque (Nm)	14.05422

Confirm Hmax

Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	1.808
Hmax Torque (Nm)	8.959126
Soleus H/M	35.9%

Subject 6 Session 3 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.325	10.7%	9.895	47.9%	7.910	10.724
0:20	H	0.996		4.735		3.103	4.207
0:30	**M**	8.928	11.2%	9.896	46.9%	9.134	12.384
0:40	H	0.997		4.641		3.213	4.356
0:50	**M**	8.932	10.4%	9.895	48.7%	9.292	12.598
1:00	H	0.930		4.815		3.075	4.169
1:30	**M**	8.828	10.3%	9.895	47.6%	9.314	12.628
2:00	H	0.909		4.711		3.252	4.409
2:30	**M**	8.851	10.5%	9.895	50.4%	9.178	12.444
3:00	H	0.926		4.986		3.171	4.299
3:30	**M**	8.865	10.3%	9.895	50.5%	9.293	12.599
4:00	H	0.917		5.001		3.111	4.218
4:30	**M**	8.852	10.7%	9.895	49.9%	9.100	12.338
5:00	H	0.944		4.937		3.075	4.169
5:30	**M**	8.828	10.3%	9.895	51.1%	9.001	12.204
6:00	H	0.912		5.052		2.953	4.004
6:30	**M**	8.736	10.2%	9.896	51.1%	8.884	12.045
7:00	H	0.890		5.057		3.044	4.127
7:30	**M**	8.505	10.3%	9.895	51.8%	8.940	12.121
8:00	H	0.878		5.125		2.973	4.031
8:30	**M**	8.381	10.4%	9.895	51.1%	8.592	11.649
9:00	H	0.869		5.053		2.811	3.811
9:30	**M**	8.310	10.6%	9.896	52.2%	8.611	11.675
10:00	H	0.885		5.161		2.906	3.940
11:00	**M**	8.325	11.1%	9.895	51.9%	8.549	11.591
12:00	H	0.923		5.131		2.767	3.751
13:00	**M**	8.104	10.9%	9.896	50.9%	8.619	11.686
14:00	H	0.882		5.035		2.681	3.635
15:00	**M**	8.044	11.4%	9.895	48.9%	8.221	11.146
16:00	H	0.918		4.838		2.586	3.506
17:00	**M**	7.740	12.1%	9.895	53.2%	8.270	11.212
18:00	H	0.938		5.266		2.509	3.402
19:00	**M**	7.966	11.1%	9.896	51.4%	8.559	11.604
20:00	H	0.883		5.088		2.583	3.502

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	1.216		Hmax Amplitude (mV):	4.994
Hmax Torque (Nm)	3.230	4.379234	Hmax Torque (Nm)	4.379234
Mmax Stim Intensity (mA):	100		Mmax Stim Intensity (mA):	100
Mmax Amlitude (mV):	8.844		Mmax Amlitude (mV):	9.893
Mmax Torque (Nm)	8.688	11.77919	Mmax Torque (Nm)	11.77919
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	8		Hmax Stim Intensity (mA):	8
Hmax Amplitude (mV):	1.012		Hmax Amplitude (mV):	4.347
Hmax Torque (Nm)	2.793	3.786749	Hmax Torque (Nm)	3.786749
Gastroc H/M	11.4%		Soleus H/M	43.9%

Subject 7 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.874	6.9%	9.895	17.5%	13.169	17.855
0:20	H	0.685		1.731		3.220	4.366
0:30	**M**	9.844	8.5%	9.895	21.0%	13.552	18.374
0:40	H	0.835		2.077		3.738	5.068
0:50	**M**	9.832	8.9%	9.896	24.3%	12.581	17.057
1:00	H	0.876		2.404		4.097	5.555
1:30	**M**	9.842	11.1%	9.895	37.2%	12.554	17.021
2:00	H	1.089		3.676		9.418	12.769
2:30	**M**	9.499	12.2%	9.894	35.2%	11.884	16.112
3:00	H	1.155		3.483		4.521	6.130
3:30	**M**	9.732	9.4%	9.894	28.5%	11.788	15.982
4:00	H	0.914		2.818		6.861	9.302
4:30	**M**	9.679	9.1%	9.895	26.1%	11.888	16.118
5:00	H	0.879		2.578		4.495	6.094
5:30	**M**	9.656	9.6%	9.895	29.7%	12.136	16.454
6:00	H	0.928		2.939		4.366	5.919
6:30	**M**	9.677	8.6%	9.894	25.3%	12.018	16.294
7:00	H	0.829		2.508		4.324	5.862
7:30	**M**	9.565	9.7%	9.895	24.6%	12.038	16.321
8:00	H	0.925		2.435		4.203	5.698
8:30	**M**	9.614	8.3%	9.894	22.2%	12.751	17.288
9:00	H	0.798		2.196		4.212	5.711
9:30	**M**	9.430	11.7%	9.894	29.9%	12.563	17.033
10:00	H	1.106		2.956		4.522	6.131
11:00	**M**	9.450	9.1%	9.895	26.7%	11.253	15.257
12:00	H	0.856		2.641		3.882	5.263
13:00	**M**	9.238	8.8%	9.894	22.2%	11.563	15.677
14:00	H	0.815		2.195		3.669	4.974
15:00	**M**	9.254	9.1%	9.895	27.7%	11.802	16.001
16:00	H	0.846		2.737		4.270	5.789
17:00	**M**	9.390	7.4%	9.895	16.9%	11.715	15.883
18:00	H	0.697		1.669		3.851	5.221
19:00	**M**	9.689	11.8%	9.894	32.1%	11.842	16.055
20:00	H	1.140		3.180		3.860	5.233

Gastroc			Soleus		
Recruitment Curve			Recruitment Curve		
Hmax Stim Intensity (mA):	8		Hmax Stim Intensity (mA):	8	
Hmax Amplitude (mV):	1.229		Hmax Amplitude (mV):	2.830	
Hmax Torque (Nm)	6.653	9.020	Hmax Torque (Nm)	9.020137	
Mmax Stim Intensity (mA):	100		Mmax Stim Intensity (mA):	100	
Mmax Amplitude (mV):	9.818		Mmax Amplitude (mV):	9.893	
Mmax Torque (Nm)	11.453	15.528	Mmax Torque (Nm)	15.52798	
Confirm Hmax			Confirm Hmax		
Hmax Stim Intensity (mA):	6		Hmax Stim Intensity (mA):	6	
Hmax Amplitude (mV):	1.367		Hmax Amplitude (mV):	3.753	
Hmax Torque (Nm)	6.569	8.906	Hmax Torque (Nm)	8.90625	
Gastroc H/M	13.9%		Soleus H/M	37.9%	

Subject 7 Session 2 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.387	13.0%	4.168	63.3%	12.007	16.279
0:20	H	1.221		2.638		4.572	6.199
0:30	**3**	8.843	13.1%	3.851	61.6%	9.904	13.428
0:40	H	1.158		2.372		4.758	6.451
0:50	**M**	8.503	13.2%	3.846	60.9%	10.099	13.692
1:00	H	1.123		2.342		4.649	6.303
1:30	**M**	9.895	12.3%	3.711	70.6%	11.283	15.297
2:00	H	1.221		2.621		5.026	6.814
2:30	**M**	8.057	15.2%	3.207	83.6%	12.289	16.661
3:00	H	1.221		2.681		5.939	8.052
3:30	**M**	9.894	12.6%	3.146	86.6%	11.080	15.022
4:00	H	1.251		2.724		5.463	7.407
4:30	**M**	9.895	12.1%	3.278	77.5%	11.598	15.725
5:00	H	1.199		2.541		6.331	8.584
5:30	**M**	9.894	10.1%	3.129	71.2%	11.243	15.243
6:00	H	0.997		2.229		4.934	6.690
6:30	**M**	9.895	12.1%	4.326	63.3%	11.778	15.969
7:00	H	1.194		2.737		5.402	7.324
7:30	**M**	9.895	12.1%	3.474	85.2%	11.210	15.199
8:00	H	1.201		2.961		4.392	5.955
8:30	**M**	9.894	9.3%	4.259	65.1%	10.400	14.100
9:00	H	0.921		2.774		4.121	5.587
9:30	**M**	9.895	12.4%	4.588	75.2%	10.034	13.604
10:00	H	1.228		3.449		3.511	4.760
11:00	**M**	9.872	14.0%	5.132	66.7%	10.295	13.958
12:00	H	1.384		3.424		4.383	5.942
13:00	**M**	9.894	12.8%	4.417	71.3%	11.693	15.853
14:00	H	1.270		3.148		4.815	6.528
15:00	**M**	9.896	13.0%	4.413	68.7%	10.074	13.658
16:00	H	1.287		3.033		4.646	6.299
17:00	**M**	9.895	11.8%	4.305	73.5%	10.560	14.317
18:00	H	1.164		3.164		5.159	6.995
19:00	**M**	9.894	13.1%	4.114	66.5%	9.893	13.413
20:00	H	1.301		2.735		5.186	7.031

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	8		Hmax Stim Intensity (mA):	8
Hmax Amplitude (mV):	1.031		Hmax Amplitude (mV):	1.555
Hmax Torque (Nm)	5.808	7.874	Hmax Torque (Nm)	7.874486
Mmax Stim Intensity (mA):	90		Mmax Stim Intensity (mA):	90
Mmax Amlitude (mV):	8.130		Mmax Amlitude (mV):	3.114
Mmax Torque (Nm)	8.360	11.334	Mmax Torque (Nm)	11.33449
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	6		Hmax Stim Intensity (mA):	6
Hmax Amplitude (mV):	1.159		Hmax Amplitude (mV):	2.387
Hmax Torque (Nm)	3.323	4.505	Hmax Torque (Nm)	4.505323
Gastroc H/M	14.30%		Soleus H/M	76.70%

Subject 7 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.129	6.1%	9.896	11.9%	15.827	21.458
0:20	H	0.557		1.180		6.295	8.535
0:30	**M**	9.503	5.8%	9.895	12.5%	11.941	16.190
0:40	H	0.553		1.232		6.612	8.965
0:50	**M**	9.479	6.7%	9.895	13.1%	11.670	15.822
1:00	H	0.636		1.296		7.068	9.583
1:30	**M**	9.575	6.3%	9.895	13.5%	11.758	15.941
2:00	H	0.608		1.337		7.750	10.507
2:30	**M**	9.525	7.3%	9.896	16.3%	12.357	16.754
3:00	H	0.693		1.614		6.865	9.308
3:30	**M**	9.428	6.6%	9.895	13.7%	12.552	17.018
4:00	H	0.622		1.353		7.735	10.487
4:30	**M**	9.421	6.9%	9.896	14.0%	12.038	16.321
5:00	H	0.654		1.386		7.236	9.811
5:30	**M**	9.566	6.3%	9.896	14.1%	12.995	17.619
6:00	H	0.598		1.397		7.687	10.422
6:30	**M**	9.416	7.1%	9.895	15.3%	12.418	16.836
7:00	H	0.671		1.513		7.384	10.011
7:30	**M**	9.480	6.3%	9.895	14.2%	12.881	17.464
8:00	H	0.597		1.408		7.668	10.396
8:30	**M**	9.586	6.5%	9.896	13.9%	11.711	15.878
9:00	H	0.627		1.379		7.581	10.278
9:30	**M**	9.591	6.5%	9.895	13.2%	11.935	16.181
10:00	H	0.621		1.305		8.405	11.395
11:00	**M**	9.415	6.5%	9.895	15.2%	12.681	17.193
12:00	H	0.608		1.500		7.731	10.482
13:00	**M**	9.348	6.6%	9.895	18.0%	12.822	17.384
14:00	H	0.621		1.785		4.909	6.656
15:00	**M**	9.603	7.9%	9.896	18.7%	11.738	15.914
16:00	H	0.755		1.847		7.277	9.866
17:00	**M**	9.421	7.5%	9.896	20.2%	11.431	15.498
18:00	H	0.706		1.999		6.994	9.482
19:00	**M**	9.556	7.5%	9.896	19.3%	11.949	16.200
20:00	H	0.719		1.914		7.118	9.651

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.663		Hmax Amplitude (mV):	1.754
Hmax Torque (Nm)	6.512	8.829	Hmax Torque (Nm)	8.82897
Mmax Stim Intensity (mA):	100		Mmax Stim Intensity (mA):	100
Mmax Amlitude (mV):	9.473		Mmax Amlitude (mV):	7.795
Mmax Torque (Nm)	9.818	13.311	Mmax Torque (Nm)	13.31124
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.842		Hmax Amplitude (mV):	2.181
Hmax Torque (Nm)	5.988	8.119	Hmax Torque (Nm)	8.11853
Gastroc H/M	8.9%		Soleus H/M	28.0%

Subject 8 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.205	14.0%	9.894	26.4%	10.931	14.820
0:20	H	1.288		2.610		6.251	8.475
0:30	**M**	9.301	10.7%	9.896	21.0%	11.577	15.696
0:40	H	0.993		2.078		7.154	9.699
0:50	**M**	9.720	11.0%	9.895	21.4%	14.063	19.067
1:00	H	1.074		2.113		7.225	9.796
1:30	**M**	9.346	11.1%	9.895	22.5%	14.257	19.330
2:00	H	1.036		2.225		8.463	11.474
2:30	**M**	9.411	10.5%	9.894	23.5%	13.814	18.729
3:00	H	0.990		2.326		8.261	11.200
3:30	**M**	9.342	12.4%	9.895	23.9%	12.657	17.160
4:00	H	1.158		2.368		7.829	10.615
4:30	**M**	9.399	12.6%	9.894	26.6%	12.271	16.637
5:00	H	1.187		2.630		7.224	9.794
5:30	**M**	9.167	13.4%	9.895	28.7%	11.320	15.348
6:00	H	1.230		2.839		6.369	8.635
6:30	**M**	9.196	12.7%	9.895	32.1%	10.217	13.852
7:00	H	1.170		3.176		6.723	9.115
7:30	**M**	9.789	9.2%	9.895	33.7%	11.631	15.769
8:00	H	0.896		3.335		7.427	10.070
8:30	**M**	9.894	11.1%	9.894	23.3%	10.074	13.658
9:00	H	1.099		2.304		7.314	9.916
9:30	**M**	9.639	12.0%	9.895	24.5%	10.771	14.603
10:00	H	1.160		2.425		6.076	8.238
11:00	**M**	9.186	12.3%	9.895	26.3%	10.273	13.928
12:00	H	1.132		2.605		5.838	7.915
13:00	**M**	8.392	12.0%	9.895	35.9%	9.682	13.127
14:00	H	1.005		3.555		5.080	6.887
15:00	**M**	7.513	15.4%	9.895	38.3%	8.810	11.945
16:00	H	1.159		3.793		4.619	6.262
17:00	**M**	7.740	18.7%	9.895	43.8%	8.142	11.039
18:00	H	1.445		4.331		4.074	5.524
19:00	**M**	7.702	19.6%	9.895	44.7%	7.682	10.415
20:00	H	1.513		4.421		4.018	5.448

Gastroc		
Recruitment Curve		
Hmax Stim Intensity (mA):	14	
Hmax Amplitude (mV):	1.841	
Hmax Torque (Nm)	5.658	7.671116
Mmax Stim Intensity (mA):	80	
Mmax Amplitude (mV):	9.893	
Mmax Torque (Nm)	8.554	11.59751
Confirm Hmax		
Hmax Stim Intensity (mA):	18	
Hmax Amplitude (mV):	1.154	
Hmax Torque (Nm)	6.901	9.356376
Gastroc H/M	11.7%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	2.145
Hmax Torque (Nm)	7.671116
Mmax Stim Intensity (mA):	80
Mmax Amplitude (mV):	9.894
Mmax Torque (Nm)	11.59751
Confirm Hmax	
Hmax Stim Intensity (mA):	18
Hmax Amplitude (mV):	2.292
Hmax Torque (Nm)	9.356376
Soleus H/M	23.2%

Subject 8 Session 2 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	8.012	6.3%	6.382	61.7%	12.631	17.125
0:20	H	0.507		3.938		6.744	9.144
0:30	**M**	7.931	5.9%	5.757	64.8%	12.600	17.083
0:40	H	0.470		3.732		6.703	9.088
0:50	**M**	7.870	6.4%	5.551	69.6%	12.489	16.933
1:00	H	0.501		3.861		6.271	8.502
1:30	**M**	7.950	14.1%	6.091	64.8%	12.663	17.168
2:00	H	1.120		3.947		7.015	9.511
2:30	**M**	8.364	14.4%	5.851	71.3%	12.503	16.952
3:00	H	1.208		4.173		7.136	9.675
3:30	**M**	8.536	16.0%	6.577	60.0%	12.183	16.518
4:00	H	1.368		3.945		7.187	9.744
4:30	**M**	8.353	15.7%	6.731	59.9%	12.148	16.470
5:00	H	1.309		4.033		7.499	10.167
5:30	**M**	8.313	11.6%	6.621	59.0%	12.077	16.374
6:00	H	0.961		3.907		6.738	9.135
6:30	**M**	8.295	15.5%	6.311	66.5%	12.369	16.770
7:00	H	1.284		4.194		7.282	9.873
7:30	**M**	8.352	16.5%	7.208	55.4%	12.399	16.811
8:00	H	1.382		3.995		7.245	9.823
8:30	**M**	8.374	10.6%	9.894	40.9%	12.269	16.634
9:00	H	0.888		4.049		6.612	8.965
9:30	**M**	8.151	14.3%	9.894	39.9%	12.417	16.835
10:00	H	1.162		3.948		6.854	9.293
11:00	**M**	8.422	15.0%	9.894	39.4%	12.088	16.389
12:00	H	1.260		3.897		6.675	9.050
13:00	**M**	8.840	5.7%	9.894	36.7%	11.417	15.479
14:00	H	0.501		3.627		6.460	8.758
15:00	**M**	8.409	16.3%	9.894	43.2%	12.850	17.422
16:00	H	1.374		4.275		7.186	9.743
17:00	**M**	8.202	17.4%	9.894	43.4%	12.795	17.347
18:00	H	1.425		4.291		6.750	9.152
19:00	**M**	8.151	14.0%	9.895	42.6%	11.648	15.792
20:00	H	1.143		4.215		6.759	9.164

Gastroc		
Recruitment Curve		
Hmax Stim Intensity (mA):	18	
Hmax Amplitude (mV):	1.341	
Hmax Torque (Nm)	8.678	11.76563
Mmax Stim Intensity (mA):	75	
Mmax Amlitude (mV):	8.730	
Mmax Torque (Nm)	11.028	14.95176
Confirm Hmax		
Hmax Stim Intensity (mA):	14	
Hmax Amplitude (mV):	0.604	
Hmax Torque (Nm)	5.725	7.761955
Gastroc H/M	6.9%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	18
Hmax Amplitude (mV):	1.562
Hmax Torque (Nm)	11.76563
Mmax Stim Intensity (mA):	75
Mmax Amplitude (mV):	4.097
Mmax Torque (Nm)	14.95176
Confirm Hmax	
Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	1.563
Hmax Torque (Nm)	7.761955
Soleus H/M	38.1%

Subject 8 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	4.6%	9.895	35.4%	14.334	19.434
0:20	H	0.452		3.502		11.104	15.055
0:30	**M**	9.896	4.9%	9.894	36.7%	18.223	24.707
0:40	H	0.483		3.629		12.339	16.729
0:50	**M**	9.894	5.5%	9.894	37.7%	18.276	24.779
1:00	H	0.541		3.726		11.882	16.110
1:30	**M**	9.894	6.1%	9.895	40.9%	17.813	24.151
2:00	H	0.599		4.045		11.805	16.005
2:30	**M**	7.691	7.6%	9.895	32.4%	16.682	22.617
3:00	H	0.582		3.206		9.002	12.205
3:30	**M**	7.717	5.4%	9.895	39.4%	17.438	23.642
4:00	H	0.413		3.898		11.261	15.268
4:30	**M**	7.573	7.6%	9.894	39.7%	16.392	22.224
5:00	H	0.572		3.932		10.399	14.099
5:30	**M**	7.856	8.0%	9.895	40.2%	16.507	22.380
6:00	H	0.628		3.976		10.398	14.098
6:30	**M**	7.520	8.6%	9.896	39.4%	16.176	21.931
7:00	H	0.649		3.896		10.218	13.854
7:30	**M**	8.521	6.2%	9.895	41.2%	15.756	21.362
8:00	H	0.525		4.078		9.822	13.317
8:30	**M**	7.731	8.8%	9.894	39.6%	15.418	20.904
9:00	H	0.680		3.919		9.844	13.346
9:30	**M**	8.409	6.9%	9.895	41.8%	13.831	18.752
10:00	H	0.583		4.135		9.800	13.287
11:00	**M**	7.621	10.0%	9.895	40.1%	14.219	19.278
12:00	H	0.764		3.963		8.969	12.160
13:00	**M**	9.895	6.6%	9.894	40.7%	13.472	18.265
14:00	H	0.656		4.022		8.620	11.687
15:00	**M**	9.895	6.8%	9.894	39.1%	12.912	17.506
16:00	H	0.670		3.866		8.337	11.303
17:00	**M**	9.894	7.4%	9.894	37.3%	16.158	21.907
18:00	H	0.736		3.688		8.851	12.000
19:00	**M**	9.894	4.0%	9.894	32.5%	15.277	20.713
20:00	H	0.398		3.219		10.924	14.811

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	16		Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	0.594		Hmax Amplitude (mV):	3.977
Hmax Torque (Nm)	6.338	8.59306	Hmax Torque (Nm)	8.59306
Mmax Stim Intensity (mA):	95		Mmax Stim Intensity (mA):	95
Mmax Amlitude (mV):	9.893		Mmax Amplitude (mV):	9.894
Mmax Torque (Nm)	14.429	19.56284	Mmax Torque (Nm)	19.56284
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	20		Hmax Stim Intensity (mA):	20
Hmax Amplitude (mV):	0.609		Hmax Amplitude (mV):	3.563
Hmax Torque (Nm)	9.015	12.22254	Hmax Torque (Nm)	12.22254
Gastroc H/M	6.2%		Soleus H/M	36.0%

Subject 9 Session 1 Control

1st

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	7.4%	7.571	39.8%	8.192	11.107
0:20	H	0.732		3.013		1.619	2.195
0:30	**M**	9.893	8.1%	8.080	38.7%	7.629	10.343
0:40	H	0.798		3.129		1.379	1.870
0:50	**M**	9.893	6.6%	8.714	30.0%	7.562	10.253
1:00	H	0.649		2.614		1.555	2.108
1:30	**M**	9.894	8.0%	7.459	44.6%	8.035	10.894
2:00	H	0.787		3.330		2.331	3.160
2:30	**M**	9.893	6.6%	8.383	28.2%	8.457	11.466
3:00	H	0.651		2.363		2.032	2.755
3:30	**M**	9.893	8.0%	8.345	34.0%	7.969	10.804
4:00	H	0.792		2.834		1.881	2.550
4:30	**M**	9.893	7.8%	8.759	31.3%	8.425	11.423
5:00	H	0.770		2.740		1.700	2.305
5:30	**M**	9.893	2.7%	8.420	16.6%	8.081	10.956
6:00	H	0.265		1.398		1.871	2.537
6:30	**M**	9.893	6.7%	8.234	30.9%	7.571	10.265
7:00	H	0.661		2.548		1.582	2.145
7:30	**M**	9.893	4.5%	8.173	26.5%	6.633	8.993
8:00	H	0.445		2.164		1.266	1.716
8:30	**M**	9.893	7.4%	7.781	38.6%	6.345	8.603
9:00	H	0.736		3.006		2.570	3.484
9:30	**M**	9.893	3.6%	8.223	18.8%	9.444	12.804
10:00	H	0.352		1.548		1.742	2.362
11:00	**M**	9.893	5.8%	8.062	30.6%	8.344	11.313
12:00	H	0.577		2.470		1.748	2.370
13:00	**M**	9.893	6.2%	8.543	27.5%	7.502	10.171
14:00	H	0.613		2.352		2.281	3.093
15:00	**M**	9.894	8.5%	7.248	45.6%	8.305	11.260
16:00	H	0.837		3.307		2.374	3.219
17:00	**M**	9.895	10.0%	7.574	50.5%	7.924	10.743
18:00	H	0.991		3.827		2.306	3.126
19:00	**M**	9.895	5.1%	8.273	27.5%	8.079	10.954
20:00	H	0.508		2.276		1.532	2.077

2nd

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	10.4%	8.287	48.7%	7.225	9.796
0:20	H	1.024		4.039		2.017	2.735
0:30	**M**	9.894	12.0%	7.990	52.8%	7.429	10.072
0:40	H	1.184		4.218		2.024	2.744
0:50	**M**	9.894	9.0%	7.527	45.5%	7.211	9.777
1:00	H	0.893		3.428		1.842	2.497
1:30	**M**	9.896	10.0%	8.359	45.7%	7.006	9.499
2:00	H	0.985		3.821		1.827	2.477
2:30	**M**	9.894	11.3%	7.765	52.9%	6.798	9.217
3:00	H	1.117		4.107		1.784	2.419
3:30	**M**	9.894	8.0%	8.273	35.9%	6.706	9.092
4:00	H	0.787		2.972		1.320	1.790
4:30	**M**	9.895	9.6%	8.538	41.6%	6.429	8.716
5:00	H	0.953		3.550		1.387	1.880
5:30	**M**	9.894	11.3%	8.382	50.0%	6.524	8.845
6:00	H	1.120		4.191		1.517	2.057
6:30	**M**	9.895	10.2%	7.555	52.3%	6.163	8.356
7:00	H	1.007		3.955		1.263	1.712
7:30	**M**	9.895	9.1%	8.450	39.6%	5.480	7.430
8:00	H	0.904		3.350		1.160	1.573
8:30	**M**	9.896	10.2%	8.515	42.0%	5.984	8.113
9:00	H	1.006		3.574		1.129	1.531
9:30	**M**	9.894	11.2%	8.437	50.1%	5.233	7.095
10:00	H	1.111		4.225		1.033	1.401
11:00	**M**	9.894	9.7%	8.404	43.6%	4.884	6.622
12:00	H	0.955		3.667		1.108	1.502
13:00	**M**	9.896	11.5%	7.469	56.4%	6.002	8.138
14:00	H	1.138		4.212		1.421	1.927
15:00	**M**	9.894	8.7%	8.304	40.2%	5.817	7.887
16:00	H	0.864		3.341		1.309	1.775
17:00	**M**	9.893	10.1%	7.211	48.3%	7.572	10.266
18:00	H	1.002		3.481		1.815	2.461
19:00	**M**	9.894	9.4%	7.164	49.7%	7.007	9.500
20:00	H	0.928		3.563		1.720	2.332

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	1.212		Hmax Amplitude (mV):	4.309
Hmax Torque (Nm)	2.644	3.584735	Hmax Torque (Nm)	3.584735
Mmax Stim Intensity (mA):	40		Mmax Stim Intensity (mA):	40
Mmax Amplitude (mV):	9.892		Mmax Amplitude (mV):	7.584
Mmax Torque (Nm)	6.902	9.357732	Mmax Torque (Nm)	9.357732
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.747		Hmax Amplitude (mV):	2.942
Hmax Torque (Nm)	2.141	2.902768	Hmax Torque (Nm)	2.902768
Gastroc H/M	7.6%		Soleus H/M	38.8%

Subject 9 Session 2 Control

1st

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	17.2%	7.637	58.9%	4.545	6.162
0:20	H	1.704		4.497		1.325	1.796
0:30	**M**	9.893	15.5%	7.909	55.1%	4.912	6.660
0:40	H	1.533		4.355		1.228	1.665
0:50	**M**	9.894	19.3%	7.662	61.5%	4.996	6.774
1:00	H	1.906		4.713		1.592	2.158
1:30	**M**	9.895	13.3%	7.590	54.7%	5.324	7.218
2:00	H	1.317		4.151		1.246	1.689
2:30	**M**	9.894	17.4%	7.660	59.3%	4.721	6.401
3:00	H	1.720		4.542		1.122	1.521
3:30	**M**	9.894	13.0%	7.585	53.4%	4.622	6.267
4:00	H	1.290		4.054		1.281	1.737
4:30	**M**	9.894	18.6%	7.659	45.5%	4.567	6.192
5:00	H	1.842		3.482		1.588	2.153
5:30	**M**	9.893	21.3%	7.887	63.9%	4.847	6.572
6:00	H	2.107		5.043		1.226	1.662
6:30	**M**	9.894	20.9%	7.811	66.1%	4.620	6.264
7:00	H	2.064		5.162		1.217	1.650
7:30	**M**	9.893	19.9%	7.765	63.5%	4.566	6.191
8:00	H	1.970		4.927		1.114	1.510
8:30	**M**	9.896	20.5%	7.583	65.6%	4.466	6.055
9:00	H	2.030		4.972		1.157	1.569
9:30	**M**	9.895	21.0%	7.773	63.8%	4.713	6.390
10:00	H	2.082		4.958		1.109	1.504
11:00	**M**	9.895	11.5%	7.685	53.4%	4.553	6.173
12:00	H	1.137		4.105		0.981	1.330
13:00	**M**	9.894	10.4%	7.650	45.9%	4.639	6.290
14:00	H	1.025		3.513		0.952	1.291
15:00	**M**	9.894	11.0%	7.892	47.9%	4.579	6.208
16:00	H	1.090		3.783		1.049	1.422
17:00	**M**	9.896	18.9%	7.746	60.8%	4.556	6.177
18:00	H	1.871		4.713		1.108	1.502
19:00	**M**	9.893	18.5%	7.921	50.5%	4.626	6.272
20:00	H	1.831		4.001		4.282	5.806

2nd

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.896	15.9%	7.872	55.9%	5.450	7.389
0:20	H	1.575		4.404		1.989	2.697
0:30	**M**	9.894	10.1%	7.536	49.6%	5.785	7.843
0:40	H	1.001		3.737		1.718	2.329
0:50	**M**	9.893	11.7%	7.938	50.7%	5.630	7.633
1:00	H	1.156		4.025		1.632	2.213
1:30	**M**	9.898	17.8%	7.895	57.9%	5.866	7.953
2:00	H	1.757		4.574		1.541	2.089
2:30	**M**	9.895	12.0%	7.423	51.6%	5.457	7.399
3:00	H	1.184		3.832		1.515	2.054
3:30	**M**	9.895	11.5%	7.611	50.2%	5.617	7.616
4:00	H	1.139		3.822		1.763	2.390
4:30	**M**	9.894	22.2%	7.988	60.5%	5.580	7.565
5:00	H	2.192		4.833		1.928	2.614
5:30	**M**	9.895	13.5%	8.144	47.1%	6.686	9.065
6:00	H	1.338		3.833		1.899	2.575
6:30	**M**	9.895	9.1%	8.028	36.9%	6.611	8.963
7:00	H	0.904		2.963		1.741	2.360
7:30	**M**	9.896	10.0%	7.837	38.2%	5.943	8.058
8:00	H	0.987		2.990		1.876	2.543
8:30	**M**	9.894	19.2%	7.902	56.3%	6.052	8.205
9:00	H	1.903		4.447		2.014	2.731
9:30	**M**	9.894	11.7%	7.680	52.6%	5.932	8.043
10:00	H	1.154		4.037		1.765	2.393
11:00	**M**	9.895	14.3%	7.641	55.8%	6.065	8.223
12:00	H	1.416		4.265		1.874	2.541
13:00	**M**	9.893	12.4%	7.402	49.8%	7.102	9.629
14:00	H	1.231		3.687		2.114	2.866
15:00	**M**	9.898	14.5%	7.326	58.1%	6.597	8.944
16:00	H	1.435		4.255		2.187	2.965
17:00	**M**	9.893	11.4%	7.928	47.5%	6.147	8.334
18:00	H	1.129		3.764		2.261	3.065
19:00	**M**	9.895	16.8%	7.296	55.8%	7.081	9.600
20:00	H	1.667		4.074		2.419	3.280

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	1.213		Hmax Amplitude (mV):	3.475
Hmax Torque (Nm)	3.192	4.327714	Hmax Torque (Nm)	4.327714
Mmax Stim Intensity (mA):	30		Mmax Stim Intensity (mA):	30
Mmax Amlitude (mV):	9.892		Mmax Amplitude (mV):	6.589
Mmax Torque (Nm)	6.689	9.068946	Mmax Torque (Nm)	9.068946
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	1.286		Hmax Amplitude (mV):	3.598
Hmax Torque (Nm)	1.763	2.390275	Hmax Torque (Nm)	2.390275
Gastroc H/M	13.0%		Soleus H/M	54.6%

Subject 10 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.896	11.5%	7.504	34.2%	10.327	14.001
0:20	H	1.139		2.567		6.763	9.169
0:30	**M**	9.894	13.4%	7.709	32.2%	10.215	13.849
0:40	H	1.330		2.480		6.668	9.040
0:50	**M**	9.894	14.8%	7.810	33.0%	10.154	13.767
1:00	H	1.465		2.577		7.125	9.660
1:30	**M**	9.893	14.8%	7.421	34.2%	10.120	13.721
2:00	H	1.465		2.539		7.529	10.208
2:30	**M**	9.894	14.6%	7.240	36.3%	10.360	14.046
3:00	H	1.448		2.630		7.279	9.869
3:30	**M**	9.893	14.3%	6.947	36.3%	9.959	13.502
4:00	H	1.412		2.523		7.097	9.622
4:30	**M**	9.893	15.7%	7.201	35.6%	10.073	13.657
5:00	H	1.558		2.565		7.677	10.408
5:30	**M**	9.894	15.8%	7.000	36.6%	10.042	13.615
6:00	H	1.560		2.564		7.693	10.430
6:30	**M**	9.894	15.5%	7.187	35.8%	10.054	13.631
7:00	H	1.531		2.574		7.427	10.070
7:30	**M**	9.895	15.1%	7.115	34.4%	10.061	13.641
8:00	H	1.493		2.446		6.969	9.449
8:30	**M**	9.893	15.7%	7.114	35.4%	9.993	13.549
9:00	H	1.554		2.521		6.604	8.954
9:30	**M**	9.896	14.0%	8.108	30.7%	9.933	13.467
10:00	H	1.383		2.486		6.583	8.925
11:00	**M**	9.893	14.3%	8.761	29.4%	9.861	13.370
12:00	H	1.414		2.574		6.603	8.952
13:00	**M**	9.894	14.6%	8.811	29.6%	9.889	13.408
14:00	H	1.448		2.610		6.427	8.714
15:00	**M**	9.895	15.2%	7.921	31.6%	9.627	13.052
16:00	H	1.500		2.504		6.982	9.466
17:00	**M**	9.894	14.2%	9.842	27.4%	9.503	12.884
18:00	H	1.401		2.697		6.462	8.761
19:00	**M**	9.893	14.9%	9.893	26.9%	9.591	13.003
20:00	H	1.470		2.660		6.572	8.910

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	8		Hmax Stim Intensity (mA):	8
Hmax Amplitude (mV):	1.449		Hmax Amplitude (mV):	2.615
Hmax Torque (Nm)	8.866	12.02052	Hmax Torque (Nm)	12.02052
Mmax Stim Intensity (mA):	50		Mmax Stim Intensity (mA):	50
Mmax Amplitude (mV):	9.892		Mmax Amplitude (mV):	7.861
Mmax Torque (Nm)	10.578	14.34165	Mmax Torque (Nm)	14.34165
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	8		Hmax Stim Intensity (mA):	8
Hmax Amplitude (mV):	1.323		Hmax Amplitude (mV):	2.718
Hmax Torque (Nm)	8.951	12.13577	Hmax Torque (Nm)	12.13577
Gastroc H/M	13.4%		Soleus H/M	34.6%

Subject 10 Session 2 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	8.446	11.0%	9.896	9.1%	12.856	17.430
0:20	H	0.932		0.897		10.814	14.662
0:30	**M**	8.440	12.3%	9.895	13.2%	12.844	17.414
0:40	H	1.035		1.303		10.838	14.694
0:50	**M**	8.638	12.4%	9.894	12.0%	12.745	17.280
1:00	H	1.072		1.188		10.848	14.708
1:30	**M**	8.714	14.5%	9.895	17.9%	12.624	17.116
2:00	H	1.267		1.770		10.439	14.153
2:30	**M**	8.333	15.5%	9.896	17.2%	12.469	16.905
3:00	H	1.288		1.704		10.265	13.917
3:30	**M**	8.315	16.2%	9.895	17.9%	12.560	17.029
4:00	H	1.344		1.771		9.994	13.550
4:30	**M**	8.194	15.3%	9.896	15.9%	12.017	16.293
5:00	H	1.253		1.570		10.045	13.619
5:30	**M**	8.451	15.0%	9.896	17.2%	11.749	15.929
6:00	H	1.266		1.700		9.727	13.188
6:30	**M**	8.505	14.1%	9.894	16.4%	11.595	15.721
7:00	H	1.197		1.618		9.908	13.433
7:30	**M**	8.321	10.1%	9.895	9.3%	11.493	15.582
8:00	H	0.839		0.921		10.272	13.927
8:30	**M**	8.310	11.2%	9.895	8.9%	11.653	15.799
9:00	H	0.933		0.884		10.354	14.038
9:30	**M**	8.274	10.9%	9.894	10.2%	11.453	15.528
10:00	H	0.898		1.006		10.029	13.597
11:00	**M**	8.053	15.4%	9.896	16.6%	11.297	15.316
12:00	H	1.238		1.639		9.403	12.749
13:00	**M**	8.162	14.9%	9.895	15.8%	11.095	15.043
14:00	H	1.218		1.561		9.300	12.609
15:00	**M**	8.634	14.1%	9.895	16.9%	11.124	15.082
16:00	H	1.215		1.675		9.257	12.551
17:00	**M**	8.552	15.7%	9.895	18.0%	10.915	14.799
18:00	H	1.343		1.778		8.746	11.858
19:00	**M**	8.527	15.2%	9.895	20.3%	10.629	14.411
20:00	H	1.295		2.009		7.637	10.354

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	1.457		Hmax Amplitude (mV):	1.805
Hmax Torque (Nm)	8.650	11.72767	Hmax Torque (Nm)	11.72767
Mmax Stim Intensity (mA):	80		Mmax Stim Intensity (mA):	80
Mmax Amlitude (mV):	7.738		Mmax Amplitude (mV):	7.980
Mmax Torque (Nm)	10.495	14.22912	Mmax Torque (Nm)	14.22912
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	1.170		Hmax Amplitude (mV):	1.830
Hmax Torque (Nm)	8.659	11.73987	Hmax Torque (Nm)	11.73987
Gastroc H/M	15.1%		Soleus H/M	22.9%

Subject 10 Session 3 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	8.381	5.1%	9.893	6.6%	9.783	13.264
0:20	H	0.427		0.652		8.453	11.461
0:30	**M**	9.262	4.2%	9.895	5.4%	10.411	14.115
0:40	H	0.385		0.539		8.409	11.401
0:50	**M**	9.896	4.7%	9.898	5.7%	10.369	14.058
1:00	H	0.467		0.565		8.493	11.515
1:30	**M**	9.893	4.4%	9.894	6.7%	10.478	14.206
2:00	H	0.435		0.662		8.422	11.419
2:30	**M**	9.893	5.5%	9.893	6.8%	10.407	14.110
3:00	H	0.542		0.675		8.433	11.433
3:30	**M**	9.895	6.0%	9.894	7.2%	10.349	14.031
4:00	H	0.592		0.712		8.261	11.200
4:30	**M**	9.895	6.3%	9.895	7.1%	10.030	13.599
5:00	H	0.620		0.698		8.495	11.518
5:30	**M**	9.894	6.3%	9.894	7.2%	10.284	13.943
6:00	H	0.627		0.716		8.402	11.391
6:30	**M**	9.893	5.4%	9.894	7.1%	10.248	13.894
7:00	H	0.532		0.704		8.232	11.161
7:30	**M**	9.893	5.5%	9.894	6.2%	10.259	13.909
8:00	H	0.545		0.618		8.236	11.166
8:30	**M**	9.893	6.4%	9.894	8.0%	10.263	13.915
9:00	H	0.631		0.793		7.839	10.628
9:30	**M**	9.895	5.9%	9.895	7.9%	9.903	13.426
10:00	H	0.587		0.778		8.112	10.998
11:00	**M**	9.893	6.8%	9.894	8.8%	9.953	13.494
12:00	H	0.676		0.866		8.029	10.886
13:00	**M**	9.895	6.7%	9.895	9.0%	9.710	13.165
14:00	H	0.664		0.890		7.983	10.823
15:00	**M**	7.954	7.9%	9.895	9.6%	9.921	13.451
16:00	H	0.631		0.946		7.855	10.650
17:00	**M**	8.680	7.4%	9.895	8.1%	9.796	13.281
18:00	H	0.641		0.804		7.670	10.399
19:00	**M**	7.636	9.3%	9.895	8.1%	9.881	13.397
20:00	H	0.712		0.805		7.554	10.242

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	1.057		Hmax Amplitude (mV):	1.291
Hmax Torque (Nm)	7.215	9.782097	Hmax Torque (Nm)	9.782097
Mmax Stim Intensity (mA):	80		Mmax Stim Intensity (mA):	80
Mmax Amlitude (mV):	9.892		Mmax Amplitude (mV):	9.893
Mmax Torque (Nm)	9.742	13.2082	Mmax Torque (Nm)	13.2082
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.944		Hmax Amplitude (mV):	1.350
Hmax Torque (Nm)	6.885	9.334683	Hmax Torque (Nm)	9.334683
Gastroc H/M	9.5%		Soleus H/M	13.6%

Subject 11 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	2.5%	6.607	25.0%	7.230	9.802
0:20	H	0.245		1.652		5.175	7.016
0:30	**M**	9.893	2.5%	7.604	22.0%	7.629	10.343
0:40	H	0.251		1.674		5.470	7.416
0:50	**M**	9.894	2.6%	9.735	19.2%	7.615	10.324
1:00	H	0.262		1.870		5.759	7.808
1:30	**M**	9.893	2.7%	9.895	19.3%	7.781	10.549
2:00	H	0.264		1.907		5.890	7.986
2:30	**M**	9.893	2.8%	9.895	19.4%	7.646	10.366
3:00	H	0.273		1.922		5.873	7.963
3:30	**M**	9.893	2.8%	8.578	23.7%	7.484	10.147
4:00	H	0.274		2.037		5.787	7.846
4:30	**M**	9.339	2.7%	9.894	18.3%	7.539	10.221
5:00	H	0.249		1.813		5.630	7.633
5:30	**M**	9.894	2.8%	9.894	19.9%	7.428	10.071
6:00	H	0.280		1.968		5.953	8.071
6:30	**M**	9.894	2.6%	9.896	19.0%	7.354	9.971
7:00	H	0.262		1.885		5.623	7.624
7:30	**M**	8.740	3.0%	9.894	18.4%	7.153	9.698
8:00	H	0.266		1.820		5.421	7.350
8:30	**M**	9.893	2.6%	9.894	17.2%	7.148	9.691
9:00	H	0.254		1.701		5.502	7.460
9:30	**M**	9.624	2.8%	9.894	20.6%	7.009	9.503
10:00	H	0.269		2.042		5.523	7.488
11:00	**M**	9.715	2.6%	7.897	21.6%	7.137	9.676
12:00	H	0.248		1.707		5.372	7.283
13:00	**M**	9.695	2.9%	9.894	20.4%	6.797	9.215
14:00	H	0.280		2.017		5.150	6.982
15:00	**M**	9.674	2.8%	9.895	20.5%	6.429	8.716
16:00	H	0.267		2.031		4.782	6.483
17:00	**M**	9.790	3.1%	9.895	24.2%	6.415	8.697
18:00	H	0.305		2.394		4.850	6.576
19:00	**M**	9.894	2.7%	9.894	17.8%	6.081	8.245
20:00	H	0.265		1.759		4.391	5.953

Gastroc

Recruitment Curve

Hmax Stim Intensity (mA):	18	
Hmax Amplitude (mV):	0.301	
Hmax Torque (Nm)	4.255	5.768929
Mmax Stim Intensity (mA):	60	
Mmax Amplitude (mV):	9.891	
Mmax Torque (Nm)	5.194	7.042025

Confirm Hmax

Hmax Stim Intensity (mA):	18	
Hmax Amplitude (mV):	0.272	
Hmax Torque (Nm)	5.050	6.84679
Gastroc H/M	2.7%	

Soleus

Recruitment Curve

Hmax Stim Intensity (mA):	18
Hmax Amplitude (mV):	2.097
Hmax Torque (Nm)	5.768929
Mmax Stim Intensity (mA):	60
Mmax Amplitude (mV):	9.892
Mmax Torque (Nm)	7.042025

Confirm Hmax

Hmax Stim Intensity (mA):	18
Hmax Amplitude (mV):	2.177
Hmax Torque (Nm)	6.84679
Soleus H/M	22.0%

Subject 11 Session 2 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	2.6%	9.894	1.2%	6.317	8.565
0:20	H	0.261		0.114		3.230	4.379
0:30	**M**	9.894	2.7%	9.895	1.1%	6.768	9.176
0:40	H	0.267		0.108		3.109	4.215
0:50	**M**	9.894	2.6%	9.894	1.1%	6.863	9.305
1:00	H	0.257		0.105		3.163	4.288
1:30	**M**	8.163	3.3%	9.894	1.1%	6.833	9.264
2:00	H	0.268		0.111		3.126	4.238
2:30	**M**	9.662	2.7%	9.894	1.2%	6.836	9.268
3:00	H	0.259		0.120		3.128	4.241
3:30	**M**	9.894	2.6%	9.894	1.1%	6.925	9.389
4:00	H	0.258		0.113		3.249	4.405
4:30	**M**	9.894	2.8%	9.894	1.1%	6.939	9.408
5:00	H	0.278		0.110		3.220	4.366
5:30	**M**	9.894	2.7%	9.894	1.2%	6.992	9.480
6:00	H	0.271		0.114		3.178	4.309
6:30	**M**	9.894	2.7%	9.894	1.2%	6.879	9.327
7:00	H	0.272		0.115		3.100	4.203
7:30	**M**	9.894	2.7%	9.894	1.1%	6.722	9.114
8:00	H	0.264		0.110		3.090	4.189
8:30	**M**	9.893	2.6%	9.894	1.1%	6.845	9.280
9:00	H	0.261		0.108		3.210	4.352
9:30	**M**	9.893	2.6%	9.894	1.1%	6.734	9.130
10:00	H	0.259		0.112		3.100	4.203
11:00	**M**	9.894	2.6%	9.894	1.1%	6.771	9.180
12:00	H	0.258		0.110		3.055	4.142
13:00	**M**	9.893	2.6%	9.894	1.0%	6.865	9.308
14:00	H	0.257		0.102		3.249	4.405
15:00	**M**	9.895	2.6%	9.895	1.2%	6.813	9.237
16:00	H	0.255		0.114		3.185	4.318
17:00	**M**	9.893	2.5%	9.894	1.1%	6.859	9.299
18:00	H	0.252		0.105		3.130	4.244
19:00	**M**	9.893	2.6%	9.894	1.0%	6.667	9.039
20:00	H	0.254		0.103		3.095	4.196

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	16		Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	0.231		Hmax Amplitude (mV):	0.115
Hmax Torque (Nm)	3.136	4.251789	Hmax Torque (Nm)	4.251789
Mmax Stim Intensity (mA):	60		Mmax Stim Intensity (mA):	60
Mmax Amlitude (mV):	9.891		Mmax Amplitude (mV):	8.388
Mmax Torque (Nm)	6.839	9.272316	Mmax Torque (Nm)	9.272316
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	16		Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	0.196		Hmax Amplitude (mV):	0.116
Hmax Torque (Nm)	3.222	4.368388	Hmax Torque (Nm)	4.368388
Gastroc H/M	2.0%		Soleus H/M	1.4%

Subject 11 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	2.1%	9.894	2.3%	7.692	10.429
0:20	H	0.204		0.232		3.876	5.255
0:30	**M**	9.894	2.0%	9.894	2.1%	8.481	11.499
0:40	H	0.201		0.209		4.034	5.469
0:50	**M**	9.893	2.0%	9.894	2.0%	8.613	11.678
1:00	H	0.198		0.193		4.189	5.679
1:30	**M**	9.893	2.1%	9.894	1.8%	8.577	11.629
2:00	H	0.208		0.177		4.105	5.566
2:30	**M**	9.894	2.1%	9.894	1.7%	8.637	11.710
3:00	H	0.204		0.171		3.977	5.392
3:30	**M**	9.893	2.1%	9.894	1.6%	8.402	11.391
4:00	H	0.210		0.162		3.894	5.279
4:30	**M**	9.894	2.1%	9.894	1.5%	8.101	10.983
5:00	H	0.204		0.146		3.892	5.277
5:30	**M**	9.893	2.1%	9.894	1.5%	7.896	10.705
6:00	H	0.205		0.151		3.797	5.148
6:30	**M**	9.894	2.2%	9.895	1.5%	7.742	10.497
7:00	H	0.213		0.149		3.676	4.984
7:30	**M**	9.894	2.0%	9.894	1.5%	7.736	10.488
8:00	H	0.198		0.144		3.534	4.791
8:30	**M**	9.771	2.0%	9.895	1.4%	7.477	10.137
9:00	H	0.192		0.139		3.467	4.701
9:30	**M**	9.894	2.0%	9.894	1.4%	7.441	10.089
10:00	H	0.198		0.137		3.494	4.737
11:00	**M**	9.752	2.0%	9.893	1.4%	7.221	9.790
12:00	H	0.199		0.135		3.387	4.592
13:00	**M**	9.893	2.0%	9.895	1.3%	7.086	9.607
14:00	H	0.198		0.130		3.272	4.436
15:00	**M**	9.893	2.2%	9.894	1.2%	6.935	9.402
16:00	H	0.213		0.123		3.191	4.326
17:00	**M**	9.894	2.1%	9.894	1.2%	6.599	8.947
18:00	H	0.211		0.119		3.297	4.470
19:00	**M**	9.893	2.1%	9.894	1.2%	6.411	8.692
20:00	H	0.207		0.121		3.279	4.446

Gastroc		
Recruitment Curve		
Hmax Stim Intensity (mA):	12	
Hmax Amplitude (mV):	0.163	
Hmax Torque (Nm)	3.850	5.21983
Mmax Stim Intensity (mA):	60	
Mmax Amlitude (mV):	9.892	
Mmax Torque (Nm)	7.859	10.65523
Confirm Hmax		
Hmax Stim Intensity (mA):	12	
Hmax Amplitude (mV):	0.174	
Hmax Torque (Nm)	3.487	4.727675
Gastroc H/M	1.8%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.119
Hmax Torque (Nm)	5.21983
Mmax Stim Intensity (mA):	60
Mmax Amplitude (mV):	6.647
Mmax Torque (Nm)	10.65523
Confirm Hmax	
Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.116
Hmax Torque (Nm)	4.727675
Soleus H/M	1.7%

Subject 12 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	8.4%	4.875	73.6%	6.531	8.855
0:20	H	0.830		3.589		3.984	5.402
0:30	**M**	9.894	7.3%	5.675	57.3%	6.046	8.197
0:40	H	0.718		3.249		4.143	5.617
0:50	**M**	9.895	8.0%	5.734	58.3%	5.621	7.621
1:00	H	0.792		3.341		4.218	5.719
1:30	**M**	9.896	8.8%	5.785	63.2%	5.228	7.088
2:00	H	0.872		3.659		3.909	5.300
2:30	**M**	9.895	6.7%	5.979	57.8%	4.740	6.426
3:00	H	0.667		3.456		4.037	5.473
3:30	**M**	9.895	7.2%	5.681	65.1%	4.778	6.478
4:00	H	0.715		3.7		3.794	5.144
4:30	**M**	9.895	7.5%	6.039	57.8%	4.559	6.181
5:00	H	0.741		3.491		3.926	5.323
5:30	**M**	9.895	7.7%	6.05	56.1%	4.550	6.169
6:00	H	0.762		3.392		3.763	5.102
6:30	**M**	9.895	7.9%	6.102	56.9%	4.344	5.890
7:00	H	0.785		3.469		3.767	5.107
7:30	**M**	9.895	6.6%	6.083	60.7%	4.336	5.879
8:00	H	0.650		3.691		3.560	4.827
8:30	**M**	9.895	7.0%	6.026	66.2%	4.203	5.698
9:00	H	0.689		3.991		3.734	5.063
9:30	**M**	9.895	7.9%	5.966	59.0%	4.089	5.544
10:00	H	0.786		3.519		3.556	4.821
11:00	**M**	9.895	6.2%	6.17	53.9%	3.965	5.376
12:00	H	0.612		3.324		3.338	4.526
13:00	**M**	9.895	6.4%	6.011	51.3%	3.901	5.289
14:00	H	0.637		3.084		3.622	4.911
15:00	**M**	9.896	8.7%	6.198	60.3%	3.706	5.025
16:00	H	0.864		3.74		3.306	4.482
17:00	**M**	9.895	6.9%	6.265	51.7%	3.601	4.882
18:00	H	0.686		3.239		3.359	4.554
19:00	**M**	9.895	5.0%	6.291	44.9%	3.474	4.710
20:00	H	0.499		2.826		3.253	4.410

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.788		Hmax Amplitude (mV):	1.890
Hmax Torque (Nm)	4.234	5.740457	Hmax Torque (Nm)	5.740457
Mmax Stim Intensity (mA):	30		Mmax Stim Intensity (mA):	30
Mmax Amplitude (mV):	9.893		Mmax Amplitude (mV):	5.634
Mmax Torque (Nm)	4.393	5.956029	Mmax Torque (Nm)	5.956029
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.789		Hmax Amplitude (mV):	3.758
Hmax Torque (Nm)	3.268	4.430754	Hmax Torque (Nm)	4.430754
Gastroc H/M	8.0%		Soleus H/M	66.7%

Subject 12 Session 2 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	7.096	8.9%	5.631	46.1%	5.085	6.894
0:20	H	0.634		2.598		3.664	4.968
0:30	**M**	7.499	8.7%	5.708	54.4%	5.352	7.256
0:40	H	0.654		3.104		4.641	6.292
0:50	**M**	8.110	8.9%	5.76	61.2%	5.173	7.014
1:00	H	0.725		3.527		4.778	6.478
1:30	**M**	8.853	9.7%	5.748	68.7%	4.910	6.657
2:00	H	0.857		3.948		4.715	6.393
2:30	**M**	9.138	9.4%	5.507	71.3%	4.936	6.692
3:00	H	0.855		3.924		4.709	6.384
3:30	**M**	9.185	9.3%	5.955	60.7%	4.742	6.429
4:00	H	0.856		3.612		4.442	6.022
4:30	**M**	9.250	9.6%	5.852	59.3%	4.509	6.113
5:00	H	0.885		3.471		4.210	5.708
5:30	**M**	8.934	10.0%	5.675	64.3%	4.376	5.933
6:00	H	0.895		3.648		4.116	5.580
6:30	**M**	9.618	9.4%	5.601	68.4%	4.481	6.075
7:00	H	0.903		3.832		3.987	5.406
7:30	**M**	9.569	6.1%	5.431	68.6%	4.095	5.552
8:00	H	0.587		3.728		4.029	5.463
8:30	**M**	8.971	8.7%	5.724	50.6%	4.823	6.539
9:00	H	0.779		2.896		4.022	5.453
9:30	**M**	9.894	7.3%	5.608	56.3%	4.837	6.558
10:00	H	0.720		3.157		4.525	6.135
11:00	**M**	9.751	7.8%	5.617	56.2%	4.606	6.245
12:00	H	0.757		3.154		4.446	6.028
13:00	**M**	9.590	8.3%	5.402	57.8%	4.305	5.837
14:00	H	0.799		3.12		4.104	5.564
15:00	**M**	9.894	7.8%	5.49	61.0%	4.322	5.860
16:00	H	0.769		3.351		4.210	5.708
17:00	**M**	9.894	7.8%	5.539	57.1%	4.186	5.675
18:00	H	0.774		3.165		4.078	5.529
19:00	**M**	9.894	7.8%	5.613	59.7%	4.006	5.431
20:00	H	0.773		3.351		3.946	5.350

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.556		Hmax Amplitude (mV):	0.990
Hmax Torque (Nm)	3.731	5.05849	Hmax Torque (Nm)	5.05849
Mmax Stim Intensity (mA):	35		Mmax Stim Intensity (mA):	35
Mmax Amlitude (mV):	9.892		Mmax Amplitude (mV):	5.792
Mmax Torque (Nm)	5.162	6.99864	Mmax Torque (Nm)	6.99864
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.934		Hmax Amplitude (mV):	4.404
Hmax Torque (Nm)	4.016	5.444893	Hmax Torque (Nm)	5.444893
Gastroc H/M	9.4%		Soleus H/M	76.0%

Subject 12 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	7.439	6.9%	4.778	54.6%	8.597	11.656
0:20	H	0.516		2.609		5.991	8.123
0:30	**M**	7.274	7.5%	5.189	57.2%	8.699	11.794
0:40	H	0.543		2.966		6.095	8.264
0:50	**M**	7.268	7.3%	5.137	59.1%	7.299	9.896
1:00	H	0.534		3.035		5.846	7.926
1:30	**M**	7.491	7.2%	5.478	48.2%	6.885	9.335
2:00	H	0.541		2.641		5.130	6.955
2:30	**M**	7.670	6.4%	4.870	58.1%	5.878	7.969
3:00	H	0.489		2.828		5.667	7.683
3:30	**M**	9.101	5.2%	5.058	51.7%	5.324	7.218
4:00	H	0.477		2.614		5.254	7.123
4:30	**M**	8.977	4.3%	5.091	54.4%	6.003	8.139
5:00	H	0.385		2.768		5.560	7.538
5:30	**M**	9.574	5.3%	5.413	52.4%	5.831	7.906
6:00	H	0.509		2.834		5.254	7.123
6:30	**M**	9.783	6.0%	4.859	65.3%	5.238	7.102
7:00	H	0.585		3.172		4.811	6.523
7:30	**M**	8.982	4.3%	5.207	55.5%	5.117	6.938
8:00	H	0.388		2.891		5.021	6.807
8:30	**M**	9.467	4.8%	5.448	47.4%	5.014	6.798
9:00	H	0.458		2.585		4.778	6.478
9:30	**M**	9.633	5.1%	5.308	49.1%	4.639	6.290
10:00	H	0.495		2.606		4.458	6.044
11:00	**M**	9.341	4.9%	5.326	49.7%	4.496	6.096
12:00	H	0.461		2.648		4.486	6.082
13:00	**M**	7.541	5.3%	5.614	44.5%	4.686	6.353
14:00	H	0.398		2.498		4.154	5.632
15:00	**M**	7.858	4.0%	5.778	36.7%	4.094	5.551
16:00	H	0.316		2.118		3.884	5.266
17:00	**M**	7.735	3.9%	5.941	34.6%	3.871	5.248
18:00	H	0.302		2.054		3.806	5.160
19:00	**M**	7.715	3.3%	5.956	30.3%	3.904	5.293
20:00	H	0.258		1.806		3.673	4.980

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.788		Hmax Amplitude (mV):	2.021
Hmax Torque (Nm)	3.321	4.502612	Hmax Torque (Nm)	
Mmax Stim Intensity (mA):	35		Mmax Stim Intensity (mA):	35
Mmax Amlitude (mV):	9.893		Mmax Amplitude (mV):	5.579
Mmax Torque (Nm)	4.469	6.05907	Mmax Torque (Nm)	
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.701		Hmax Amplitude (mV):	2.021
Hmax Torque (Nm)	3.324	4.506679	Hmax Torque (Nm)	
Gastroc H/M	7.1%		Soleus H/M	36.2%

Subject 13 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	4.8%	5.73	66.1%	5.790	7.850
0:20	H	0.475		3.786		5.294	7.178
0:30	**M**	9.894	5.1%	9.812	40.9%	6.147	8.334
0:40	H	0.505		4.018		6.016	8.156
0:50	**M**	9.895	6.1%	5.517	82.8%	6.244	8.466
1:00	H	0.601		4.567		6.239	8.459
1:30	**M**	9.894	6.5%	5.806	79.0%	6.227	8.443
2:00	H	0.645		4.587		5.732	7.771
2:30	**M**	9.895	6.8%	5.918	77.0%	6.253	8.478
3:00	H	0.668		4.557		5.420	7.348
3:30	**M**	9.895	7.5%	5.78	83.5%	6.503	8.817
4:00	H	0.740		4.824		5.240	7.104
4:30	**M**	9.894	7.8%	5.938	78.8%	6.256	8.482
5:00	H	0.768		4.678		5.471	7.418
5:30	**M**	9.895	7.8%	5.964	78.5%	6.022	8.165
6:00	H	0.771		4.679		5.201	7.052
6:30	**M**	9.894	7.1%	5.814	75.5%	5.978	8.105
7:00	H	0.705		4.388		5.072	6.877
7:30	**M**	9.895	6.9%	5.878	78.3%	5.809	7.876
8:00	H	0.678		4.605		5.245	7.111
8:30	**M**	9.894	7.0%	5.702	81.1%	5.677	7.697
9:00	H	0.691		4.623		5.104	6.920
9:30	**M**	9.894	6.9%	5.881	75.7%	5.742	7.785
10:00	H	0.685		4.454		4.970	6.738
11:00	**M**	9.894	6.9%	5.789	75.5%	5.691	7.716
12:00	H	0.680		4.37		4.889	6.629
13:00	**M**	9.894	6.5%	5.959	72.9%	5.634	7.639
14:00	H	0.646		4.345		5.048	6.844
15:00	**M**	9.895	6.3%	5.954	72.8%	5.451	7.390
16:00	H	0.619		4.335		4.845	6.569
17:00	**M**	9.895	6.2%	5.801	69.6%	5.552	7.527
18:00	H	0.611		4.036		5.124	6.947
19:00	**M**	9.894	5.5%	5.923	70.6%	5.575	7.559
20:00	H	0.545		4.181		4.849	6.574

Gastroc			Soleus		
Recruitment Curve			Recruitment Curve		
Hmax Stim Intensity (mA):	18		Hmax Stim Intensity (mA):	18	
Hmax Amplitude (mV):	0.667		Hmax Amplitude (mV):	3.804	
Hmax Torque (Nm)	3.541	4.800888	Hmax Torque (Nm)		4.800888
Mmax Stim Intensity (mA):	45		Mmax Stim Intensity (mA):	45	
Mmax Amplitude (mV):	9.894		Mmax Amplitude (mV):	5.198	
Mmax Torque (Nm)	4.738	6.42378	Mmax Torque (Nm)		6.42378
Confirm Hmax			Confirm Hmax		
Hmax Stim Intensity (mA):	20		Hmax Stim Intensity (mA):	20	
Hmax Amplitude (mV):	0.625		Hmax Amplitude (mV):	4.192	
Hmax Torque (Nm)	5.720	7.755176	Hmax Torque (Nm)		7.755176
Gastroc H/M	6.3%		Soleus H/M	80.6%	

Subject 13 Session 2 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	3.9%	6.285	49.8%	7.700	10.440
0:20	H	0.390		3.127		4.715	6.393
0:30	**M**	9.893	3.7%	6.324	45.0%	7.475	10.135
0:40	H	0.370		2.847		4.263	5.780
0:50	**M**	9.894	3.3%	6.208	43.7%	6.963	9.440
1:00	H	0.325		2.712		4.428	6.003
1:30	**M**	9.894	4.0%	6.289	58.4%	7.521	10.197
2:00	H	0.391		3.67		4.711	6.387
2:30	**M**	9.894	5.0%	6.529	64.4%	7.311	9.912
3:00	H	0.492		4.205		4.912	6.660
3:30	**M**	9.895	4.3%	6.322	66.1%	6.816	9.241
4:00	H	0.428		4.182		4.975	6.745
4:30	**M**	9.895	4.2%	6.301	60.0%	7.113	9.644
5:00	H	0.420		3.78		4.624	6.269
5:30	**M**	9.894	4.8%	6.418	61.1%	7.113	9.644
6:00	H	0.470		3.923		4.874	6.608
6:30	**M**	9.893	2.8%	6.558	45.2%	7.275	9.863
7:00	H	0.274		2.964		3.985	5.403
7:30	**M**	9.894	4.7%	6.209	68.9%	6.802	9.222
8:00	H	0.461		4.277		4.684	6.351
8:30	**M**	9.894	4.8%	6.352	67.0%	6.729	9.123
9:00	H	0.470		4.255		5.095	6.908
9:30	**M**	9.894	4.2%	6.049	65.6%	7.071	9.587
10:00	H	0.412		3.966		4.819	6.534
11:00	**M**	9.894	4.2%	6.104	67.0%	7.052	9.561
12:00	H	0.417		4.092		5.190	7.037
13:00	**M**	9.894	4.4%	6.247	66.8%	7.011	9.506
14:00	H	0.440		4.17		5.087	6.897
15:00	**M**	9.894	3.7%	6.346	49.5%	6.891	9.343
16:00	H	0.362		3.143		4.244	5.754
17:00	**M**	9.894	4.5%	6.343	61.5%	7.058	9.569
18:00	H	0.442		3.902		4.704	6.378
19:00	**M**	9.894	4.9%	6.368	71.1%	6.740	9.138
20:00	H	0.486		4.528		5.071	6.875

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.302		Hmax Amplitude (mV):	3.312
Hmax Torque (Nm)	4.947	6.707143	Hmax Torque (Nm)	6.707143
Mmax Stim Intensity (mA):	55		Mmax Stim Intensity (mA):	55
Mmax Amlitude (mV):	9.892		Mmax Amplitude (mV):	5.402
Mmax Torque (Nm)	6.603	8.952347	Mmax Torque (Nm)	8.952347
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.407		Hmax Amplitude (mV):	3.559
Hmax Torque (Nm)	6.617	8.971329	Hmax Torque (Nm)	8.971329
Gastroc H/M	4.1%		Soleus H/M	65.9%

Subject 13 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	6.7%	5.754	68.1%	8.971	12.163
0:20	H	0.665		3.916		7.643	10.362
0:30	**M**	9.894	6.2%	5.602	65.8%	8.664	11.747
0:40	H	0.612		3.687		7.372	9.995
0:50	**M**	9.895	6.5%	5.605	62.8%	8.736	11.844
1:00	H	0.646		3.521		7.571	10.265
1:30	**M**	9.894	6.3%	5.613	66.6%	8.936	12.115
2:00	H	0.623		3.738		7.616	10.326
2:30	**M**	9.895	6.8%	5.503	69.9%	9.079	12.309
3:00	H	0.677		3.846		7.775	10.541
3:30	**M**	9.894	7.4%	5.642	69.9%	8.981	12.176
4:00	H	0.737		3.946		7.840	10.629
4:30	**M**	9.894	6.3%	5.449	71.9%	8.905	12.073
5:00	H	0.620		3.919		7.637	10.354
5:30	**M**	9.894	6.4%	5.55	71.2%	8.791	11.919
6:00	H	0.632		3.954		7.593	10.295
6:30	**M**	9.894	5.3%	5.618	56.7%	8.921	12.095
7:00	H	0.521		3.185		7.482	10.144
7:30	**M**	9.894	6.3%	5.466	68.5%	8.561	11.607
8:00	H	0.619		3.745		7.178	9.732
8:30	**M**	9.895	6.9%	5.48	72.4%	8.268	11.210
9:00	H	0.687		3.966		7.169	9.720
9:30	**M**	9.894	7.4%	5.615	71.9%	8.268	11.210
10:00	H	0.732		4.036		7.047	9.554
11:00	**M**	9.894	7.0%	5.589	72.4%	8.251	11.187
12:00	H	0.696		4.046		7.065	9.579
13:00	**M**	9.894	7.3%	5.534	71.0%	7.999	10.845
14:00	H	0.718		3.93		6.894	9.347
15:00	**M**	9.895	6.3%	5.533	69.8%	7.998	10.844
16:00	H	0.628		3.86		6.948	9.420
17:00	**M**	9.894	6.4%	5.546	69.9%	7.765	10.528
18:00	H	0.629		3.875		6.870	9.314
19:00	**M**	9.895	6.1%	5.56	66.1%	7.980	10.819
20:00	H	0.608		3.673		6.459	8.757

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.698		Hmax Amplitude (mV):	3.599
Hmax Torque (Nm)	8.103	10.98605	Hmax Torque (Nm)	10.98605
Mmax Stim Intensity (mA):	55		Mmax Stim Intensity (mA):	55
Mmax Amlitude (mV):	9.893		Mmax Amplitude (mV):	4.696
Mmax Torque (Nm)	8.543	11.5826	Mmax Torque (Nm)	11.5826
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.707		Hmax Amplitude (mV):	3.511
Hmax Torque (Nm)	7.122	9.656008	Hmax Torque (Nm)	9.656008
Gastroc H/M	7.1%		Soleus H/M	74.8%

Subject 14 Session 1 Control

1st

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.865	4.1%	9.894	34.0%	9.104	12.343
0:20	H	0.403		3.36		7.595	10.297
0:30	**M**	9.867	4.3%	9.893	35.1%	9.798	13.284
0:40	H	0.424		3.477		7.482	10.144
0:50	**M**	9.866	3.9%	9.894	35.0%	9.804	13.292
1:00	H	0.383		3.467		7.418	10.057
1:30	**M**	9.870	4.2%	9.893	35.3%	9.842	13.344
2:00	H	0.419		3.491		7.318	9.922
2:30	**M**	9.894	4.4%	9.895	34.4%	9.918	13.447
3:00	H	0.435		3.402		7.584	10.282
3:30	**M**	9.893	4.5%	9.894	36.5%	9.914	13.441
4:00	H	0.444		3.608		7.630	10.345
4:30	**M**	9.893	4.9%	9.893	37.5%	10.030	13.599
5:00	H	0.486		3.712		7.572	10.266
5:30	**M**	9.893	5.1%	9.895	36.4%	9.872	13.384
6:00	H	0.502		3.598		7.511	10.183
6:30	**M**	9.893	4.2%	9.894	32.6%	9.798	13.284
7:00	H	0.413		3.229		7.590	10.291
7:30	**M**	9.894	4.5%	9.894	32.9%	9.880	13.395
8:00	H	0.449		3.252		7.604	10.310
8:30	**M**	9.894	4.1%	9.894	32.1%	10.010	13.572
9:00	H	0.401		3.174		7.683	10.417
9:30	**M**	9.894	4.0%	9.894	32.0%	9.942	13.479
10:00	H	0.399		3.166		7.373	9.996
11:00	**M**	9.894	3.9%	9.894	32.4%	9.937	13.473
12:00	H	0.389		3.204		7.553	10.240
13:00	**M**	9.893	4.0%	9.894	32.1%	10.040	13.612
14:00	H	0.398		3.174		7.458	10.112
15:00	**M**	9.895	3.8%	9.894	31.8%	10.011	13.573
16:00	H	0.372		3.149		7.442	10.090
17:00	**M**	9.893	3.4%	9.895	29.6%	10.113	13.711
18:00	H	0.339		2.93		7.572	10.266
19:00	**M**	9.893	4.0%	9.894	31.9%	10.183	13.806
20:00	H	0.392		3.155		7.482	10.144

2nd

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.354	3.8%	9.894	31.4%	10.403	14.104
0:20	H	0.353		3.104		8.140	11.036
0:30	**M**	9.893	3.5%	9.894	30.6%	11.006	14.922
0:40	H	0.350		3.023		7.918	10.735
0:50	**M**	9.641	4.7%	9.894	33.8%	10.931	14.820
1:00	H	0.451		3.349		8.107	10.991
1:30	**M**	9.895	4.6%	9.896	32.6%	10.971	14.874
2:00	H	0.460		3.225		8.053	10.918
2:30	**M**	9.373	4.1%	9.894	32.6%	10.969	14.872
3:00	H	0.383		3.221		8.113	11.000
3:30	**M**	9.229	4.6%	9.894	30.9%	10.950	14.846
4:00	H	0.424		3.058		8.144	11.042
4:30	**M**	8.556	3.7%	9.895	29.1%	11.024	14.946
5:00	H	0.320		2.884		7.918	10.735
5:30	**M**	9.160	3.4%	9.895	31.1%	10.745	14.568
6:00	H	0.308		3.082		7.892	10.700
6:30	**M**	9.007	4.7%	9.895	32.4%	10.745	14.568
7:00	H	0.419		3.21		7.770	10.535
7:30	**M**	9.621	4.0%	9.894	31.5%	10.661	14.454
8:00	H	0.382		3.12		7.706	10.448
8:30	**M**	8.758	3.9%	9.895	28.9%	10.650	14.439
9:00	H	0.345		2.858		7.602	10.307
9:30	**M**	8.064	4.4%	9.894	31.4%	10.514	14.255
10:00	H	0.353		3.107		7.435	10.080
11:00	**M**	8.304	4.2%	9.895	28.4%	10.576	14.339
12:00	H	0.348		2.81		7.571	10.265
13:00	**M**	9.526	3.1%	9.894	28.1%	10.858	14.721
14:00	H	0.292		2.783		7.596	10.299
15:00	**M**	9.484	4.0%	9.895	28.6%	10.531	14.278
16:00	H	0.381		2.827		7.549	10.235
17:00	**M**	9.894	3.0%	9.894	23.6%	10.558	14.315
18:00	H	0.301		2.337		7.513	10.186
19:00	**M**	9.601	3.1%	9.895	25.1%	10.412	14.117
20:00	H	0.293		2.481		7.442	10.090

Gastroc		
Recruitment Curve		
Hmax Stim Intensity (mA):	16	
Hmax Amplitude (mV):	0.522	
Hmax Torque (Nm)	5.131	6.95661
Mmax Stim Intensity (mA):	60	
Mmax Amplitude (mV):	9.892	
Mmax Torque (Nm)	8.640	11.71411
Confirm Hmax		
Hmax Stim Intensity (mA):	16	
Hmax Amplitude (mV):	0.382	
Hmax Torque (Nm)	7.673	10.40305
Gastroc H/M	3.9%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	3.379
Hmax Torque (Nm)	6.95661
Mmax Stim Intensity (mA):	60
Mmax Amplitude (mV):	9.891
Mmax Torque (Nm)	11.71411
Confirm Hmax	
Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	3.185
Hmax Torque (Nm)	10.40305
Soleus H/M	32.2%

Subject 14 Session 2 Control

1st

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	4.0%	9.894	24.4%	11.155	15.124
0:20	H	0.396		2.412		8.537	11.574
0:30	**M**	9.893	4.0%	9.894	22.9%	12.530	16.988
0:40	H	0.391		2.268		8.574	11.625
0:50	**M**	9.893	3.6%	9.894	21.5%	12.688	17.202
1:00	H	0.358		2.128		8.431	11.431
1:30	**M**	9.893	3.4%	9.893	17.7%	12.577	17.052
2:00	H	0.336		1.753		8.260	11.199
2:30	**M**	9.893	3.9%	9.895	23.7%	12.727	17.255
3:00	H	0.390		2.350		8.793	11.922
3:30	**M**	9.893	4.1%	9.894	24.4%	12.662	17.167
4:00	H	0.408		2.410		8.946	12.129
4:30	**M**	9.893	4.1%	9.893	25.5%	12.678	17.189
5:00	H	0.407		2.525		8.962	12.151
5:30	**M**	9.893	4.0%	9.894	24.9%	12.659	17.163
6:00	H	0.396		2.460		9.084	12.316
6:30	**M**	9.893	4.0%	9.893	25.8%	12.642	17.140
7:00	H	0.395		2.557		8.879	12.038
7:30	**M**	9.893	4.4%	9.893	25.2%	12.501	16.949
8:00	H	0.437		2.494		9.176	12.441
8:30	**M**	9.893	4.1%	9.893	24.1%	12.704	17.224
9:00	H	0.408		2.385		8.865	12.019
9:30	**M**	9.893	4.1%	9.895	25.2%	12.721	17.247
10:00	H	0.406		2.493		8.862	12.015
11:00	**M**	9.893	4.1%	9.894	25.1%	12.727	17.255
12:00	H	0.402		2.487		9.101	12.339
13:00	**M**	9.893	4.0%	9.894	25.3%	12.696	17.213
14:00	H	0.398		2.505		9.007	12.212
15:00	**M**	9.893	3.9%	9.894	24.3%	12.556	17.023
16:00	H	0.385		2.401		8.871	12.027
17:00	**M**	9.893	3.7%	9.894	23.2%	12.480	16.920
18:00	H	0.364		2.291		8.848	11.996
19:00	**M**	9.894	3.5%	9.894	21.9%	12.503	16.952
20:00	H	0.349		2.170		8.680	11.768

2nd

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	4.3%	9.894	23.9%	13.871	18.806
0:20	H	0.422		2.367		9.620	13.043
0:30	**M**	9.893	4.0%	9.893	25.1%	13.966	18.935
0:40	H	0.400		2.488		10.198	13.826
0:50	**M**	9.894	4.1%	9.894	25.1%	13.953	18.917
1:00	H	0.403		2.484		10.094	13.685
1:30	**M**	9.893	4.1%	9.894	24.4%	13.688	18.558
2:00	H	0.410		2.417		9.873	13.386
2:30	**M**	9.894	4.4%	9.894	26.2%	13.745	18.635
3:00	H	0.438		2.597		9.851	13.356
3:30	**M**	9.893	3.7%	9.894	24.6%	13.769	18.668
4:00	H	0.362		2.433		10.224	13.862
4:30	**M**	9.894	3.9%	9.894	24.8%	13.590	18.425
5:00	H	0.385		2.456		9.984	13.536
5:30	**M**	9.893	3.7%	9.894	25.1%	13.626	18.474
6:00	H	0.363		2.482		9.860	13.368
6:30	**M**	9.893	3.7%	9.894	23.9%	13.622	18.469
7:00	H	0.367		2.365		9.602	13.018
7:30	**M**	9.893	3.4%	9.894	22.3%	13.770	18.669
8:00	H	0.341		2.208		9.876	13.390
8:30	**M**	9.893	3.5%	9.893	20.2%	13.489	18.288
9:00	H	0.351		1.995		9.294	12.601
9:30	**M**	9.893	3.6%	9.894	23.1%	13.700	18.574
10:00	H	0.358		2.282		9.605	13.022
11:00	**M**	9.893	3.2%	9.894	22.5%	13.416	18.189
12:00	H	0.314		2.228		9.604	13.021
13:00	**M**	9.893	4.0%	9.894	23.4%	13.495	18.297
14:00	H	0.394		2.317		9.324	12.641
15:00	**M**	9.893	3.5%	9.895	22.3%	13.448	18.233
16:00	H	0.344		2.204		9.701	13.153
17:00	**M**	9.894	3.2%	9.894	22.1%	13.491	18.291
18:00	H	0.317		2.182		9.771	13.248
19:00	**M**	9.894	3.5%	9.894	22.9%	13.297	18.028
20:00	H	0.347		2.262		9.652	13.086

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.415		Hmax Amplitude (mV):	2.085
Hmax Torque (Nm)	7.150	9.69397	Hmax Torque (Nm)	9.69397
Mmax Stim Intensity (mA):	50		Mmax Stim Intensity (mA):	50
Mmax Amlitude (mV):	9.891		Mmax Amplitude (mV):	9.892
Mmax Torque (Nm)	10.044	13.61766	Mmax Torque (Nm)	13.61766
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.329		Hmax Amplitude (mV):	2.088
Hmax Torque (Nm)	7.663	10.3895	Hmax Torque (Nm)	10.3895
Gastroc H/M	3.3%		Soleus H/M	21.1%

Subject 15 Session 1 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	4.5%	4.546	58.9%	6.539	8.866
0:20	H	0.447		2.678		4.060	5.505
0:30	**M**	9.894	4.6%	4.661	62.6%	6.471	8.773
0:40	H	0.459		2.919		3.856	5.228
0:50	**M**	9.895	3.1%	4.696	45.2%	6.336	8.590
1:00	H	0.304		2.121		3.721	5.045
1:30	**M**	9.894	4.8%	4.682	68.8%	6.315	8.562
2:00	H	0.479		3.221		3.822	5.182
2:30	**M**	9.894	4.9%	4.668	69.9%	6.351	8.611
3:00	H	0.482		3.264		3.850	5.220
3:30	**M**	9.895	4.9%	4.777	63.9%	6.323	8.573
4:00	H	0.488		3.054		3.762	5.101
4:30	**M**	9.895	4.9%	4.740	70.3%	6.323	8.573
5:00	H	0.486		3.332		3.568	4.837
5:30	**M**	9.895	4.2%	4.848	52.5%	6.668	9.040
6:00	H	0.414		2.543		3.167	4.294
6:30	**M**	9.895	4.8%	4.817	72.1%	6.070	8.230
7:00	H	0.473		3.475		3.495	4.739
7:30	**M**	9.895	4.7%	4.918	66.0%	5.859	7.944
8:00	H	0.463		3.245		3.589	4.866
8:30	**M**	9.895	4.3%	4.988	61.8%	5.826	7.899
9:00	H	0.430		3.083		3.427	4.646
9:30	**M**	9.894	4.6%	4.922	63.1%	5.881	7.973
10:00	H	0.459		3.104		3.085	4.183
11:00	**M**	9.896	5.0%	5.060	68.9%	5.788	7.847
12:00	H	0.496		3.484		3.414	4.629
13:00	**M**	9.895	4.7%	4.994	71.1%	6.157	8.348
14:00	H	0.466		3.551		3.777	5.121
15:00	**M**	9.894	5.7%	5.543	64.0%	6.446	8.739
16:00	H	0.564		3.545		3.822	5.182
17:00	**M**	9.894	4.0%	5.364	45.3%	6.435	8.725
18:00	H	0.394		2.431		3.668	4.973
19:00	**M**	9.894	4.9%	5.066	64.0%	6.842	9.276
20:00	H	0.489		3.241		3.754	5.090

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.475		Hmax Amplitude (mV):	1.963
Hmax Torque (Nm)	6.032	8.178186	Hmax Torque (Nm)	8.1781856
Mmax Stim Intensity (mA):	35		Mmax Stim Intensity (mA):	35
Mmax Amplitude (mV):	9.893		Mmax Amplitude (mV):	3.288
Mmax Torque (Nm)	8.601	11.66124	Mmax Torque (Nm)	11.661236
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	10		Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	0.428		Hmax Amplitude (mV):	1.830
Hmax Torque (Nm)	5.477	7.425717	Hmax Torque (Nm)	7.4257166
Gastroc H/M	4.3%		Soleus H/M	55.7%

Subject 15 Session 2 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	2.3%	2.747	45.8%	10.272	13.927
0:20	H	0.229		1.259		6.516	8.834
0:30	**M**	9.894	3.4%	3.107	56.0%	10.287	13.947
0:40	H	0.336		1.739		6.743	9.142
0:50	**M**	9.894	2.6%	2.896	54.6%	10.165	13.782
1:00	H	0.262		1.582		6.477	8.782
1:30	**M**	9.895	2.6%	2.972	49.7%	9.985	13.538
2:00	H	0.259		1.477		6.827	9.256
2:30	**M**	9.894	2.9%	2.962	54.5%	9.516	12.902
3:00	H	0.286		1.614		7.189	9.747
3:30	**M**	9.895	2.4%	2.876	47.1%	9.793	13.277
4:00	H	0.241		1.355		7.834	10.621
4:30	**M**	9.894	3.4%	2.954	64.9%	9.246	12.536
5:00	H	0.338		1.918		7.283	9.874
5:30	**M**	9.894	2.9%	2.959	53.7%	9.657	13.093
6:00	H	0.284		1.590		6.974	9.455
6:30	**M**	9.894	3.3%	3.396	48.3%	8.882	12.042
7:00	H	0.328		1.640		6.810	9.233
7:30	**M**	9.894	2.1%	3.279	39.3%	9.292	12.598
8:00	H	0.211		1.289		6.046	8.197
8:30	**M**	9.894	2.9%	3.033	53.5%	9.496	12.875
9:00	H	0.285		1.624		6.688	9.068
9:30	**M**	9.894	1.8%	3.281	23.7%	9.708	13.162
10:00	H	0.181		0.778		7.347	9.961
11:00	**M**	9.895	3.2%	2.999	56.8%	10.617	14.395
12:00	H	0.317		1.702		7.843	10.634
13:00	**M**	9.895	2.5%	2.644	53.6%	9.172	12.435
14:00	H	0.250		1.417		6.663	9.034
15:00	**M**	9.894	2.4%	3.429	52.8%	6.631	8.990
16:00	H	0.241		1.811		4.666	6.326
17:00	**M**	9.894	2.6%	3.858	39.9%	5.993	8.125
18:00	H	0.256		1.538		6.019	8.161
19:00	**M**	9.894	2.9%	3.213	53.1%	9.564	12.967
20:00	H	0.284		1.707		6.896	9.350

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.304		Hmax Amplitude (mV):	1.464
Hmax Torque (Nm)	5.915	8.019557	Hmax Torque (Nm)	8.019557
Mmax Stim Intensity (mA):	35		Mmax Stim Intensity (mA):	35
Mmax Amlitude (mV):	9.894		Mmax Amplitude (mV):	2.598
Mmax Torque (Nm)	8.692	11.78461	Mmax Torque (Nm)	11.78461
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.284		Hmax Amplitude (mV):	1.502
Hmax Torque (Nm)	6.442	8.734064	Hmax Torque (Nm)	8.734064
Gastroc H/M	2.9%		Soleus H/M	57.8%

Subject 15 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	4.6%	5.733	37.9%	12.444	16.872
0:20	H	0.457		2.171		8.634	11.706
0:30	**M**	9.894	5.0%	7.777	30.9%	12.805	17.361
0:40	H	0.492		2.404		9.141	12.393
0:50	**M**	9.894	4.6%	7.468	28.1%	12.882	17.465
1:00	H	0.456		2.102		8.829	11.970
1:30	**M**	9.895	4.4%	7.944	28.2%	12.426	16.847
2:00	H	0.439		2.237		9.347	12.673
2:30	**M**	9.894	5.8%	9.512	32.7%	12.132	16.449
3:00	H	0.574		3.113		8.671	11.756
3:30	**M**	9.893	5.8%	8.953	32.7%	12.085	16.385
4:00	H	0.575		2.925		8.508	11.535
4:30	**M**	9.893	5.7%	9.894	25.8%	12.202	16.543
5:00	H	0.564		2.550		8.469	11.482
5:30	**M**	9.893	5.2%	9.894	23.7%	11.506	15.600
6:00	H	0.511		2.343		8.689	11.781
6:30	**M**	9.893	5.1%	9.894	21.7%	11.804	16.004
7:00	H	0.509		2.143		8.857	12.008
7:30	**M**	9.894	4.9%	9.893	21.3%	11.617	15.750
8:00	H	0.485		2.112		8.299	11.252
8:30	**M**	9.893	5.2%	9.438	23.2%	12.257	16.618
9:00	H	0.511		2.188		8.362	11.337
9:30	**M**	9.893	5.2%	9.894	26.3%	11.717	15.886
10:00	H	0.512		2.606		8.783	11.908
11:00	**M**	9.893	5.0%	9.894	22.5%	11.562	15.676
12:00	H	0.493		2.226		8.808	11.942
13:00	**M**	9.894	4.1%	9.893	21.3%	11.850	16.066
14:00	H	0.403		2.105		7.579	10.276
15:00	**M**	9.894	5.3%	9.896	26.5%	10.684	14.485
16:00	H	0.521		2.626		7.763	10.525
17:00	**M**	9.893	4.9%	7.102	37.1%	10.041	13.614
18:00	H	0.486		2.634		7.577	10.273
19:00	**M**	9.893	3.1%	9.894	18.7%	9.014	12.221
20:00	H	0.308		1.846		7.208	9.773

Gatroc		
Recruitment Curve		
Hmax Stim Intensity (mA):	12	
Hmax Amplitude (mV):	0.365	
Hmax Torque (Nm)	5.838	7.91516
Mmax Stim Intensity (mA):	65	
Mmax Amlitude (mV):	9.892	
Mmax Torque (Nm)	10.990	14.90024
Confirm Hmax		
Hmax Stim Intensity (mA):	14	
Hmax Amplitude (mV):	0.462	
Hmax Torque (Nm)	7.837	10.6254
Gastroc H/M	4.7%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	1.207
Hmax Torque (Nm)	7.91516
Mmax Stim Intensity (mA):	65
Mmax Amplitude (mV):	9.894
Mmax Torque (Nm)	14.90024
Confirm Hmax	
Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	1.402
Hmax Torque (Nm)	10.6254
Soleus H/M	14.2%

Subject 16 Session 1 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	2.9%	5.538	24.1%	8.722	11.825
0:20	H	0.286		1.332		5.792	7.853
0:30	**M**	9.894	3.8%	5.557	41.1%	8.823	11.962
0:40	H	0.379		2.286		5.879	7.971
0:50	**M**	9.894	3.8%	5.579	36.5%	8.523	11.555
1:00	H	0.375		2.038		5.698	7.725
1:30	**M**	9.894	4.2%	5.332	43.8%	8.541	11.580
2:00	H	0.416		2.336		5.915	8.020
2:30	**M**	9.894	4.3%	5.451	44.0%	8.601	11.661
3:00	H	0.421		2.401		5.957	8.077
3:30	**M**	9.894	4.2%	5.408	43.7%	8.366	11.343
4:00	H	0.420		2.363		5.771	7.824
4:30	**M**	9.894	4.3%	5.433	42.7%	8.398	11.386
5:00	H	0.430		2.318		5.726	7.763
5:30	**M**	9.894	4.5%	5.432	45.1%	8.238	11.169
6:00	H	0.446		2.451		5.945	8.060
6:30	**M**	9.894	4.5%	5.227	47.6%	8.346	11.316
7:00	H	0.443		2.486		6.017	8.158
7:30	**M**	9.894	4.5%	5.467	48.7%	8.344	11.313
8:00	H	0.445		2.665		6.043	8.193
8:30	**M**	9.895	4.6%	5.471	46.9%	8.245	11.179
9:00	H	0.456		2.566		6.054	8.208
9:30	**M**	9.894	4.6%	5.378	44.8%	8.269	11.211
10:00	H	0.455		2.412		6.107	8.280
11:00	**M**	9.894	4.0%	5.212	44.7%	8.497	11.520
12:00	H	0.399		2.329		6.315	8.562
13:00	**M**	9.894	4.5%	5.234	45.7%	8.437	11.439
14:00	H	0.449		2.394		6.067	8.226
15:00	**M**	9.894	4.2%	5.403	45.6%	8.590	11.646
16:00	H	0.415		2.462		6.402	8.680
17:00	**M**	9.894	4.1%	5.136	41.6%	8.699	11.794
18:00	H	0.404		2.139		6.528	8.851
19:00	**M**	9.894	4.2%	5.068	48.8%	8.744	11.855
20:00	H	0.417		2.471		6.646	9.011

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	24		Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	0.391		Hmax Amplitude (mV):	2.221
Hmax Torque (Nm)	5.915	8.019557	Hmax Torque (Nm)	8.019557
Mmax Stim Intensity (mA):	70		Mmax Stim Intensity (mA):	70
Mmax Amplitude (mV):	9.893		Mmax Amplitude (mV):	5.214
Mmax Torque (Nm)	9.805	13.29362	Mmax Torque (Nm)	13.29362
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	24		Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	0.356		Hmax Amplitude (mV):	2.203
Hmax Torque (Nm)	5.606	7.600615	Hmax Torque (Nm)	7.600615
Gastroc H/M	3.6%		Soleus H/M	42.3%

Subject 16 Session 2 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.896	1.7%	6.093	11.8%	12.082	16.381
0:20	H	0.166		0.718		8.841	11.987
0:30	**M**	9.893	1.7%	6.742	11.8%	12.753	17.291
0:40	H	0.170		0.798		8.970	12.162
0:50	**M**	9.894	1.7%	6.434	13.4%	12.649	17.150
1:00	H	0.167		0.863		9.203	12.477
1:30	**M**	9.894	1.9%	6.815	15.3%	12.566	17.037
2:00	H	0.187		1.040		9.279	12.580
2:30	**M**	9.893	2.6%	6.719	16.0%	12.280	16.649
3:00	H	0.253		1.077		9.221	12.502
3:30	**M**	9.893	2.4%	6.847	19.7%	11.626	15.763
4:00	H	0.237		1.350		8.389	11.374
4:30	**M**	9.893	1.8%	6.817	20.6%	11.011	14.929
5:00	H	0.182		1.404		8.191	11.105
5:30	**M**	9.895	2.3%	6.601	17.8%	10.343	14.023
6:00	H	0.230		1.173		8.236	11.166
6:30	**M**	9.894	2.3%	6.503	21.6%	11.138	15.101
7:00	H	0.223		1.402		7.404	10.038
7:30	**M**	9.894	2.2%	7.094	17.4%	9.718	13.176
8:00	H	0.215		1.231		7.667	10.395
8:30	**M**	9.896	2.2%	7.189	19.6%	9.714	13.170
9:00	H	0.222		1.407		7.634	10.350
9:30	**M**	9.894	2.1%	6.676	17.6%	9.355	12.684
10:00	H	0.207		1.172		7.531	10.211
11:00	**M**	9.894	2.0%	6.677	15.2%	9.596	13.010
12:00	H	0.200		1.015		7.415	10.053
13:00	**M**	9.894	2.2%	6.625	20.7%	9.288	12.593
14:00	H	0.218		1.373		7.476	10.136
15:00	**M**	9.893	2.2%	5.024	21.7%	9.137	12.388
16:00	H	0.213		1.092		9.279	12.580
17:00	**M**	9.895	1.8%	6.319	16.9%	9.001	12.204
18:00	H	0.182		1.065		7.037	9.541
19:00	**M**	9.895	1.9%	5.532	19.3%	8.930	12.107
20:00	H	0.188		1.070		7.017	9.514

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	22		Hmax Stim Intensity (mA):	22
Hmax Amplitude (mV):	0.247		Hmax Amplitude (mV):	1.341
Hmax Torque (Nm)	5.971	8.095482	Hmax Torque (Nm)	8.095482
Mmax Stim Intensity (mA):	60		Mmax Stim Intensity (mA):	60
Mmax Amlitude (mV):	9.892		Mmax Amplitude (mV):	5.291
Mmax Torque (Nm)	8.012	10.86267	Mmax Torque (Nm)	10.86267
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	24		Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	0.265		Hmax Amplitude (mV):	1.341
Hmax Torque (Nm)	6.806	9.227575	Hmax Torque (Nm)	9.227575
Gastroc H/M	2.7%		Soleus H/M	25.3%

Subject 16 Session 3 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	3.3%	6.342	22.5%	10.610	14.385
0:20	H	0.327		1.428		7.334	9.943
0:30	**M**	9.893	3.4%	5.623	26.6%	10.535	14.283
0:40	H	0.338		1.495		6.981	9.465
0:50	**M**	9.893	3.5%	5.713	22.7%	10.613	14.389
1:00	H	0.345		1.297		7.620	10.331
1:30	**M**	9.893	4.0%	6.522	29.5%	11.400	15.456
2:00	H	0.392		1.924		8.198	11.115
2:30	**M**	9.893	4.5%	5.840	38.4%	11.356	15.396
3:00	H	0.441		2.244		8.265	11.206
3:30	**M**	9.894	3.7%	5.933	29.7%	11.143	15.108
4:00	H	0.364		1.762		7.732	10.483
4:30	**M**	9.893	3.7%	5.852	29.9%	10.583	14.348
5:00	H	0.370		1.750		7.679	10.411
5:30	**M**	9.893	3.9%	5.982	32.2%	10.490	14.222
6:00	H	0.384		1.929		7.732	10.483
6:30	**M**	9.893	3.7%	6.184	28.5%	10.118	13.718
7:00	H	0.363		1.761		7.557	10.246
7:30	**M**	9.893	3.4%	6.084	26.2%	9.962	13.506
8:00	H	0.338		1.591		7.416	10.055
8:30	**M**	9.893	3.6%	6.429	24.1%	10.057	13.635
9:00	H	0.358		1.550		7.181	9.736
9:30	**M**	9.893	3.3%	6.141	25.9%	9.857	13.364
10:00	H	0.324		1.589		7.092	9.615
11:00	**M**	9.893	3.8%	6.361	30.2%	9.812	13.303
12:00	H	0.380		1.918		7.248	9.827
13:00	**M**	9.893	3.5%	6.112	27.6%	9.768	13.243
14:00	H	0.351		1.684		7.134	9.672
15:00	**M**	9.893	2.9%	6.763	15.9%	9.756	13.227
16:00	H	0.287		1.072		6.949	9.421
17:00	**M**	9.893	3.6%	6.021	31.0%	9.657	13.093
18:00	H	0.353		1.864		7.210	9.775
19:00	**M**	9.894	3.6%	6.530	23.0%	9.650	13.083
20:00	H	0.356		1.500		7.069	9.584

Recruitment Curve		
Hmax Stim Intensity (mA):	20	
Hmax Amplitude (mV):	0.435	
Hmax Torque (Nm)	6.366	8.631023
Mmax Stim Intensity (mA):	50	
Mmax Amlitude (mV):	9.892	
Mmax Torque (Nm)	8.740	11.84969
Confirm Hmax		
Hmax Stim Intensity (mA):	20	
Hmax Amplitude (mV):	0.355	
Hmax Torque (Nm)	8.125	11.01588
Gastroc H/M	3.6%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	20
Hmax Amplitude (mV):	2.227
Hmax Torque (Nm)	8.631023
Mmax Stim Intensity (mA):	50
Mmax Amplitude (mV):	5.766
Mmax Torque (Nm)	11.84969
Confirm Hmax	
Hmax Stim Intensity (mA):	20
Hmax Amplitude (mV):	1.546
Hmax Torque (Nm)	11.01588
Soleus H/M	26.8%

Subject 17 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	4.2%	6.012	31.7%	9.714	13.170
0:20	H	0.417		1.903		5.744	7.788
0:30	**M**	9.893	5.2%	5.926	39.4%	9.353	12.681
0:40	H	0.517		2.333		5.767	7.819
0:50	**M**	9.893	6.0%	5.827	51.8%	10.027	13.595
1:00	H	0.589		3.021		5.933	8.044
1:30	**M**	9.893	6.1%	5.955	46.4%	10.109	13.706
2:00	H	0.606		2.764		5.645	7.653
2:30	**M**	9.893	6.5%	5.764	53.0%	9.641	13.071
3:00	H	0.645		3.055		5.729	7.767
3:30	**M**	9.893	6.3%	5.984	50.5%	9.556	12.956
4:00	H	0.625		3.024		5.497	7.453
4:30	**M**	9.893	6.8%	5.81	46.2%	9.426	12.780
5:00	H	0.670		2.683		5.151	6.984
5:30	**M**	9.893	6.7%	5.952	53.3%	8.968	12.159
6:00	H	0.664		3.17		5.110	6.928
6:30	**M**	9.893	7.0%	5.972	52.1%	9.111	12.353
7:00	H	0.693		3.111		5.171	7.011
7:30	**M**	9.893	6.9%	5.715	57.0%	8.871	12.027
8:00	H	0.679		3.258		4.876	6.611
8:30	**M**	9.893	6.8%	5.934	47.0%	8.767	11.886
9:00	H	0.676		2.787		4.977	6.748
9:30	**M**	9.893	7.3%	5.994	49.4%	8.651	11.729
10:00	H	0.722		2.96		4.957	6.721
11:00	**M**	9.895	7.1%	5.661	55.4%	8.655	11.734
12:00	H	0.699		3.138		4.681	6.346
13:00	**M**	9.893	6.6%	5.968	51.7%	8.300	11.253
14:00	H	0.649		3.085		4.378	5.936
15:00	**M**	9.893	7.4%	5.731	47.9%	7.986	10.827
16:00	H	0.735		2.744		3.901	5.289
17:00	**M**	9.893	7.3%	5.718	55.7%	7.555	10.243
18:00	H	0.718		3.183		4.050	5.491
19:00	**M**	9.893	7.1%	6.002	57.4%	7.399	10.032
20:00	H	0.701		3.443		3.910	5.301

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.709		Hmax Amplitude (mV):	3.082
Hmax Torque (Nm)	5.452	7.391822	Hmax Torque (Nm)	7.391822
Mmax Stim Intensity (mA):	60		Mmax Stim Intensity (mA):	60
Mmax Amplitude (mV):	9.892		Mmax Amplitude (mV):	5.598
Mmax Torque (Nm)	8.794	11.92291	Mmax Torque (Nm)	11.92291
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.644		Hmax Amplitude (mV):	2.908
Hmax Torque (Nm)	4.664	6.323451	Hmax Torque (Nm)	6.323451
Gastroc H/M	6.5%		Soleus H/M	51.9%

Subject 17 Session 2 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	1.5%	4.985	17.6%	8.697	11.791
0:20	H	0.147		0.878		6.835	9.267
0:30	**M**	9.893	2.4%	5.191	27.3%	8.377	11.358
0:40	H	0.234		1.419		6.807	9.229
0:50	**M**	9.893	2.1%	5.209	28.6%	8.633	11.705
1:00	H	0.210		1.491		6.684	9.062
1:30	**M**	9.893	2.2%	5.14	27.5%	8.560	11.606
2:00	H	0.213		1.414		6.561	8.895
2:30	**M**	9.893	2.3%	5.209	30.1%	8.190	11.104
3:00	H	0.231		1.57		6.331	8.584
3:30	**M**	9.893	2.6%	5.187	28.2%	7.765	10.528
4:00	H	0.259		1.464		5.862	7.948
4:30	**M**	9.893	2.7%	5.236	27.3%	7.851	10.644
5:00	H	0.271		1.429		6.014	8.154
5:30	**M**	9.893	2.9%	5.334	30.7%	7.828	10.613
6:00	H	0.283		1.639		6.020	8.162
6:30	**M**	9.893	2.7%	5.321	29.7%	7.844	10.635
7:00	H	0.264		1.579		5.991	8.123
7:30	**M**	9.895	2.4%	5.24	25.3%	7.717	10.463
8:00	H	0.238		1.328		5.961	8.082
8:30	**M**	9.893	2.9%	5.326	29.7%	7.485	10.148
9:00	H	0.284		1.581		5.815	7.884
9:30	**M**	9.894	3.0%	5.415	28.8%	7.486	10.150
10:00	H	0.296		1.558		5.608	7.603
11:00	**M**	9.894	3.1%	5.476	30.9%	7.662	10.388
12:00	H	0.303		1.691		5.296	7.180
13:00	**M**	9.893	3.4%	5.36	36.5%	7.214	9.781
14:00	H	0.333		1.955		4.963	6.729
15:00	**M**	9.894	3.5%	5.551	35.6%	7.298	9.895
16:00	H	0.344		1.977		4.823	6.539
17:00	**M**	9.893	3.5%	5.603	37.3%	7.060	9.572
18:00	H	0.349		2.088		4.939	6.696
19:00	**M**	9.894	3.5%	5.559	36.0%	7.344	9.957
20:00	H	0.351		2.001		5.125	6.948

Gastroc		
Recruitment Curve		
Hmax Stim Intensity (mA):	12	
Hmax Amplitude (mV):	0.679	
Hmax Torque (Nm)	5.113	6.932205
Mmax Stim Intensity (mA):	45	
Mmax Amlitude (mV):	9.893	
Mmax Torque (Nm)	8.186	11.09858
Confirm Hmax		
Hmax Stim Intensity (mA):	14	
Hmax Amplitude (mV):	0.611	
Hmax Torque (Nm)	5.542	7.513844
Gastroc H/M	6.2%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	2.873
Hmax Torque (Nm)	6.932205
Mmax Stim Intensity (mA):	45
Mmax Amplitude (mV):	5.130
Mmax Torque (Nm)	11.09858
Confirm Hmax	
Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	2.482
Hmax Torque (Nm)	7.513844
Soleus H/M	48.4%

Subject 17 Session 3 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	4.5%	4.737	49.9%	6.599	8.947
0:20	H	0.448		2.366		4.542	6.158
0:30	**M**	9.895	6.5%	5.026	52.8%	7.016	9.512
0:40	H	0.640		2.655		3.898	5.285
0:50	**M**	9.893	7.1%	5.159	54.0%	6.753	9.156
1:00	H	0.701		2.784		3.548	4.810
1:30	**M**	9.893	7.9%	5.22	57.2%	6.728	9.122
2:00	H	0.777		2.986		3.531	4.787
2:30	**M**	9.893	8.0%	5.284	54.2%	6.454	8.750
3:00	H	0.791		2.863		3.261	4.421
3:30	**M**	9.894	8.1%	5.354	53.7%	5.889	7.984
4:00	H	0.806		2.873		3.006	4.076
4:30	**M**	9.893	7.6%	5.351	50.2%	5.848	7.929
5:00	H	0.755		2.687		2.985	4.047
5:30	**M**	9.895	8.0%	5.407	49.7%	5.745	7.789
6:00	H	0.795		2.689		2.655	3.600
6:30	**M**	9.893	8.4%	5.5	52.0%	5.263	7.136
7:00	H	0.829		2.858		2.511	3.404
7:30	**M**	9.893	8.5%	5.531	53.1%	5.197	7.046
8:00	H	0.842		2.937		2.363	3.204
8:30	**M**	9.893	7.3%	5.51	46.5%	5.069	6.873
9:00	H	0.719		2.562		2.324	3.151
9:30	**M**	9.895	7.1%	5.602	43.5%	4.925	6.677
10:00	H	0.704		2.435		2.036	2.760
11:00	**M**	9.893	8.0%	5.582	49.4%	4.634	6.283
12:00	H	0.794		2.757		1.961	2.659
13:00	**M**	9.895	8.1%	5.657	48.7%	4.473	6.064
14:00	H	0.802		2.754		1.870	2.535
15:00	**M**	9.893	8.5%	5.703	49.4%	4.211	5.709
16:00	H	0.838		2.815		1.832	2.484
17:00	**M**	9.894	7.9%	5.739	45.8%	3.759	5.096
18:00	H	0.781		2.627		1.751	2.374
19:00	**M**	9.893	7.9%	5.733	44.7%	3.815	5.172
20:00	H	0.784		2.561		1.679	2.276

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.602		Hmax Amplitude (mV):	2.057
Hmax Torque (Nm)	4.004	5.428623	Hmax Torque (Nm)	5.428623
Mmax Stim Intensity (mA):	65		Mmax Stim Intensity (mA):	65
Mmax Amlitude (mV):	9.893		Mmax Amplitude (mV):	5.104
Mmax Torque (Nm)	6.239	8.458836	Mmax Torque (Nm)	8.458836
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.659		Hmax Amplitude (mV):	2.683
Hmax Torque (Nm)	5.592	7.581634	Hmax Torque (Nm)	7.581634
Gastroc H/M	6.7%		Soleus H/M	52.6%

Subject 18 Session 1 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	11.4%	8.584	54.4%	7.768	10.532
0:20	H	1.131		4.671		6.396	8.672
0:30	**M**	9.893	11.2%	8.228	49.8%	8.238	11.169
0:40	H	1.104		4.095		6.619	8.974
0:50	**M**	9.893	11.4%	8.297	51.0%	8.359	11.333
1:00	H	1.131		4.23		6.742	9.141
1:30	**M**	9.895	11.0%	8.134	50.6%	8.483	11.501
2:00	H	1.085		4.114		6.639	9.001
2:30	**M**	9.894	10.9%	8.401	48.1%	8.592	11.649
3:00	H	1.080		4.037		6.667	9.039
3:30	**M**	9.894	10.6%	8.404	44.4%	8.326	11.288
4:00	H	1.050		3.732		6.449	8.744
4:30	**M**	9.894	10.5%	8.162	45.2%	8.402	11.391
5:00	H	1.042		3.693		6.424	8.710
5:30	**M**	9.895	9.4%	8.409	39.0%	8.476	11.492
6:00	H	0.933		3.282		6.318	8.566
6:30	**M**	9.895	10.1%	8.228	44.0%	8.077	10.951
7:00	H	1.001		3.623		6.268	8.498
7:30	**M**	9.895	10.5%	8.083	48.6%	7.984	10.825
8:00	H	1.039		3.93		6.374	8.642
8:30	**M**	9.894	10.1%	8.512	42.0%	8.297	11.249
9:00	H	0.998		3.574		6.484	8.791
9:30	**M**	9.893	11.9%	8.632	50.9%	8.300	11.253
10:00	H	1.182		4.394		5.996	8.129
11:00	**M**	9.894	9.8%	8.173	40.1%	7.942	10.768
12:00	H	0.965		3.281		5.648	7.658
13:00	**M**	9.893	7.2%	8.559	28.0%	8.361	11.336
14:00	H	0.710		2.398		5.959	8.079
15:00	**M**	9.893	9.1%	9.689	36.2%	7.796	10.570
16:00	H	0.903		3.506		6.158	8.349
17:00	**M**	9.893	10.7%	9.045	43.1%	8.060	10.928
18:00	H	1.063		3.899		6.370	8.636
19:00	**M**	9.893	9.1%	9.893	31.7%	8.165	11.070
20:00	H	0.899		3.136		6.233	8.451

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	24		Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	0.862		Hmax Amplitude (mV):	3.103
Hmax Torque (Nm)	6.084	8.248687	Hmax Torque (Nm)	8.248687
Mmax Stim Intensity (mA):	65		Mmax Stim Intensity (mA):	65
Mmax Amplitude (mV):	9.892		Mmax Amplitude (mV):	6.083
Mmax Torque (Nm)	7.430	10.07359	Mmax Torque (Nm)	10.07359
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	24		Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	1.019		Hmax Amplitude (mV):	3.517
Hmax Torque (Nm)	5.373	7.284713	Hmax Torque (Nm)	7.284713
Gastroc H/M	10.3%		Soleus H/M	57.8%

Subject 18 Session 2 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	8.2%	8.875	54.9%	8.647	11.724
0:20	H	0.808		4.87		7.097	9.622
0:30	**M**	9.895	8.8%	8.741	55.1%	8.927	12.103
0:40	H	0.875		4.816		7.132	9.670
0:50	**M**	9.894	8.9%	8.78	59.5%	9.029	12.242
1:00	H	0.878		5.228		7.043	9.549
1:30	**M**	9.893	9.0%	8.846	55.3%	9.021	12.231
2:00	H	0.888		4.888		7.015	9.511
2:30	**M**	9.893	8.4%	8.617	61.1%	8.923	12.098
3:00	H	0.834		5.263		7.198	9.759
3:30	**M**	9.894	9.4%	8.59	66.9%	8.833	11.976
4:00	H	0.928		5.743		7.278	9.868
4:30	**M**	9.893	8.2%	8.558	58.4%	9.004	12.208
5:00	H	0.808		4.998		7.108	9.637
5:30	**M**	9.896	9.3%	8.706	64.0%	8.755	11.870
6:00	H	0.918		5.57		6.567	8.904
6:30	**M**	9.894	7.1%	8.685	51.3%	8.484	11.503
7:00	H	0.703		4.454		6.642	9.005
7:30	**M**	9.893	7.6%	8.634	51.9%	8.568	11.616
8:00	H	0.753		4.477		6.850	9.287
8:30	**M**	9.893	8.5%	8.725	63.2%	8.176	11.085
9:00	H	0.843		5.513		6.472	8.775
9:30	**M**	9.894	8.2%	8.711	52.3%	8.330	11.294
10:00	H	0.808		4.553		6.555	8.887
11:00	**M**	9.894	7.4%	8.4	52.4%	8.027	10.883
12:00	H	0.732		4.399		6.204	8.411
13:00	**M**	9.894	8.0%	8.752	57.7%	7.849	10.642
14:00	H	0.789		5.053		6.112	8.287
15:00	**M**	9.894	7.9%	8.815	50.3%	7.965	10.799
16:00	H	0.777		4.436		5.949	8.066
17:00	**M**	9.893	7.6%	8.785	50.0%	7.824	10.608
18:00	H	0.754		4.389		5.807	7.873
19:00	**M**	9.895	9.1%	8.721	63.1%	7.826	10.610
20:00	H	0.897		5.505		5.822	7.893

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	16		Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	0.797		Hmax Amplitude (mV):	5.337
Hmax Torque (Nm)	6.385	8.656783	Hmax Torque (Nm)	8.656783
Mmax Stim Intensity (mA):	40		Mmax Stim Intensity (mA):	40
Mmax Amlitude (mV):	9.892		Mmax Amplitude (mV):	8.380
Mmax Torque (Nm)	7.423	10.0641	Mmax Torque (Nm)	10.0641
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	18		Hmax Stim Intensity (mA):	18
Hmax Amplitude (mV):	0.769		Hmax Amplitude (mV):	4.413
Hmax Torque (Nm)	6.775	9.185545	Hmax Torque (Nm)	9.185545
Gastroc H/M	7.8%		Soleus H/M	52.7%

Subject 18 Session 3 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	4.7%	8.674	20.0%	7.895	10.704
0:20	H	0.467		1.733		6.271	8.502
0:30	**M**	9.894	5.1%	8.45	25.5%	8.854	12.004
0:40	H	0.509		2.154		6.499	8.811
0:50	**M**	9.896	5.1%	7.92	22.2%	8.926	12.102
1:00	H	0.506		1.76		6.792	9.209
1:30	**M**	9.897	4.7%	7.581	21.8%	9.058	12.281
2:00	H	0.467		1.653		6.774	9.184
2:30	**M**	9.894	4.6%	7.28	21.7%	9.269	12.567
3:00	H	0.456		1.58		6.907	9.365
3:30	**M**	9.894	5.3%	6.751	30.1%	9.397	12.740
4:00	H	0.522		2.031		6.306	8.550
4:30	**M**	9.894	5.4%	8.109	23.5%	8.277	11.222
5:00	H	0.537		1.907		6.407	8.687
5:30	**M**	9.894	4.4%	8.406	16.8%	8.836	11.980
6:00	H	0.434		1.416		6.634	8.994
6:30	**M**	9.898	5.6%	8.156	25.8%	9.075	12.304
7:00	H	0.554		2.101		6.830	9.260
7:30	**M**	9.894	4.6%	6.948	19.1%	9.242	12.530
8:00	H	0.457		1.324		6.709	9.096
8:30	**M**	9.894	5.0%	7.442	20.9%	9.156	12.414
9:00	H	0.490		1.554		6.972	9.453
9:30	**M**	9.897	4.8%	6.773	27.0%	9.159	12.418
10:00	H	0.479		1.831		6.901	9.356
11:00	**M**	9.895	5.3%	6.776	22.3%	9.126	12.373
12:00	H	0.521		1.51		6.940	9.409
13:00	**M**	9.894	4.6%	8.23	18.6%	8.096	10.977
14:00	H	0.451		1.528		5.982	8.110
15:00	**M**	9.894	4.8%	8.445	18.1%	8.063	10.932
16:00	H	0.473		1.532		5.945	8.060
17:00	**M**	9.894	4.7%	8.429	17.9%	8.158	11.061
18:00	H	0.461		1.507		5.918	8.024
19:00	**M**	9.895	4.4%	8.498	16.1%	8.016	10.868
20:00	H	0.438		1.367		5.910	8.013

Gastroc		
Recruitment Curve		
Hmax Stim Intensity (mA):	24	
Hmax Amplitude (mV):	0.534	
Hmax Torque (Nm)	5.415	7.341657
Mmax Stim Intensity (mA):	65	
Mmax Amlitude (mV):	9.894	
Mmax Torque (Nm)	6.701	9.085216
Confirm Hmax		
Hmax Stim Intensity (mA):	24	
Hmax Amplitude (mV):	0.435	
Hmax Torque (Nm)	7.030	9.531274
Gastroc H/M	4.4%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	1.925
Hmax Torque (Nm)	7.341657
Mmax Stim Intensity (mA):	65
Mmax Amplitude (mV):	8.407
Mmax Torque (Nm)	9.085216
Confirm Hmax	
Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	1.832
Hmax Torque (Nm)	9.531274
Soleus H/M	21.8%

Subject 19 Session 1 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	13.3%	5.581	79.3%	8.309	11.265
0:20	H	1.317		4.425		7.107	9.636
0:30	**M**	9.895	14.4%	5.835	76.4%	8.809	11.943
0:40	H	1.421		4.459		7.289	9.882
0:50	**M**	9.896	14.6%	5.763	77.0%	8.841	11.987
1:00	H	1.441		4.437		7.357	9.975
1:30	**M**	9.893	14.8%	5.749	76.8%	8.686	11.776
2:00	H	1.467		4.415		7.321	9.926
2:30	**M**	9.893	13.3%	5.92	77.4%	8.429	11.428
3:00	H	1.320		4.585		7.207	9.771
3:30	**M**	9.895	14.1%	6.025	76.3%	8.411	11.404
4:00	H	1.398		4.596		7.086	9.607
4:30	**M**	9.893	16.2%	5.954	76.2%	8.257	11.195
5:00	H	1.598		4.539		6.623	8.979
5:30	**M**	9.894	14.3%	5.979	75.7%	7.787	10.558
6:00	H	1.415		4.524		6.510	8.826
6:30	**M**	9.896	14.8%	6.072	75.5%	7.875	10.677
7:00	H	1.469		4.586		6.541	8.868
7:30	**M**	9.897	15.4%	6.223	73.6%	7.820	10.602
8:00	H	1.527		4.582		6.519	8.838
8:30	**M**	9.893	12.8%	6.231	74.1%	7.633	10.349
9:00	H	1.266		4.62		6.439	8.730
9:30	**M**	9.895	12.9%	6.257	74.3%	7.605	10.311
10:00	H	1.273		4.652		6.585	8.928
11:00	**M**	9.895	15.5%	6.288	76.0%	7.953	10.783
12:00	H	1.531		4.781		6.610	8.962
13:00	**M**	9.894	13.4%	6.416	74.6%	7.520	10.196
14:00	H	1.323		4.788		6.573	8.912
15:00	**M**	9.896	12.7%	6.502	72.4%	7.595	10.297
16:00	H	1.260		4.705		6.241	8.462
17:00	**M**	9.894	12.6%	6.438	72.4%	7.416	10.055
18:00	H	1.247		4.662		6.101	8.272
19:00	**M**	9.897	12.7%	6.489	72.2%	7.555	10.243
20:00	H	1.256		4.682		6.462	8.761

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	18		Hmax Stim Intensity (mA):	18
Hmax Amplitude (mV):	1.468		Hmax Amplitude (mV):	1.105
Hmax Torque (Nm)	3.964	5.374391	Hmax Torque (Nm)	5.374391
Mmax Stim Intensity (mA):	45		Mmax Stim Intensity (mA):	45
Mmax Amplitude (mV):	9.893		Mmax Amplitude (mV):	6.207
Mmax Torque (Nm)	5.482	7.432496	Mmax Torque (Nm)	7.432496
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	16		Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	1.055		Hmax Amplitude (mV):	2.836
Hmax Torque (Nm)	5.219	7.07592	Hmax Torque (Nm)	7.07592
Gastroc H/M	10.7%		Soleus H/M	45.7%

Subject 19 Session 2 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	2.4%	2.375	17.1%	8.256	11.193
0:20	H	0.237		0.407		7.026	9.526
0:30	**M**	9.895	2.5%	3.164	16.0%	8.182	11.093
0:40	H	0.247		0.507		6.274	8.506
0:50	**M**	9.898	3.0%	3.492	13.9%	8.024	10.879
1:00	H	0.293		0.484		6.198	8.403
1:30	**M**	9.897	2.8%	3.158	16.1%	7.764	10.526
2:00	H	0.279		0.508		6.398	8.674
2:30	**M**	9.896	2.7%	3.367	14.3%	7.685	10.419
3:00	H	0.272		0.482		6.124	8.303
3:30	**M**	9.894	2.7%	3.108	17.0%	7.739	10.493
4:00	H	0.269		0.527		6.042	8.192
4:30	**M**	9.894	3.3%	3.535	16.9%	7.624	10.337
5:00	H	0.327		0.597		6.257	8.483
5:30	**M**	9.894	2.8%	3.338	13.8%	7.879	10.682
6:00	H	0.274		0.462		5.953	8.071
6:30	**M**	9.894	2.9%	3.588	15.8%	7.584	10.282
7:00	H	0.290		0.568		5.902	8.002
7:30	**M**	9.894	3.0%	2.967	20.5%	7.993	10.837
8:00	H	0.295		0.608		5.769	7.822
8:30	**M**	9.894	2.8%	3.527	13.6%	7.616	10.326
9:00	H	0.280		0.481		5.889	7.984
9:30	**M**	9.894	2.6%	3.681	15.4%	7.428	10.071
10:00	H	0.261		0.568		5.364	7.273
11:00	**M**	9.895	3.1%	3.067	19.4%	7.667	10.395
12:00	H	0.304		0.596		5.901	8.001
13:00	**M**	9.894	3.0%	2.919	18.3%	7.606	10.312
14:00	H	0.296		0.533		5.943	8.058
15:00	**M**	9.895	3.0%	3.378	17.4%	7.571	10.265
16:00	H	0.292		0.589		5.634	7.639
17:00	**M**	9.894	2.8%	3.427	18.2%	7.287	9.880
18:00	H	0.278		0.624		5.572	7.555
19:00	**M**	9.894	2.9%	3.885	14.3%	7.149	9.693
20:00	H	0.290		0.554		5.234	7.096

Gastroc		
Recruitment Curve		
Hmax Stim Intensity (mA):	20	
Hmax Amplitude (mV):	0.311	
Hmax Torque (Nm)	5.385	7.300983
Mmax Stim Intensity (mA):	45	
Mmax Amlitude (mV):	9.893	
Mmax Torque (Nm)	9.541	12.93569
Confirm Hmax		
Hmax Stim Intensity (mA):	24	
Hmax Amplitude (mV):	0.360	
Hmax Torque (Nm)	6.651	9.017426
Gastroc H/M	3.6%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	20
Hmax Amplitude (mV):	0.643
Hmax Torque (Nm)	7.300983
Mmax Stim Intensity (mA):	45
Mmax Amplitude (mV):	3.213
Mmax Torque (Nm)	12.93569
Confirm Hmax	
Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	0.568
Hmax Torque (Nm)	9.017426
Soleus H/M	17.7%

Subject 19 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	1.9%	3.773	33.0%	10.085	13.673
0:20	H	0.188		1.246		8.170	11.077
0:30	**M**	9.893	2.6%	3.720	44.5%	9.999	13.557
0:40	H	0.257		1.655		8.148	11.047
0:50	**M**	9.894	2.3%	3.773	36.6%	9.824	13.319
1:00	H	0.223		1.381		8.075	10.948
1:30	**M**	9.894	2.5%	3.736	41.4%	9.698	13.149
2:00	H	0.243		1.545		8.105	10.989
2:30	**M**	9.894	2.3%	3.744	41.5%	9.491	12.868
3:00	H	0.229		1.553		8.154	11.055
3:30	**M**	9.893	2.3%	3.683	36.9%	9.240	12.528
4:00	H	0.223		1.358		8.241	11.173
4:30	**M**	9.894	2.3%	3.632	39.1%	9.155	12.412
5:00	H	0.230		1.421		7.982	10.822
5:30	**M**	9.894	2.1%	3.616	35.7%	8.845	11.992
6:00	H	0.212		1.291		7.765	10.528
6:30	**M**	9.893	2.3%	3.601	42.2%	8.482	11.500
7:00	H	0.229		1.521		7.322	9.927
7:30	**M**	9.893	2.2%	3.603	37.2%	8.120	11.009
8:00	H	0.213		1.342		6.974	9.455
8:30	**M**	9.894	2.4%	3.593	41.9%	7.860	10.657
9:00	H	0.238		1.504		6.857	9.297
9:30	**M**	9.893	2.3%	3.644	37.5%	7.642	10.361
10:00	H	0.226		1.367		6.758	9.162
11:00	**M**	9.894	2.2%	3.661	38.3%	7.381	10.007
12:00	H	0.221		1.401		6.495	8.806
13:00	**M**	9.895	2.5%	3.647	41.2%	7.135	9.674
14:00	H	0.247		1.503		6.248	8.471
15:00	**M**	9.894	2.2%	3.707	40.3%	6.943	9.413
16:00	H	0.213		1.493		6.089	8.255
17:00	**M**	9.895	2.4%	3.678	44.7%	6.670	9.043
18:00	H	0.242		1.644		5.901	8.001
19:00	**M**	9.895	2.1%	3.734	37.4%	6.528	8.851
20:00	H	0.208		1.397		5.682	7.704

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.190		Hmax Amplitude (mV):	0.567
Hmax Torque (Nm)	7.149	9.692614	Hmax Torque (Nm)	9.692614
Mmax Stim Intensity (mA):	45		Mmax Stim Intensity (mA):	45
Mmax Amlitude (mV):	9.892		Mmax Amplitude (mV):	2.861
Mmax Torque (Nm)	7.889	10.69591	Mmax Torque (Nm)	10.69591
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.208		Hmax Amplitude (mV):	0.925
Hmax Torque (Nm)	7.582	10.27968	Hmax Torque (Nm)	10.27968
Gastroc H/M	2.1%		Soleus H/M	32.3%

Subject 20 Session 1 Control

1st

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	13.3%	5.581	79.3%	8.596	11.654
0:20	H	1.317		4.425		6.026	8.170
0:30	**M**	9.895	14.4%	5.835	76.4%	8.701	11.797
0:40	H	1.421		4.459		5.861	7.946
0:50	**M**	9.896	14.6%	5.763	77.0%	8.553	11.596
1:00	H	1.441		4.437		6.011	8.150
1:30	**M**	9.893	14.8%	5.749	76.8%	8.359	11.333
2:00	H	1.467		4.415		6.072	8.232
2:30	**M**	9.893	13.3%	5.920	77.4%	8.218	11.142
3:00	H	1.320		4.585		6.062	8.219
3:30	**M**	9.895	14.1%	6.025	76.3%	8.189	11.103
4:00	H	1.398		4.596		5.258	7.129
4:30	**M**	9.893	16.2%	5.954	76.2%	8.011	10.861
5:00	H	1.598		4.539		5.894	7.991
5:30	**M**	9.894	14.3%	5.979	75.7%	7.863	10.661
6:00	H	1.415		4.524		5.293	7.176
6:30	**M**	9.896	14.8%	6.072	75.5%	7.855	10.650
7:00	H	1.469		4.586		4.761	6.455
7:30	**M**	9.897	15.4%	6.223	73.6%	7.730	10.480
8:00	H	1.527		4.582		4.923	6.675
8:30	**M**	9.893	12.8%	6.231	74.1%	7.566	10.258
9:00	H	1.266		4.620		5.031	6.821
9:30	**M**	9.895	12.9%	6.257	74.3%	7.640	10.358
10:00	H	1.273		4.652		5.284	7.164
11:00	**M**	9.895	15.5%	6.288	76.0%	7.582	10.280
12:00	H	1.531		4.781		4.961	6.726
13:00	**M**	9.894	13.4%	6.416	74.6%	7.191	9.750
14:00	H	1.323		4.788		5.136	6.963
15:00	**M**	9.896	12.7%	6.502	72.4%	7.230	9.802
16:00	H	1.260		4.705		4.934	6.690
17:00	**M**	9.894	12.6%	6.438	72.4%	7.031	9.533
18:00	H	1.247		4.662		5.302	7.188
19:00	**M**	9.897	12.7%	6.489	72.2%	7.214	9.781
20:00	H	1.256		4.682		5.533	7.502

2nd

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.896	12.3%	5.776	73.8%	8.209	11.130
0:20	H	1.218		4.260		6.857	9.297
0:30	**M**	9.894	14.0%	6.052	71.5%	8.418	11.413
0:40	H	1.385		4.328		6.721	9.112
0:50	**M**	9.894	13.3%	6.120	70.4%	8.428	11.427
1:00	H	1.316		4.309		6.418	8.702
1:30	**M**	9.896	14.0%	5.971	73.6%	8.486	11.505
2:00	H	1.387		4.392		6.738	9.135
2:30	**M**	9.894	13.5%	6.050	69.1%	8.494	11.516
3:00	H	1.340		4.180		6.283	8.518
3:30	**M**	9.894	12.9%	6.122	66.9%	8.723	11.827
4:00	H	1.281		4.095		6.832	9.263
4:30	**M**	9.897	13.0%	5.984	70.6%	8.569	11.618
5:00	H	1.286		4.222		6.296	8.536
5:30	**M**	9.897	11.7%	6.205	65.9%	8.599	11.659
6:00	H	1.156		4.088		6.601	8.950
6:30	**M**	9.894	12.2%	6.136	70.9%	8.415	11.409
7:00	H	1.203		4.348		6.302	8.544
7:30	**M**	9.896	12.3%	6.199	66.1%	8.330	11.294
8:00	H	1.219		4.099		6.675	9.050
8:30	**M**	9.894	12.0%	6.134	66.5%	7.947	10.775
9:00	H	1.183		4.081		6.562	8.897
9:30	**M**	9.894	13.4%	6.187	70.4%	7.882	10.686
10:00	H	1.326		4.354		6.098	8.268
11:00	**M**	9.894	13.3%	5.983	72.6%	6.267	8.497
12:00	H	1.317		4.341		5.276	7.153
13:00	**M**	9.893	13.4%	6.048	71.5%	7.101	9.628
14:00	H	1.327		4.322		5.601	7.594
15:00	**M**	9.894	13.2%	6.108	67.9%	7.881	10.685
16:00	H	1.302		4.146		5.559	7.537
17:00	**M**	9.895	12.5%	6.131	68.8%	7.549	10.235
18:00	H	1.233		4.221		5.220	7.077
19:00	**M**	9.894	13.1%	6.046	70.4%	7.235	9.809
20:00	H	1.301		4.259		5.525	7.491

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	8		Hmax Stim Intensity (mA):	8
Hmax Amplitude (mV):	1.589		Hmax Amplitude (mV):	4.295
Hmax Torque (Nm)	3.697	5.012393	Hmax Torque (Nm)	5.012393
Mmax Stim Intensity (mA):	22		Mmax Stim Intensity (mA):	22
Mmax Amplitude (mV):	9.892		Mmax Amplitude (mV):	5.317
Mmax Torque (Nm)	5.635	7.639933	Mmax Torque (Nm)	7.639933
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	8		Hmax Stim Intensity (mA):	8
Hmax Amplitude (mV):	1.385		Hmax Amplitude (mV):	4.133
Hmax Torque (Nm)	5.413	7.338945	Hmax Torque (Nm)	7.338945
Gastroc H/M	14.0%		Soleus H/M	77.7%

Subject 20 Session 2 Control

1st

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	11.8%	4.736	85.4%	6.896	9.350
0:20	H	1.170		4.046		4.317	5.853
0:30	**M**	9.893	13.1%	5.102	80.7%	7.205	9.769
0:40	H	1.294		4.118		4.332	5.873
0:50	**M**	9.894	13.5%	5.162	82.5%	7.137	9.676
1:00	H	1.339		4.257		4.274	5.795
1:30	**M**	9.894	13.1%	5.233	81.6%	7.065	9.579
2:00	H	1.294		4.269		4.800	6.508
2:30	**M**	9.895	13.7%	5.158	81.2%	7.197	9.758
3:00	H	1.360		4.189		4.670	6.332
3:30	**M**	9.895	11.9%	5.437	77.4%	6.996	9.485
4:00	H	1.176		4.209		4.541	6.157
4:30	**M**	9.893	11.1%	5.374	79.8%	6.935	9.402
5:00	H	1.098		4.290		4.599	6.235
5:30	**M**	9.894	11.2%	5.562	80.6%	6.772	9.181
6:00	H	1.107		4.485		4.624	6.269
6:30	**M**	9.894	11.7%	5.565	76.7%	7.125	9.660
7:00	H	1.156		4.271		4.264	5.781
7:30	**M**	9.894	11.8%	5.736	79.3%	7.151	9.695
8:00	H	1.168		4.547		4.357	5.907
8:30	**M**	9.895	14.5%	5.737	79.2%	7.012	9.507
9:00	H	1.436		4.541		4.336	5.879
9:30	**M**	9.894	13.9%	5.795	81.4%	6.722	9.114
10:00	H	1.374		4.720		4.216	5.716
11:00	**M**	9.894	15.9%	5.702	80.2%	6.726	9.119
12:00	H	1.573		4.575		6.085	8.250
13:00	**M**	9.894	12.9%	5.928	81.8%	6.281	8.516
14:00	H	1.272		4.848		4.810	6.521
15:00	**M**	9.894	12.9%	5.995	69.7%	6.011	8.150
16:00	H	1.274		4.176		4.350	5.898
17:00	**M**	9.894	12.0%	5.244	83.1%	6.007	8.144
18:00	H	1.185		4.360		4.613	6.254
19:00	**M**	9.894	13.0%	5.707	80.1%	6.001	8.136
20:00	H	1.284		4.572		4.519	6.127

2nd

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	13.7%	5.461	78.2%	6.917	9.378
0:20	H	1.359		4.268		5.720	7.755
0:30	**M**	9.894	14.1%	5.273	83.2%	7.392	10.022
0:40	H	1.391		4.387		5.105	6.921
0:50	**M**	9.894	10.6%	5.539	73.5%	7.694	10.432
1:00	H	1.047		4.070		4.900	6.643
1:30	**M**	9.895	12.8%	5.571	77.7%	7.735	10.487
2:00	H	1.269		4.326		5.167	7.005
2:30	**M**	9.894	12.1%	5.600	77.5%	7.433	10.078
3:00	H	1.194		4.341		5.762	7.812
3:30	**M**	9.894	12.2%	5.555	78.0%	7.371	9.994
4:00	H	1.205		4.334		5.036	6.828
4:30	**M**	9.895	13.2%	5.571	76.7%	7.538	10.220
5:00	H	1.303		4.272		5.437	7.371
5:30	**M**	9.895	14.1%	5.717	75.9%	7.219	9.788
6:00	H	1.396		4.342		4.836	6.557
6:30	**M**	9.896	9.7%	5.736	77.0%	6.614	8.967
7:00	H	0.956		4.419		4.720	6.399
7:30	**M**	9.895	10.7%	5.896	74.3%	7.155	9.701
8:00	H	1.063		4.383		5.238	7.102
8:30	**M**	9.895	9.6%	5.954	72.8%	6.718	9.108
9:00	H	0.948		4.336		4.869	6.601
9:30	**M**	9.894	11.0%	6.066	74.7%	6.532	8.856
10:00	H	1.089		4.529		4.677	6.341
11:00	**M**	9.895	12.1%	5.487	79.0%	7.257	9.839
12:00	H	1.202		4.333		4.626	6.272
13:00	**M**	9.894	10.8%	5.754	75.2%	6.603	8.952
14:00	H	1.072		4.328		4.443	6.024
15:00	**M**	9.894	9.0%	5.903	73.0%	6.345	8.603
16:00	H	0.890		4.309		4.532	6.144
17:00	**M**	9.894	12.7%	5.489	78.6%	6.201	8.407
18:00	H	1.253		4.316		4.657	6.314
19:00	**M**	9.894	11.2%	5.695	76.6%	6.119	8.296
20:00	H	1.104		4.363		4.525	6.135

Gastroc		
Recruitment Curve		
Hmax Stim Intensity (mA):	10	
Hmax Amplitude (mV):	1.374	
Hmax Torque (Nm)	5.781	7.83788
Mmax Stim Intensity (mA):	45	
Mmax Amlitude (mV):	9.892	
Mmax Torque (Nm)	7.741	10.49525
Confirm Hmax		
Hmax Stim Intensity (mA):	8	
Hmax Amplitude (mV):	1.432	
Hmax Torque (Nm)	5.218	7.074564
Gastroc H/M	14.5%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	10
Hmax Amplitude (mV):	4.016
Hmax Torque (Nm)	7.83788
Mmax Stim Intensity (mA):	45
Mmax Amplitude (mV):	5.191
Mmax Torque (Nm)	10.49525
Confirm Hmax	
Hmax Stim Intensity (mA):	8
Hmax Amplitude (mV):	4.140
Hmax Torque (Nm)	7.074564
Soleus H/M	79.8%

Subject 21 Session 1 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.339	5.7%	5.017	77.8%	13.359	18.112
0:20	H	0.533		3.903		4.091	5.547
0:30	**M**	9.894	4.8%	5.253	57.6%	14.138	19.168
0:40	H	0.470		3.026		3.894	5.279
0:50	**M**	9.893	5.2%	5.135	70.0%	14.270	19.347
1:00	H	0.515		3.592		4.162	5.643
1:30	**M**	9.894	5.2%	5.067	75.2%	14.280	19.361
2:00	H	0.512		3.808		4.502	6.104
2:30	**M**	9.894	5.0%	5.033	78.7%	14.079	19.088
3:00	H	0.499		3.963		4.676	6.340
3:30	**M**	9.894	5.3%	5.126	76.9%	13.938	18.897
4:00	H	0.526		3.941		4.324	5.862
4:30	**M**	9.894	3.9%	5.301	76.9%	13.697	18.570
5:00	H	0.390		4.079		4.524	6.134
5:30	**M**	9.894	3.4%	5.386	73.2%	13.279	18.004
6:00	H	0.333		3.940		4.170	5.654
6:30	**M**	9.896	3.8%	5.292	76.2%	13.020	17.653
7:00	H	0.374		4.035		4.433	6.010
7:30	**M**	9.894	4.8%	5.303	77.1%	12.620	17.110
8:00	H	0.472		4.089		4.275	5.796
8:30	**M**	9.894	4.5%	5.255	77.8%	12.438	16.863
9:00	H	0.449		4.090		4.276	5.797
9:30	**M**	9.895	5.1%	5.262	78.2%	12.145	16.466
10:00	H	0.501		4.114		3.994	5.415
11:00	**M**	9.894	4.6%	5.098	79.5%	11.852	16.069
12:00	H	0.457		4.052		4.506	6.109
13:00	**M**	9.895	2.7%	5.395	75.4%	11.440	15.510
14:00	H	0.263		4.066		4.858	6.586
15:00	**M**	9.894	5.9%	5.421	73.5%	11.077	15.018
16:00	H	0.580		3.986		4.129	5.598
17:00	**M**	9.895	5.3%	5.430	74.1%	10.972	14.876
18:00	H	0.522		4.025		4.291	5.818
19:00	**M**	9.894	5.9%	5.541	71.3%	10.881	14.752
20:00	H	0.579		3.952		3.954	5.361

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	22		Hmax Stim Intensity (mA):	22
Hmax Amplitude (mV):	0.462		Hmax Amplitude (mV):	3.004
Hmax Torque (Nm)	3.598	4.878168	Hmax Torque (Nm)	4.878168
Mmax Stim Intensity (mA):	45		Mmax Stim Intensity (mA):	45
Mmax Amplitude (mV):	9.892		Mmax Amplitude (mV):	4.555
Mmax Torque (Nm)	9.852	13.35734	Mmax Torque (Nm)	13.35734
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	22		Hmax Stim Intensity (mA):	22
Hmax Amplitude (mV):	0.407		Hmax Amplitude (mV):	2.607
Hmax Torque (Nm)	2.373	3.217313	Hmax Torque (Nm)	3.217313
Gastroc H/M	4.1%		Soleus H/M	57.2%

Subject 21 Session 2 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	6.2%	3.539	30.0%	13.582	18.414
0:20	H	0.610		1.061		8.367	11.344
0:30	**M**	9.894	6.5%	3.646	33.4%	14.373	19.487
0:40	H	0.643		1.216		8.242	11.175
0:50	**M**	9.894	7.0%	3.894	34.1%	14.296	19.383
1:00	H	0.688		1.326		8.367	11.344
1:30	**M**	9.894	6.7%	3.545	38.5%	14.239	19.305
2:00	H	0.663		1.365		8.314	11.272
2:30	**M**	9.894	6.7%	4.006	41.2%	14.364	19.475
3:00	H	0.663		1.652		8.841	11.987
3:30	**M**	9.894	6.8%	3.667	40.6%	14.470	19.618
4:00	H	0.675		1.489		7.768	10.532
4:30	**M**	9.894	7.2%	3.47	54.1%	13.656	18.515
5:00	H	0.716		1.878		8.978	12.172
5:30	**M**	9.895	7.1%	3.639	53.8%	13.763	18.660
6:00	H	0.704		1.956		8.590	11.646
6:30	**M**	9.894	7.7%	3.66	41.1%	13.764	18.661
7:00	H	0.765		1.504		7.928	10.749
7:30	**M**	9.894	7.5%	3.505	58.3%	13.411	18.183
8:00	H	0.739		2.044		8.553	11.596
8:30	**M**	9.895	7.1%	3.869	46.9%	13.392	18.157
9:00	H	0.706		1.814		8.447	11.452
9:30	**M**	9.894	7.1%	3.564	54.5%	13.257	17.974
10:00	H	0.698		1.944		8.419	11.414
11:00	**M**	9.894	7.5%	3.402	60.3%	13.129	17.800
12:00	H	0.739		2.05		8.370	11.348
13:00	**M**	9.894	7.1%	3.367	56.8%	13.140	17.815
14:00	H	0.698		1.911		7.842	10.632
15:00	**M**	9.894	7.4%	3.715	54.6%	12.791	17.342
16:00	H	0.736		2.027		8.943	12.125
17:00	**M**	9.894	7.2%	3.585	56.3%	13.104	17.766
18:00	H	0.717		2.02		8.360	11.334
19:00	**M**	9.894	7.3%	3.883	46.0%	13.226	17.932
20:00	H	0.727		1.786		8.417	11.412

Gastroc		
Recruitment Curve		
Hmax Stim Intensity (mA):	24	
Hmax Amplitude (mV):	0.602	
Hmax Torque (Nm)	8.000	10.8464
Mmax Stim Intensity (mA):	45	
Mmax Amlitude (mV):	9.893	
Mmax Torque (Nm)	11.976	16.23706
Confirm Hmax		
Hmax Stim Intensity (mA):	26	
Hmax Amplitude (mV):	0.692	
Hmax Torque (Nm)	8.386	11.36974
Gastroc H/M	7.0%	

Soleus	
Recruitment Curve	
Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	1.209
Hmax Torque (Nm)	10.8464
Mmax Stim Intensity (mA):	45
Mmax Amplitude (mV):	3.486
Mmax Torque (Nm)	16.23706
Confirm Hmax	
Hmax Stim Intensity (mA):	26
Hmax Amplitude (mV):	1.786
Hmax Torque (Nm)	11.36974
Soleus H/M	51.2%

Subject 21 Session 3 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	5.6%	3.977	75.9%	18.860	25.570
0:20	H	0.558		3.019		8.573	11.623
0:30	**M**	9.893	6.0%	3.930	73.3%	17.779	24.105
0:40	H	0.594		2.882		8.424	11.421
0:50	**M**	9.893	6.2%	4.072	75.7%	17.049	23.115
1:00	H	0.611		3.084		8.700	11.795
1:30	**M**	9.894	6.2%	4.235	73.1%	16.436	22.284
2:00	H	0.616		3.094		8.709	11.808
2:30	**M**	9.893	6.5%	4.224	75.2%	16.260	22.045
3:00	H	0.642		3.178		8.694	11.787
3:30	**M**	9.893	6.3%	4.174	74.8%	15.971	21.653
4:00	H	0.619		3.121		8.356	11.329
4:30	**M**	9.894	6.5%	4.040	79.8%	15.226	20.643
5:00	H	0.640		3.225		8.187	11.100
5:30	**M**	9.893	6.4%	4.073	80.5%	14.530	19.700
6:00	H	0.638		3.279		7.747	10.503
6:30	**M**	9.893	6.6%	4.052	77.3%	14.361	19.471
7:00	H	0.657		3.132		7.764	10.526
7:30	**M**	9.893	6.2%	4.142	78.2%	13.884	18.824
8:00	H	0.614		3.241		7.478	10.139
8:30	**M**	9.894	6.0%	4.238	77.0%	13.465	18.256
9:00	H	0.593		3.264		7.295	9.891
9:30	**M**	9.893	6.4%	3.928	84.9%	12.820	17.381
10:00	H	0.630		3.336		7.359	9.977
11:00	**M**	9.893	6.3%	4.204	80.6%	12.472	16.910
12:00	H	0.625		3.387		7.051	9.560
13:00	**M**	9.894	5.5%	3.999	82.9%	12.073	16.369
14:00	H	0.545		3.317		6.975	9.457
15:00	**M**	9.894	6.2%	4.331	77.1%	11.579	15.699
16:00	H	0.618		3.341		6.402	8.680
17:00	**M**	9.894	6.0%	4.178	80.1%	11.201	15.186
18:00	H	0.598		3.348		6.301	8.543
19:00	**M**	9.894	6.1%	4.174	79.9%	10.899	14.777
20:00	H	0.601		3.334		5.989	8.120

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	26		Hmax Stim Intensity (mA):	26
Hmax Amplitude (mV):	0.558		Hmax Amplitude (mV):	2.348
Hmax Torque (Nm)	7.277	9.866157	Hmax Torque (Nm)	9.866157
Mmax Stim Intensity (mA):	50		Mmax Stim Intensity (mA):	50
Mmax Amlitude (mV):	9.891		Mmax Amplitude (mV):	2.747
Mmax Torque (Nm)	11.632	15.77067	Mmax Torque (Nm)	15.77067
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	24		Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	0.552		Hmax Amplitude (mV):	2.426
Hmax Torque (Nm)	6.119	8.29614	Hmax Torque (Nm)	8.29614
Gastroc H/M	5.6%		Soleus H/M	88.3%

Subject 22 Session 1 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	1.8%	8.089	9.5%	6.623	8.979
0:20	H	0.180		0.772		2.806	3.804
0:30	**M**	9.893	2.1%	8.194	11.3%	6.114	8.289
0:40	H	0.210		0.924		2.475	3.356
0:50	**M**	9.893	4.6%	8.621	31.9%	11.196	15.180
1:00	H	0.457		2.748		5.302	7.188
1:30	**M**	9.893	4.4%	7.665	37.6%	9.584	12.994
2:00	H	0.433		2.880		5.018	6.803
2:30	**M**	9.893	3.3%	7.625	25.3%	9.787	13.269
3:00	H	0.323		1.929		3.980	5.396
3:30	**M**	9.893	5.2%	7.868	39.8%	8.477	11.493
4:00	H	0.513		3.133		4.554	6.174
4:30	**M**	9.896	5.0%	7.208	48.1%	9.465	12.833
5:00	H	0.496		3.465		4.736	6.421
5:30	**M**	9.893	4.6%	7.489	36.5%	8.847	11.995
6:00	H	0.453		2.736		4.274	5.795
6:30	**M**	9.893	4.8%	7.401	37.7%	8.581	11.634
7:00	H	0.473		2.787		5.384	7.300
7:30	**M**	9.893	4.0%	7.220	28.1%	8.211	11.132
8:00	H	0.399		2.032		5.315	7.206
8:30	**M**	9.893	4.2%	7.314	32.1%	8.591	11.648
9:00	H	0.415		2.347		5.156	6.991
9:30	**M**	9.893	3.9%	7.662	31.8%	10.650	14.439
10:00	H	0.382		2.436		4.989	6.764
11:00	**M**	9.894	4.3%	7.948	32.8%	7.969	10.804
12:00	H	0.422		2.606		4.906	6.652
13:00	**M**	9.896	3.8%	7.993	29.6%	8.281	11.227
14:00	H	0.380		2.365		5.443	7.380
15:00	**M**	9.893	3.4%	7.785	25.6%	8.405	11.395
16:00	H	0.332		1.992		5.554	7.530
17:00	**M**	9.893	3.7%	7.168	26.1%	8.298	11.250
18:00	H	0.367		1.873		5.574	7.557
19:00	**M**	9.893	3.8%	7.477	27.8%	8.333	11.298
20:00	H	0.375		2.077		4.801	6.509

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	12		Hmax Stim Intensity (mA):	12
Hmax Amplitude (mV):	0.659		Hmax Amplitude (mV):	3.471
Hmax Torque (Nm)	1.971	2.672282	Hmax Torque (Nm)	
Mmax Stim Intensity (mA):	55		Mmax Stim Intensity (mA):	55
Mmax Amplitude (mV):	9.892		Mmax Amplitude (mV):	5.945
Hmax Torque (Nm)	7.128	9.664142	Mmax Torque (Nm)	
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.591		Hmax Amplitude (mV):	3.409
Hmax Torque (Nm)	4.965	6.731547	Hmax Torque (Nm)	
Gastroc H/M	6.0%		Soleus H/M	57.3%

Subject 22 Session 2 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	3.4%	8.487	43.7%	9.479	12.852
0:20	H	0.336		3.709		4.452	6.036
0:30	**M**	9.894	3.3%	9.828	38.5%	9.414	12.764
0:40	H	0.331		3.782		5.121	6.943
0:50	**M**	9.894	4.2%	9.577	50.6%	9.841	13.342
1:00	H	0.411		4.842		4.737	6.422
1:30	**M**	9.895	4.2%	8.280	56.0%	9.557	12.957
2:00	H	0.412		4.636		5.010	6.793
2:30	**M**	9.894	4.6%	8.752	56.7%	9.581	12.990
3:00	H	0.457		4.963		5.011	6.794
3:30	**M**	9.894	3.8%	9.391	44.4%	9.608	13.027
4:00	H	0.380		4.169		5.029	6.818
4:30	**M**	9.894	2.4%	9.553	25.1%	9.627	13.052
5:00	H	0.242		2.395		4.076	5.526
5:30	**M**	9.894	4.0%	9.645	43.3%	9.935	13.470
6:00	H	0.393		4.181		5.097	6.911
6:30	**M**	9.894	4.2%	9.632	45.1%	10.144	13.753
7:00	H	0.415		4.346		4.774	6.473
7:30	**M**	9.895	4.1%	9.669	44.8%	9.596	13.010
8:00	H	0.409		4.334		4.881	6.618
8:30	**M**	9.893	4.1%	8.739	46.4%	9.255	12.548
9:00	H	0.401		4.051		4.827	6.544
9:30	**M**	9.893	3.9%	9.552	38.2%	9.003	12.206
10:00	H	0.383		3.652		4.959	6.723
11:00	**M**	9.894	3.5%	8.501	43.2%	9.181	12.448
12:00	H	0.345		3.670		4.058	5.502
13:00	**M**	9.894	3.6%	9.072	43.6%	8.453	11.461
14:00	H	0.355		3.957		4.625	6.271
15:00	**M**	9.893	4.5%	8.455	52.0%	9.194	12.465
16:00	H	0.449		4.395		4.599	6.235
17:00	**M**	9.893	3.4%	9.192	41.8%	8.530	11.565
18:00	H	0.339		3.844		4.378	5.936
19:00	**M**	9.894	4.1%	8.056	51.8%	8.551	11.593
20:00	H	0.410		4.171		4.476	6.069

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.379		Hmax Amplitude (mV):	3.580
Hmax Torque (Nm)	2.252	3.053262	Hmax Torque (Nm)	3.053262
Mmax Stim Intensity (mA):	50		Mmax Stim Intensity (mA):	50
Mmax Amlitude (mV):	9.891		Mmax Amplitude (mV):	6.637
Mmax Torque (Nm)	7.753	10.51152	Mmax Torque (Nm)	10.51152
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.398		Hmax Amplitude (mV):	4.042
Hmax Torque (Nm)	5.083	6.891531	Hmax Torque (Nm)	6.891531
Gastroc H/M	4.0%		Soleus H/M	60.9%

Subject 22 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	3.2%	9.282	26.0%	9.509	12.892
0:20	H	0.320		2.411		4.691	6.360
0:30	**M**	9.894	4.2%	9.211	35.2%	9.716	13.173
0:40	H	0.417		3.246		5.160	6.996
0:50	**M**	9.895	4.6%	8.937	41.3%	10.181	13.803
1:00	H	0.452		3.687		5.315	7.206
1:30	**M**	9.893	4.6%	8.856	38.3%	9.473	12.843
2:00	H	0.452		3.388		5.561	7.540
2:30	**M**	9.894	4.3%	8.823	34.8%	10.473	14.199
3:00	H	0.429		3.073		5.880	7.972
3:30	**M**	9.894	4.4%	9.157	39.0%	10.156	13.770
4:00	H	0.431		3.570		5.819	7.889
4:30	**M**	9.895	4.4%	8.933	38.8%	9.404	12.750
5:00	H	0.438		3.463		5.648	7.658
5:30	**M**	9.894	4.1%	9.120	34.3%	9.871	13.383
6:00	H	0.404		3.132		4.520	6.128
6:30	**M**	9.894	4.4%	8.828	34.5%	8.806	11.939
7:00	H	0.431		3.048		5.056	6.855
7:30	**M**	9.895	3.6%	8.967	27.9%	8.975	12.168
8:00	H	0.356		2.498		4.637	6.287
8:30	**M**	9.894	4.0%	8.866	37.5%	9.102	12.340
9:00	H	0.398		3.324		5.353	7.258
9:30	**M**	9.893	4.2%	8.863	35.5%	8.660	11.741
10:00	H	0.420		3.146		4.547	6.165
11:00	**M**	9.895	3.4%	9.037	27.0%	8.603	11.664
12:00	H	0.340		2.444		5.235	7.098
13:00	**M**	9.894	4.0%	9.045	29.3%	8.377	11.358
14:00	H	0.395		2.654		5.579	7.564
15:00	**M**	9.894	3.6%	9.435	26.3%	8.586	11.641
16:00	H	0.353		2.477		4.889	6.629
17:00	**M**	9.896	4.5%	9.178	34.4%	9.207	12.483
18:00	H	0.448		3.158		4.839	6.561
19:00	**M**	9.895	4.5%	8.714	36.1%	8.096	10.977
20:00	H	0.448		3.146		4.775	6.474

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	20		Hmax Stim Intensity (mA):	20
Hmax Amplitude (mV):	0.390		Hmax Amplitude (mV):	3.147
Hmax Torque (Nm)	4.549	6.167534	Hmax Torque (Nm)	6.167534
Mmax Stim Intensity (mA):	55		Mmax Stim Intensity (mA):	55
Mmax Amlitude (mV):	9.892		Mmax Amplitude (mV):	9.061
Mmax Torque (Nm)	8.483	11.50125	Mmax Torque (Nm)	11.50125
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	18		Hmax Stim Intensity (mA):	18
Hmax Amplitude (mV):	0.393		Hmax Amplitude (mV):	3.597
Hmax Torque (Nm)	5.279	7.157268	Hmax Torque (Nm)	7.157268
Gastroc H/M	4.0%		Soleus H/M	39.7%

Subject 23 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	9.1%	4.595	50.1%	10.817	14.666
0:20	H	0.899		2.301		7.785	10.555
0:30	**M**	9.893	9.1%	4.226	56.6%	11.243	15.243
0:40	H	0.904		2.394		7.872	10.673
0:50	**M**	9.894	9.2%	4.574	54.6%	11.003	14.918
1:00	H	0.907		2.498		7.930	10.751
1:30	**M**	9.893	9.7%	4.845	52.4%	10.771	14.603
2:00	H	0.960		2.538		8.156	11.058
2:30	**M**	9.893	10.7%	4.736	53.7%	10.878	14.748
3:00	H	1.058		2.544		8.097	10.978
3:30	**M**	9.893	11.0%	4.980	47.4%	10.728	14.545
4:00	H	1.088		2.363		7.882	10.686
4:30	**M**	9.896	11.8%	3.722	63.2%	10.343	14.023
5:00	H	1.167		2.351		8.043	10.905
5:30	**M**	9.895	12.1%	5.434	43.5%	9.973	13.521
6:00	H	1.196		2.363		7.623	10.335
6:30	**M**	9.893	12.2%	4.927	53.3%	10.034	13.604
7:00	H	1.203		2.624		7.780	10.548
7:30	**M**	9.893	11.8%	4.798	50.1%	9.944	13.482
8:00	H	1.172		2.403		7.809	10.587
8:30	**M**	9.893	12.0%	4.405	61.5%	9.427	12.781
9:00	H	1.192		2.711		7.542	10.225
9:30	**M**	9.893	11.9%	4.301	61.3%	9.334	12.655
10:00	H	1.180		2.636		6.972	9.453
11:00	**M**	9.893	13.5%	4.889	51.5%	8.953	12.138
12:00	H	1.340		2.516		7.269	9.855
13:00	**M**	9.894	9.6%	4.175	48.6%	8.952	12.137
14:00	H	0.954		2.030		6.227	8.443
15:00	**M**	9.893	12.2%	4.382	55.2%	6.889	9.340
16:00	H	1.211		2.419		6.866	9.309
17:00	**M**	9.893	12.8%	4.267	60.6%	8.654	11.733
18:00	H	1.270		2.587		6.673	9.047
19:00	**M**	9.893	12.6%	4.275	58.0%	8.714	11.814
20:00	H	1.242		2.478		6.973	9.454

Gatroc			Soleus		
Recruitment Curve			Recruitment Curve		
Hmax Stim Intensity (mA):	24		Hmax Stim Intensity (mA):	24	
Hmax Amplitude (mV):	0.901		Hmax Amplitude (mV):	2.660	
Hmax Torque (Nm)	7.987	10.82877	Hmax Torque (Nm)	10.82877	
Mmax Stim Intensity (mA):	65		Mmax Stim Intensity (mA):	65	100
Mmax Amplitude (mV):	9.893		Mmax Amplitude (mV):	4.798	6.437
Mmax Torque (Nm)	10.160	13.77493	Mmax Torque (Nm)	13.77493	
Confirm Hmax			Confirm Hmax		
Hmax Stim Intensity (mA):	22		Hmax Stim Intensity (mA):	22	24
Hmax Amplitude (mV):	0.870		Hmax Amplitude (mV):	2.832	2.85
Hmax Torque (Nm)	8.476	11.49176	Hmax Torque (Nm)	11.49176	
Gastroc H/M	8.8%		Soleus H/M	59.0%	

Subject 23 Session 2 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	7.2%	4.670	60.0%	12.178	16.511
0:20	H	0.709		2.802		9.380	12.717
0:30	**M**	9.895	7.6%	4.710	70.7%	12.410	16.825
0:40	H	0.754		3.331		9.451	12.814
0:50	**M**	9.893	7.9%	5.198	68.4%	12.359	16.756
1:00	H	0.780		3.558		9.567	12.971
1:30	**M**	9.894	8.1%	4.691	77.9%	12.197	16.537
2:00	H	0.804		3.656		9.857	13.364
2:30	**M**	9.894	8.3%	5.847	63.1%	11.810	16.012
3:00	H	0.824		3.689		9.896	13.417
3:30	**M**	9.896	8.0%	5.105	68.0%	11.845	16.059
4:00	H	0.788		3.469		8.984	12.181
4:30	**M**	9.894	8.4%	4.954	78.1%	11.425	15.490
5:00	H	0.829		3.869		9.701	13.153
5:30	**M**	9.894	8.6%	5.010	72.2%	11.441	15.512
6:00	H	0.852		3.615		9.863	13.372
6:30	**M**	9.894	8.5%	4.940	74.1%	11.321	15.349
7:00	H	0.837		3.659		9.848	13.352
7:30	**M**	9.895	8.2%	6.053	59.1%	11.202	15.188
8:00	H	0.811		3.578		9.837	13.337
8:30	**M**	9.895	9.1%	5.296	71.7%	11.292	15.310
9:00	H	0.901		3.796		9.824	13.319
9:30	**M**	9.893	7.8%	5.443	64.6%	11.116	15.071
10:00	H	0.776		3.515		9.509	12.892
11:00	**M**	9.893	8.4%	4.904	76.6%	11.044	14.973
12:00	H	0.833		3.758		9.455	12.819
13:00	**M**	9.894	8.4%	4.739	75.6%	11.113	15.067
14:00	H	0.835		3.583		9.579	12.987
15:00	**M**	9.894	8.8%	5.548	69.1%	10.894	14.770
16:00	H	0.866		3.831		9.298	12.606
17:00	**M**	9.896	8.5%	5.309	70.1%	10.689	14.492
18:00	H	0.845		3.724		9.265	12.561
19:00	**M**	9.894	8.6%	5.199	70.8%	10.870	14.738
20:00	H	0.851		3.682		9.281	12.583

Gastroc			Soleus			
Recruitment Curve			Recruitment Curve			
Hmax Stim Intensity (mA):	28		Hmax Stim Intensity (mA):	28		
Hmax Amplitude (mV):	0.787		Hmax Amplitude (mV):	3.184		
Hmax Torque (Nm)	10.986	14.89482	Hmax Torque (Nm)	14.89482		
Mmax Stim Intensity (mA):	55		Mmax Stim Intensity (mA):	55	100	
Mmax Amlitude (mV):	9.893		Mmax Amlitude (mV):	4.513	9.893	
Mmax Torque (Nm)	12.732	17.26205	Mmax Torque (Nm)	17.26205		
Confirm Hmax			Confirm Hmax			
Hmax Stim Intensity (mA):	28		Hmax Stim Intensity (mA):	28	30	
Hmax Amplitude (mV):	0.763		Hmax Amplitude (mV):	3.163	3.321	
Hmax Torque (Nm)	11.100	15.04938	Hmax Torque (Nm)	15.04938		
Gastroc H/M	7.7%		Soleus H/M	70.1%		

Subject 23 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	5.2%	5.166	36.3%	10.596	14.366
0:20	H	0.515		1.874		8.544	11.584
0:30	**M**	9.894	5.0%	4.641	39.6%	10.518	14.260
0:40	H	0.495		1.837		8.606	11.668
0:50	**M**	9.894	4.5%	3.501	46.8%	10.224	13.862
1:00	H	0.447		1.640		8.588	11.644
1:30	**M**	9.895	4.1%	5.704	29.1%	10.014	13.577
2:00	H	0.403		1.662		8.623	11.691
2:30	**M**	9.894	4.4%	3.644	44.1%	9.968	13.515
3:00	H	0.434		1.606		8.639	11.713
3:30	**M**	9.896	3.7%	4.769	31.8%	9.926	13.458
4:00	H	0.368		1.518		8.459	11.469
4:30	**M**	9.893	3.9%	4.624	32.8%	9.640	13.070
5:00	H	0.387		1.515		8.189	11.103
5:30	**M**	9.894	4.5%	3.291	43.6%	9.352	12.679
6:00	H	0.441		1.436		8.037	10.897
6:30	**M**	9.893	4.5%	4.619	34.0%	7.633	10.349
7:00	H	0.444		1.571		7.590	10.291
7:30	**M**	9.893	4.8%	5.278	29.9%	9.179	12.445
8:00	H	0.476		1.576		7.955	10.785
8:30	**M**	9.893	4.3%	3.525	44.1%	9.168	12.430
9:00	H	0.426		1.553		8.025	10.880
9:30	**M**	9.893	4.9%	4.415	32.2%	9.132	12.381
10:00	H	0.488		1.421		7.717	10.463
11:00	**M**	9.893	4.8%	4.251	35.3%	9.004	12.208
12:00	H	0.470		1.500		7.828	10.613
13:00	**M**	9.894	4.5%	3.281	42.0%	8.853	12.003
14:00	H	0.441		1.377		7.377	10.002
15:00	**M**	9.895	4.5%	3.430	35.7%	8.418	11.413
16:00	H	0.443		1.226		7.253	9.834
17:00	**M**	9.895	3.8%	3.500	37.4%	8.529	11.564
18:00	H	0.380		1.308		7.141	9.682
19:00	**M**	9.896	4.5%	3.643	39.1%	8.292	11.242
20:00	H	0.450		1.423		7.117	9.649

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	30		Hmax Stim Intensity (mA):	30
Hmax Amplitude (mV):	0.75		Hmax Amplitude (mV):	2.556
Hmax Torque (Nm)	9.450	12.81231	Hmax Torque (Nm)	12.81231
Mmax Stim Intensity (mA):	60		Mmax Stim Intensity (mA):	60
Mmax Amlitude (mV):	9.891		Mmax Amlitude (mV):	4.534
Mmax Torque (Nm)	11.485	15.57136	Mmax Torque (Nm)	15.57136
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	28		Hmax Stim Intensity (mA):	28
Hmax Amplitude (mV):	0.599		Hmax Amplitude (mV):	2.873
Hmax Torque (Nm)	10.752	14.57756	Hmax Torque (Nm)	14.57756
Gastroc H/M	6.1%		Soleus H/M	63.4%

Subject 24 Session 1 Treatment order: 60 s rest, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	7.0%	5.928	54.0%	6.438	8.729
0:20	H	0.690		3.2		4.852	6.578
0:30	**M**	9.893	7.8%	6.31	51.4%	7.346	9.960
0:40	H	0.776		3.245		5.008	6.790
0:50	**M**	9.894	7.2%	6.434	53.9%	7.099	9.625
1:00	H	0.711		3.465		5.015	6.799
1:30	**M**	9.893	7.7%	5.924	54.0%	7.562	10.253
2:00	H	0.761		3.201		4.836	6.557
2:30	**M**	9.893	8.2%	6.278	58.5%	7.172	9.724
3:00	H	0.810		3.672		5.352	7.256
3:30	**M**	9.894	7.4%	6.321	57.5%	7.234	9.808
4:00	H	0.732		3.635		5.380	7.294
4:30	**M**	9.893	7.7%	6.877	53.0%	7.264	9.849
5:00	H	0.761		3.642		5.255	7.125
5:30	**M**	9.898	7.2%	6.335	56.4%	6.937	9.405
6:00	H	0.717		3.57		5.044	6.839
6:30	**M**	9.895	8.3%	6.606	56.6%	6.161	8.353
7:00	H	0.818		3.737		4.915	6.664
7:30	**M**	9.894	8.0%	6.67	57.3%	6.311	8.556
8:00	H	0.787		3.822		4.806	6.516
8:30	**M**	9.893	6.9%	7.802	45.8%	5.913	8.017
9:00	H	0.679		3.57		4.904	6.649
9:30	**M**	9.898	7.2%	9.893	36.1%	5.871	7.960
10:00	H	0.711		3.575		4.909	6.656
11:00	**M**	9.893	7.5%	7.874	45.8%	5.895	7.992
12:00	H	0.739		3.61		4.517	6.124
13:00	**M**	9.894	7.6%	9.894	36.7%	5.572	7.555
14:00	H	0.756		3.636		4.181	5.669
15:00	**M**	9.893	6.9%	9.894	36.2%	5.002	6.782
16:00	H	0.686		3.577		4.600	6.237
17:00	**M**	9.893	8.0%	9.894	36.8%	5.136	6.963
18:00	H	0.790		3.642		4.429	6.005
19:00	**M**	9.893	6.6%	9.898	35.6%	5.166	7.004
20:00	H	0.651		3.528		4.352	5.900

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	18		Hmax Stim Intensity (mA):	18
Hmax Amplitude (mV):	0.575		Hmax Amplitude (mV):	2.586
Hmax Torque (Nm)	5.394	7.313185	Hmax Torque (Nm)	7.313185
Mmax Stim Intensity (mA):	55		Mmax Stim Intensity (mA):	55
Mmax Amplitude (mV):	9.895		Mmax Amplitude (mV):	4.670
Mmax Torque (Nm)	6.461	8.759824	Mmax Torque (Nm)	8.759824
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.507		Hmax Amplitude (mV):	2.591
Hmax Torque (Nm)	5.897	7.995153	Hmax Torque (Nm)	7.995153
Gastroc H/M	5.10%		Soleus H/M	55.50%

Subject 24 Session 2 Treatment order: SMT, no MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	5.4%	4.588	55.7%	9.695	13.144
0:20	H	0.534		2.554		9.199	12.472
0:30	**M**	9.893	4.2%	4.585	57.1%	10.325	13.999
0:40	H	0.413		2.616		8.893	12.057
0:50	**M**	9.893	4.0%	4.232	60.7%	10.042	13.615
1:00	H	0.399		2.568		8.903	12.071
1:30	**M**	9.893	4.1%	4.663	57.9%	9.896	13.417
2:00	H	0.404		2.700		7.103	9.630
2:30	**M**	9.893	4.6%	4.422	63.7%	7.313	9.915
3:00	H	0.460		2.818		6.830	9.260
3:30	**M**	9.895	5.1%	5.077	59.8%	6.800	9.219
4:00	H	0.502		3.034		6.564	8.899
4:30	**M**	9.896	4.9%	4.998	60.3%	6.749	9.150
5:00	H	0.488		3.015		5.990	8.121
5:30	**M**	9.894	4.6%	5.134	61.0%	6.132	8.314
6:00	H	0.460		3.131		5.426	7.357
6:30	**M**	9.895	4.4%	5.250	40.8%	6.034	8.181
7:00	H	0.440		2.141		5.810	7.877
7:30	**M**	9.893	5.7%	5.218	64.5%	5.783	7.841
8:00	H	0.560		3.368		5.219	7.076
8:30	**M**	9.895	4.6%	5.394	57.9%	5.503	7.461
9:00	H	0.451		3.121		5.368	7.278
9:30	**M**	9.893	4.9%	5.113	43.4%	5.379	7.293
10:00	H	0.481		2.218		4.497	6.097
11:00	**M**	9.895	5.6%	5.493	64.2%	5.155	6.989
12:00	H	0.558		3.525		4.784	6.486
13:00	**M**	9.894	6.0%	5.371	73.1%	4.977	6.748
14:00	H	0.593		3.925		4.630	6.277
15:00	**M**	9.893	6.4%	5.354	72.9%	4.524	6.134
16:00	H	0.638		3.903		4.124	5.591
17:00	**M**	9.893	6.6%	5.597	65.7%	4.377	5.934
18:00	H	0.652		3.675		3.588	4.865
19:00	**M**	9.894	5.8%	5.458	61.6%	4.266	5.784
20:00	H	0.570		3.362		3.529	4.785

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	14		Hmax Stim Intensity (mA):	14
Hmax Amplitude (mV):	0.845		Hmax Amplitude (mV):	2.608
Hmax Torque (Nm)	5.557	7.534181	Hmax Torque (Nm)	7.534181
Mmax Stim Intensity (mA):	50		Mmax Stim Intensity (mA):	50
Mmax Amlitude (mV):	9.891		Mmax Amplitude (mV):	3.955
Mmax Torque (Nm)	9.115	12.35812	Mmax Torque (Nm)	12.35812
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	16		Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	0.811		Hmax Amplitude (mV):	2.692
Hmax Torque (Nm)	6.711	9.098774	Hmax Torque (Nm)	9.098774
Gastroc H/M	8.2%		Soleus H/M	68.1%

Subject 24 Session 3 Treatment order: SMT, MVIC, H/M

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	5.0%	8.290	11.5%	7.267	9.853
0:20	H	0.492		0.950		4.946	6.706
0:30	**M**	9.893	6.4%	8.118	18.0%	9.728	13.189
0:40	H	0.631		1.460		7.689	10.425
0:50	**M**	9.893	7.2%	9.001	14.9%	10.190	13.816
1:00	H	0.717		1.338		6.969	9.449
1:30	**M**	9.895	8.0%	9.896	16.2%	9.160	12.419
2:00	H	0.794		1.602		7.000	9.491
2:30	**M**	9.896	4.4%	9.895	6.2%	9.122	12.368
3:00	H	0.440		0.611		5.257	7.127
3:30	**M**	9.893	7.8%	7.681	23.0%	7.884	10.689
4:00	H	0.772		1.765		5.425	7.355
4:30	**M**	9.893	7.1%	8.786	21.9%	7.475	10.135
5:00	H	0.705		1.924		5.367	7.277
5:30	**M**	9.893	8.7%	9.268	21.4%	7.179	9.733
6:00	H	0.861		1.985		5.337	7.236
6:30	**M**	9.893	7.9%	6.983	29.5%	7.228	9.800
7:00	H	0.782		2.061		5.552	7.527
7:30	**M**	9.895	7.4%	9.321	19.1%	6.818	9.244
8:00	H	0.737		1.777		5.098	6.912
8:30	**M**	9.893	8.5%	7.957	28.2%	6.255	8.481
9:00	H	0.842		2.240		4.602	6.239
9:30	**M**	9.895	8.5%	7.090	30.4%	6.002	8.138
10:00	H	0.846		2.152		4.399	5.964
11:00	**M**	9.893	9.1%	7.407	32.2%	5.729	7.767
12:00	H	0.905		2.386		4.394	5.957
13:00	**M**	9.893	8.3%	8.754	24.6%	6.446	8.739
14:00	H	0.818		2.151		4.651	6.306
15:00	**M**	9.893	6.7%	9.074	17.0%	5.494	7.449
16:00	H	0.660		1.547		3.979	5.395
17:00	**M**	9.893	8.7%	9.242	21.8%	5.827	7.900
18:00	H	0.858		2.017		4.222	5.724
19:00	**M**	9.894	8.9%	8.854	23.8%	5.579	7.564
20:00	H	0.877		2.105		4.115	5.579

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	18		Hmax Stim Intensity (mA):	18
Hmax Amplitude (mV):	0.503		Hmax Amplitude (mV):	1.151
Hmax Torque (Nm)	7.289	9.882426	Hmax Torque (Nm)	9.882426
Mmax Stim Intensity (mA):	50		Mmax Stim Intensity (mA):	50
Mmax Amlitude (mV):	9.891		Mmax Amplitude (mV):	8.567
Mmax Torque (Nm)	8.644	11.71954	Mmax Torque (Nm)	11.71954
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	16		Hmax Stim Intensity (mA):	16
Hmax Amplitude (mV):	0.461		Hmax Amplitude (mV):	1.361
Hmax Torque (Nm)	8.431	11.43075	Hmax Torque (Nm)	11.43075
Gastroc H/M	4.7%		Soleus H/M	15.9%

Subject 25 Session 1 Control

1st

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.893	6.2%	9.894	25.4%	7.113	9.644
0:20	H	0.618		2.515		4.770	6.467
0:30	**M**	9.893	6.6%	9.898	24.2%	7.435	10.080
0:40	H	0.654		2.399		4.534	6.147
0:50	**M**	9.894	6.7%	9.894	25.2%	7.259	9.842
1:00	H	0.662		2.493		4.454	6.039
1:30	**M**	9.895	7.3%	9.895	29.3%	7.115	9.647
2:00	H	0.719		2.902		4.988	6.763
2:30	**M**	9.897	6.6%	9.894	26.6%	7.647	10.368
3:00	H	0.652		2.629		4.840	6.562
3:30	**M**	9.897	6.2%	9.894	24.5%	7.847	10.639
4:00	H	0.609		2.421		4.961	6.726
4:30	**M**	9.893	7.0%	9.894	28.7%	8.010	10.860
5:00	H	0.690		2.838		5.352	7.256
5:30	**M**	9.897	6.5%	9.894	26.2%	7.258	9.840
6:00	H	0.643		2.592		4.708	6.383
6:30	**M**	9.895	6.8%	9.556	28.1%	7.389	10.018
7:00	H	0.673		2.689		4.466	6.055
7:30	**M**	9.893	7.0%	9.894	27.5%	7.311	9.912
8:00	H	0.689		2.716		4.715	6.393
8:30	**M**	9.894	6.7%	9.895	27.8%	7.234	9.808
9:00	H	0.664		2.747		4.714	6.391
9:30	**M**	9.895	6.5%	9.894	26.6%	7.257	9.839
10:00	H	0.639		2.627		4.600	6.237
11:00	**M**	9.894	6.7%	9.894	25.9%	7.178	9.732
12:00	H	0.663		2.565		4.604	6.242
13:00	**M**	9.896	6.4%	9.895	24.8%	7.267	9.853
14:00	H	0.633		2.450		4.605	6.243
15:00	**M**	9.895	6.5%	9.894	24.9%	7.406	10.041
16:00	H	0.643		2.467		4.549	6.168
17:00	**M**	9.896	6.6%	9.894	24.7%	7.255	9.836
18:00	H	0.651		2.447		4.607	6.246
19:00	**M**	9.894	7.1%	9.894	30.1%	6.119	8.296
20:00	H	0.700		2.983		5.023	6.810

2nd

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	5.8%	9.895	23.9%	9.386	12.726
0:20	H	0.573		2.369		5.277	7.155
0:30	**M**	9.896	6.3%	9.895	25.2%	8.784	11.909
0:40	H	0.620		2.492		4.845	6.569
0:50	**M**	9.894	6.2%	9.894	24.2%	8.426	11.424
1:00	H	0.615		2.395		5.079	6.886
1:30	**M**	9.894	6.9%	9.894	27.1%	8.757	11.873
2:00	H	0.678		2.682		5.288	7.169
2:30	**M**	9.895	4.7%	9.895	16.5%	8.412	11.405
3:00	H	0.465		1.637		4.227	5.731
3:30	**M**	9.894	5.7%	9.894	21.2%	8.601	11.661
4:00	H	0.563		2.096		5.138	6.966
4:30	**M**	9.894	5.8%	9.894	21.6%	5.583	7.569
5:00	H	0.571		2.142		4.960	6.725
5:30	**M**	9.894	6.7%	9.896	26.4%	8.640	11.714
6:00	H	0.663		2.616		5.503	7.461
6:30	**M**	9.895	6.8%	9.894	27.0%	8.621	11.688
7:00	H	0.674		2.667		5.288	7.169
7:30	**M**	9.894	6.6%	9.894	26.4%	8.537	11.574
8:00	H	0.652		2.610		5.273	7.149
8:30	**M**	9.895	7.1%	9.895	26.8%	8.596	11.654
9:00	H	0.700		2.651		5.269	7.144
9:30	**M**	9.894	7.0%	9.895	28.2%	8.498	11.522
10:00	H	0.696		2.795		5.403	7.325
11:00	**M**	9.894	7.0%	9.897	27.2%	8.612	11.676
12:00	H	0.690		2.693		5.309	7.198
13:00	**M**	9.894	6.8%	9.895	29.8%	8.550	11.592
14:00	H	0.672		2.945		4.999	6.778
15:00	**M**	9.894	6.7%	9.894	28.1%	8.226	11.153
16:00	H	0.664		2.783		4.975	6.745
17:00	**M**	9.894	6.0%	9.895	24.4%	8.488	11.508
18:00	H	0.595		2.418		4.827	6.544
19:00	**M**	9.894	7.0%	9.894	28.6%	7.898	10.708
20:00	H	0.695		2.827		5.284	7.164

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	20		Hmax Stim Intensity (mA):	20
Hmax Amplitude (mV):	0.696		Hmax Amplitude (mV):	2.418
Hmax Torque (Nm)	2.586	3.51	Hmax Torque (Nm)	3.506099
Mmax Stim Intensity (mA):	50		Mmax Stim Intensity (mA):	50
Mmax Amplitude (mV):	9.893		Mmax Amplitude (mV):	9.893
Mmax Torque (Nm)	6.613	8.97	Mmax Torque (Nm)	8.965905
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	24		Hmax Stim Intensity (mA):	24
Hmax Amplitude (mV):	0.512		Hmax Amplitude (mV):	2.349
Hmax Torque (Nm)	4.176	5.66	Hmax Torque (Nm)	5.661821
Gastroc H/M	5.2%		Soleus H/M	23.7%

Subject 25 Session 2 Control

1st

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.894	6.7%	5.747	55.1%	7.823	10.606
0:20	H	0.658		3.168		4.526	6.136
0:30	**M**	9.894	6.5%	6.798	43.7%	8.011	10.861
0:40	H	0.647		2.971		4.229	5.734
0:50	**M**	9.895	6.2%	6.345	44.6%	7.981	10.821
1:00	H	0.615		2.829		3.946	5.350
1:30	**M**	9.894	6.5%	7.013	41.2%	7.861	10.658
2:00	H	0.646		2.886		4.248	5.759
2:30	**M**	9.895	6.7%	6.378	50.6%	7.931	10.753
3:00	H	0.667		3.225		5.280	7.159
3:30	**M**	9.894	6.8%	7.698	40.0%	9.011	12.217
4:00	H	0.668		3.083		4.788	6.492
4:30	**M**	9.894	7.0%	6.870	45.7%	8.650	11.728
5:00	H	0.692		3.143		4.717	6.395
5:30	**M**	9.894	7.1%	7.073	44.7%	8.463	11.474
6:00	H	0.699		3.165		4.396	5.960
6:30	**M**	9.894	7.1%	7.103	45.0%	8.348	11.318
7:00	H	0.698		3.194		4.529	6.140
7:30	**M**	9.894	6.8%	5.732	53.2%	8.511	11.539
8:00	H	0.676		3.049		4.254	5.768
8:30	**M**	9.895	7.8%	6.493	51.5%	5.477	7.426
9:00	H	0.770		3.342		4.122	5.589
9:30	**M**	9.896	7.6%	6.263	53.2%	7.565	10.257
10:00	H	0.756		3.331		4.022	5.453
11:00	**M**	9.894	7.9%	6.754	52.9%	8.519	11.550
12:00	H	0.786		3.575		4.863	6.593
13:00	**M**	9.896	7.2%	6.278	56.4%	6.695	9.077
14:00	H	0.715		3.541		3.984	5.402
15:00	**M**	9.894	7.2%	6.187	53.9%	7.176	9.729
16:00	H	0.710		3.332		6.607	8.958
17:00	**M**	9.895	6.6%	7.454	44.1%	6.862	9.303
18:00	H	0.657		3.284		3.524	4.778
19:00	**M**	9.894	7.4%	6.429	49.7%	6.130	8.311
20:00	H	0.729		3.195		3.154	4.276

2nd

Time (min)	H/Mmax	Gastroc (mV)	Gastroc H/M	Soleus (mV)	Soleus H/M	Torque (ft lbs)	Torque (Nm)
0:10	**M**	9.895	4.4%	7.234	23.8%	5.828	7.902
0:20	H	0.438		1.723		3.154	4.276
0:30	**M**	9.894	6.3%	6.562	45.1%	7.866	10.665
0:40	H	0.625		2.957		4.093	5.549
0:50	**M**	9.895	6.5%	7.464	38.7%	8.389	11.374
1:00	H	0.641		2.891		4.095	5.552
1:30	**M**	9.894	8.9%	6.286	58.0%	6.475	8.779
2:00	H	0.878		3.645		3.958	5.366
2:30	**M**	9.897	8.5%	6.253	57.1%	6.891	9.343
3:00	H	0.840		3.573		3.938	5.339
3:30	**M**	9.895	9.0%	7.473	50.5%	6.776	9.187
4:00	H	0.892		3.774		4.004	5.429
4:30	**M**	9.894	8.5%	6.962	52.8%	6.751	9.153
5:00	H	0.844		3.677		3.792	5.141
5:30	**M**	9.894	8.0%	6.662	54.9%	6.704	9.089
6:00	H	0.791		3.655		3.691	5.004
6:30	**M**	9.895	8.6%	6.916	53.8%	6.464	8.764
7:00	H	0.854		3.723		3.849	5.218
7:30	**M**	9.894	8.4%	6.577	55.5%	6.625	8.982
8:00	H	0.831		3.649		3.641	4.936
8:30	**M**	9.896	7.7%	7.538	46.0%	6.311	8.556
9:00	H	0.766		3.466		3.492	4.734
9:30	**M**	9.894	7.1%	6.081	55.6%	5.827	7.900
10:00	H	0.700		3.380		3.085	4.183
11:00	**M**	9.894	7.8%	6.907	50.9%	5.907	8.009
12:00	H	0.769		3.517		3.237	4.389
13:00	**M**	9.894	8.3%	6.476	57.8%	5.873	7.963
14:00	H	0.820		3.746		3.348	4.539
15:00	**M**	9.895	7.5%	7.703	44.0%	5.518	7.481
16:00	H	0.738		3.389		2.535	3.437
17:00	**M**	9.894	6.9%	8.024	40.1%	5.374	7.286
18:00	H	0.680		3.216		2.907	3.941
19:00	**M**	9.894	8.5%	8.005	46.5%	5.424	7.354
20:00	H	0.839		3.726		3.277	4.443

Gastroc			Soleus	
Recruitment Curve			Recruitment Curve	
Hmax Stim Intensity (mA):	20		Hmax Stim Intensity (mA):	20
Hmax Amplitude (mV):	0.610		Hmax Amplitude (mV):	2.542
Hmax Torque (Nm)	4.678	6.342432	Hmax Torque (Nm)	6.342432
Mmax Stim Intensity (mA):	45		Mmax Stim Intensity (mA):	45
Mmax Amlitude (mV):	9.893		Mmax Amplitude (mV):	6.115
Mmax Torque (Nm)	6.303	8.545607	Mmax Torque (Nm)	8.545607
Confirm Hmax			Confirm Hmax	
Hmax Stim Intensity (mA):	18		Hmax Stim Intensity (mA):	18
Hmax Amplitude (mV):	0.641		Hmax Amplitude (mV):	2.936
Hmax Torque (Nm)	3.568	4.837494	Hmax Torque (Nm)	4.837494
Gastroc H/M	6.5%		Soleus H/M	48.0%

References

1. Peterson D, Bergmann T. Chiropractic technique: principles and procedures. 2nd ed. St. Louis: Mosby; 2002. Chapter 5, The spine: anatomy, biomechanics, assessment and adjustive techniques; p. 175-339.
2. Redwood, D. and Cleveland III, C. (2003). Fundamentals of Chiropractic. Mosby. ISBN: 0-323-01812-2. Chapter 7. Vertebral Subluxation. Carl S. Cleveland III.
3. Hooper, P. Evolution and basic principles of the chiropractic adjustment and manipulation. In: Haldeman, S. Principles and Practice of Chiropractic. 3rd edition. The McGraw-Hill Companies, Inc. 2005. Chapter 37. pp. 749-751.
4. Hurwitz, E. Epidemiology: Spinal manipulation utilization. Journal of Electromyography and Kinesiology. 2012. 22: 648-654.
5. Spinal manipulation. (2005). Stedman's medical dictionary for the health professions and nursing (p. 1369, 5th ed). Lippincott Williams & Wilkins.
6. Gatterman, M. (2005). Foundations of Chiropractic: Subluxation. (2nd Edition). Elsevier Mosby. ISBN: 0-323-02648-6. Chapter 1. "What's in a Word?" Meridel I. Gatterman.
7. Michaleff, Z., Lin, C., Maher, M. and van Tulder, M. Spinal manipulation epidemiology: Systematic review of cost-effective studies. Journal of Electromyography and Kinesiology. 2012. 22: 655-662.
8. Goertz, C., Long, C., Hondras, M., Petri, R., Delgado, R., Lawrence, D., Owens, E. and Meeker, W. Adding chiropractic manipulative therapy to standard medical care for patients with acute low back pain. Spine. 2013. 38(8): 627-634.
9. Goertz, C., Pohlman, K., Vining, R., Brantingham, J. and Long, C. Patient-centered outcomes of high-velocity, low-amplitude spinal manipulation for low back pain: a systematic review. Journal of Electromyography and Kinesiology. 2012. 22(5): 670-91.
10. Heymann, W., Schloemer, P., Timm, J. and Muehlbauer, B. Spinal high-velocity low amplitude manipulation in acute nonspecific low back pain. Spine. 2013. 38(7): 540-548. 11. McCrory, D., et al. Evidence report: Behavioral and physical treatments for tension-type and cervicogenic headache. Duke University Evidence-Based Practice Center, Durham, North Carolina. 2001.
12. Boline, P., Kassak, K., Bronfort, G., Nelson, C. and Anderson, A. Spinal manipulation vs. amitriptyline for the treatment of chronic tension-type headaches: A randomized clinical trial. Journal of Manipulative and Physiological Therapeutics. 1995. 18(3): 148-54.
13. Nelson, C., Bronfort, G., Evans, R., Boline, P., Goldsmith, C. and Anderson, A. The efficacy of spinal manipulation, amitriptyline and the combination of both therapies for the prophylaxis ofmigraine headache. 1998. 21(8): 511-9.
14. Burton, A., Tillotson, K. and Cleary, J. Single-blind randomised controlled trial of chemonucleolysis and manipulation in the treatment of symptomatic lumbar disc herniation. European Spine Journal. 2000. 9: 202 –7.
15. Haas, M., Sharma, R. and Stano, M. Cost-effectiveness of medical and chiropractic care for acute and chronic low back pain. Journal of Manipulative and Physiological Therapeutics. 2005. 28(8): 555-563.

16. Korthals-de Bois, I., Hoving, J., Van Tulder, M., Van Molken, R., Ader, H., De Vet, H., Koes, B., Vondeling, H. and Bouter, L. Primay care – cost effectiveness of physiotherapy, manual therapy and general practitioner care for neck pain: Economic evaluation alongside a randomized controlled trial. British Medical Journal. 2003. 326: 911.
17. Wiese, G. and Callender, A. Chapter 1. History of spinal manipulation. In: Haldeman, S. Principles and Practice of Chiropractic. 3rd edition. The McGraw-Hill Companies, Inc. 2005. 5-9.
18. Evans, R., Bronfort, G., Schulz, C., Maiers, M., Bracha, Y., Svendsen, K., Grimm, R., Garvey, T. and Transfeldt, E. Supervised exercise with and without spinal manipulation performs similarly and better than home exercise for chronic neck pain: A randomized controlled trial. Spine. 2012. 37(11): 903-914.
19. Bronfort, G., Evans, R., Anserson, AV et al. Spinal manipulation, medication, or home exercise with advice for acute and subacute neck pain. Annals of Internal Medicine. 2012. 16(1): 1-10.
20. Bronfort, G., Maiers, M., Evans, R., Schulz, C., Bracha, Y., Svendsen, K., Grimm, R., Owens, E., Garvey, T. and Transfeldt, E. Supervised exercise, spinal manipulation, and home exercise for chronic low back pain: a randomized clinical trial. Spine. 2011. 11(7): 585-598.
21. Standaert, C., Friedly, J., Erwin, M., Lee, M., Rechtine, G., Henrikson, N. and Norvell, D. Comparative effectiveness of exercise, acupuncture, and spinal manipulation for low back pain. Spine. 2011. 36(21): 120-130.
22. Ferreira, M., Ferriera, P., Latimer, J., Herbert, R., Hodges, P., Jennings, M., Maher, C. and Refshauge, K. Comparison of general exercise, motor control exercise and spinal manipulative therapy for chronic low back pain: A randomized trial. Pain. 2007. 131:31-37.
23. Gale, P. Joint mobilization. In Hammer, W., editor: Functional Soft Tissue Examination and Treatment by Manual Methods. (3rd Edition). Jones and Bartlett Publishers, Inc. (2007). Chapter 11.
24. Coulter, I., Hurwitz, E., Adams, A., Genovese, B., Hays, R. and Shekelle, P. Patients using chiropractors in North America: Who are they, and why are they in chiropractic care. Spine. 2003. 27(3): 291-296.
25. Hertzman-Miller, R., Morgenstern, H., Hurwitz, E., Yu, F., Adams, A., Harber, P. and Kominski, G. Comparing the satisfaction of low back pain patients randomized to receive medical or chiropractic care: Results from the UCLA low back pain study. American Journal of Public Health. 2002. 92: 1628-1633.
26. Gemmell, H. and Hayes, B. Patient satisfaction with chiropractic physicians in an independent physicians association. Journal of Manipulative and Physiological Therapeutics. 2001. 24(9): 556-559.
27. Nyiendo, J., Haas, M. and Goodwin, P. Patient characteristics, practice activities, and one-month outcomes for chronic, recurrent low-back pain treated by chiropractors and family medicine physicians: A practice-based feasibility study. Journal of Manipulative and Physiological Therapeutics. 2000. 23: 239-245.
28. Miners, A. Chiropractic treatment and the enhancement of sport performance: a narrative literature review. Journal of the Canadian Chiropractic Association. 2010. 54(4):210-221.

29. Brolinson, P., McGinley, S. and Kerger, S. Osteopathic manipulative medicine and the athlete. Current Sports Medicine Reports. 2008. 7(1): 49-56.
30. Julian, C. et al. Sports chiropractic management at the World Ice Hockey Championships. Chiropractic and Osteopathy. 2010. 18(32): 1-9.
31. Nook, D. and Nook, B. A report of the 2009 World Games injury surveillance of individuals who voluntarily used the International Federation of Sports Chiropractic Delegation. Journal of Manipulative and Physiological Therapeutics. 2011. 34: 54-61.
32. Uchacz, G. 2010 Olympic winter games chiropractic: the making of history. Journal of the Canadian Chiropractic Association. 2010. 54(1): 14-16.
33. Stump, J. and Redwood, D. The use and role of sport chiropractors in the National Football League: A short report. Journal of Manipulative and Physiological Therapeutics. 2002. 25: E2.
34. Grindstaff, T., Hertel, J., Beazell, J., Magrum, E. and Ingersoll, C. Effects of lumbopelvic joint manipulation on quadriceps activation and strength in healthy individuals. Manual Therapy. 14: 415-420. 2009.
35. Hillermann, B., Gomes, A., Korporaal, C. and Jackson, D. A pilot study comparing the effects of spinal manipulative therapy with those of extra-spinal manipulative therapy on quadriceps muscle strength. Journal of Manipulative and Physiological Therapeutics. 29(2): 145-149. 2006.
36. Suter, E., McMorland, G., Herzog, W. and Bray, R. Conservative lower back treatment reduces inhibition in knee-extensor muscles: A randomized controlled trial. Journal of Manipulative and Physiological Therapeutics. 23(2): 76-80. 2000.
37. Suter, E., McMorland, G., Herzog, W. and Bray, R. Decrease in quadriceps inhibition after sacroiliac joint manipulation in patients with anterior knee pain. Journal of Manipulative and Physiological Therapeutics. 22(3): 149-153. 1999.
38. Pollard, H. and Ward, G. Strength change of quadriceps femoris following a single manipulation of the L3/4 vertebral motion segment: A preliminary investigation. Journal of the Neuromusculoskeletal System. 4(4): 137-144. 1996.
39. Fernández-Camero, J., Fernández-de-las-Peñas, C. & Cleland, J. Immediate hypoalgesic and motor effects after a single cervical spine manipulation in subjects with lateral epicondylalgia. Journal of Manipulative and Physiological Therapeutics. 31(9): 675-681. 2008.
40. Paungmali, A., Vicenzino, B. and Smith, M. Hypoalgesia induced by elbow manipulation in lateral epicondylalgia does not exhibit tolerance. Journal of Pain. 4(8): 448-454. 2003.
41. Abbott, J., Patla, C. and Jensen, R. The initial effects of an elbow manipulation with movement technique on grip strength in subjects with lateral epicondylalgia. Manual Therapy. 6(3): 163-169. 2001.
42. Giggey, K. and Tepe, R. A pilot study to determine the effects of a supine sacroiliac orthopedic blocking procedure on cervical spine extensor isometric strength. Journal of Chiropractic Medicine. 8: 56-61. 2009.
43. Metcalfe, S., Reese, H. and Sydenham, R. Effect of high-velocity low-amplitude manipulation on cervical spine muscle strength: A randomized clinical trial. Journal of Manul & Manipulative Therapy. 14(3): 152-158. 2006.

44. Keller, T. and Colloca, C. Mechanical force spinal manipulation increases trunk muscle strength assessed by electromyography: A comparative clinical trial. Journal of Manipulative and Physiological Therapeutics. 23(9): 585-595. 2000.
45. Bonci A, Ratliff R, Adams E, Mirtz T. Strength modulation of the spinal erector muscles immediately following manipulation of the thoracolumbar spine. Journal of Chiropractic Research and Clinical Investigation. 6(2): 29-33. 1990.
46. Suter, E. and McMorland, G. Decrease in elbow flexor inhibition after cervical spine manipulation in patients with chronic neck pain. Clinical Biomechanics. 2002. 17:541-544.
47. Bonci, A. and Ratliff, C. Strength modulation of the biceps brachii muscles immediately following a single manipulation of the C4/5 intervertebral motor unit in healthy subjects; Preliminary report. American Journal of Chiropractic Medicine. 3(1): 14-18. 1990.
48. Wang, S. and Meadows, J. Immediate and carryover changes of C5/6 joint mobilization on shoulder external rotator muscle strength. Journal of Manipulative and Physiological Therapeutics. 33(2): 102-108. 2010.
49. Cleland, J., Selleck, B., Stowell, T., Browne, L., Alberini, S., St. Cyr, H. and Caron, T. Short-term effects of thoracic manipulation on lower trapezius muscle strength. Journal of Manual & Manipulative Therapy. 12(2): 82-90. 2004.
50. Yerys, S., Makofsky, H., Byrd, C., Pennachio, J. and Cinkay, J. Effect of mobilization of the anterior hip capsule on gluteus maximus strength. Journal of Manual Therapy. 10(4): 218-224. 2002.
51. Panton, L., Figueroa, A., Kingsley, J., Hornsbuckle, L., Wilson, J., St. John, N., Abood, D., Mathis, R., VanTassel, J and McMillan, V. Effects of resistance training and chiropractic treatment in women with fibromyalgia. Journal of Alternative and Complementary Medicine. 2009. 15(3): 321-328.
52. Morningstar, M. Strength gains through lumbar lordosis restoration. Journal of Chiropractic Medicine. 4(2): 137-141. 2003.
53. Nogueira de Almeida, B., Sabatino, J. and Giraldo, P. Effects of high-velocity, low-amplitude spinal manipulation on strength and the basal tonus of female pelvic floor muscles. Journal of Manipulative and Physiological Therapeutics. 33(2): 109-116. 2010.
54. Chilibeck, P., Cornish, S., Schulte, A., Jantz, N., Magnus, C., Schwanbeck S. and Juurlink, B. The effect of spinal manipulation on imbalances in leg strength. Journal of the Canadian Chiropractic Association. 55(3): 183-192. 2011.
55. Botelho M, Andrade B. Effect of cervical spine manipulative therapy on judo athletes' grip strength. Journal of Manipulative and Physiological Therapeutics 2012;35(1):38-44.
56. MacIntosh, B., Gardiner, P. and McComas, A. Skeletal muscle: Form and function. 2nd ed. Human Kinetics. 2006.
57. Sale, D. Neural adaptation to strength training. In: Strength and Power in Sport. Ed: P.V. Komi. 1992. 1st ed. Blackwell Scientific Publications, Oxford. Pp. 249-65.
58. Binboga, E., Tok, S., Catikkas, F., Guven, S. and Dane, S. The effects of verbal encouragement and conscientiousness on maximal voluntary contraction of the triceps surae muscle in elite athletes. Journal of Sports Sciences. 2013. 31(9): 982-88.
59. Robbins, D. Postactivation potentiation and its practical applicability: a brief review. Journal of Strength and Conditioning Research. 2005. 19(2): 453-458.

60. Hodgson, M., Docherty, D. and Robbins, D. Post-activation potentiation – underlying physiology and implications for motor performance. Sports Medicine. 2005. 35(7):585-595.
61. Hamada T, Sale D, MacDougall J, Tarnopolsky M. Postactivation potentiation, fiber type, and twitch contraction time in human knee extensor muscles. Journal of Applied Physiology. 2000. 88(6):2131-7.
62. Chiu, L., Fry, A., Weiss, L., et al. Postactivation potentiation response in athletic and recreationally trained individuals. Journal of Strength and Conditioning Research. 2003. 17(4): 671-677.
63. Lorenz, D. Postactivation potentiation: An introduction. The International Journal of Sports Physical Therapy. 2011. 6(3): 234-240.
64. Gossen, E. and Sale, D. Effect of postactivation potentiation on dynamic knee extension performance. European Journal of Applied Physiology. 2000. 83(6): 524-30.
65. Palmieri, R., Ingersoll, C. and Hoffman, M. The Hoffmann Reflex: Methodologic considerations and applications for use in sports medicine and athletic training research. Journal of Athletic Training. 2004. 39(3): 268-277.
66. Knikou, M. The H-Reflex as a probe: Pathways and pitfalls. Journal of Neuroscience Methods. 2008. 171: 1-12.
67. McNeil, C., Butler, J., Taylor, J. and Gandevia, S. Testing the excitability of human motoneurons. Frontiers in Human Neuroscience. 2013. 7(152): 1-9.
68. Lehman, G. Kinesiological research: The use of surface electromyography for assessing the effects of spinal manipulation. J Electromyogr Kinesiol. 2012 Oct;22(5):692-6.
69. Shrier, I., MacDonald, D. and Uchacz, G. A pilot study on the effects of pre-event manipulation on jump height and running velocity. British Journal of Sports Medicine. 2006. 40(11):947-9.
70. Perle, S. Sports Chiropractic. Redwood, D. and Cleveland III, C. editors, in: Fundamentals of Chiropractic. 2003. Chapter 19. Mosby. ISBN: 0-323-01812-2.
71. Fernandez-de-Las-Penas C, Alonso-Blanco C, Cleland JA, Rodriguez-Blanco C, Alburquerque-Sendin F. Changes in pressure pain thresholds over C5–C6 zygapophyseal joint after a cervicothoracic junction manipulation in healthy subjects. J Manipulative Physiol Ther 2008. 31(5): 332–7.
72. Mansilla-Ferragut P, Fernandez-de-Las Penas C, Alburquerque-Sendin F, Cleland JA, Bosca-Gandia JJ. Immediate effects of atlanto-occipital joint manipulation on active mouth opening and pressure pain sensitivity in women with mechanical neck pain. J Manipulative Physiol Ther 2009. 32(2): 101–6.
73. Vernon HT, Aker P, Burns S, Viljakaanen S, Short L. Pressure pain threshold evaluation of the effect of spinal manipulation in the treatment of chronic neck pain: a pilot study. J Manipulative Physiol Ther 1990;13(1):13–6.
74. Mohammadian P, Gonsalves A, Tsai C, Hummel T, Carpenter T. Areas of capsaicin induced secondary hyperalgesia and allodynia are reduced by a single chiropractic adjustment: a preliminary study. Journal of Manipulative and Physiological Therapeutics. 2004. 27(6): 381–7.
75. Seaman, D. and Faye, J. The vertebral subluxation complex. in Gatterman, ed: Foundations of Chiropractic: Subluxation. (2nd Edition). 2005. Elsevier Mosby. ISBN: 0-323-02648-6. Chapter 9.

76. Sole G, Hamrén J, Milosavljevic S, Nicholson H, Sullivan S. Test-retest reliability of isokinetic knee extension and flexion. Archives of Physical Medicine and Rehabilitation. 2007;88:626-31.
77. United States Olympic Committee. Sports Medicine. 2015. Source: http://www.teamusa.org/For-Athletes/Medical-Services/Clinics-and-Staff.
78. Wilson, J., Duncan, N., Marin, P., Brown, L., Loenneke, J., Wilson, S., Jo, E., Lowery, R. and Ugrinowitsch, C. Meta-analysis of postactivation potentiation and power: effects of conditioning activity, volume, gender, rest periods, and training status. Journal of Strength and Conditioning Research. 2013. 27(3): 854-59.
79. Floman, Y., Liram, N. and Gilai, A. Spinal manipulation results in immediate H-reflex changes in patients with unilateral disc herniation. European Spine Journal. 1997. 6:398-401.
80. Dishman, J. and Bulbulian, R. Spinal reflex attenuation is associated with spinal manipulation. Spine. 2000. 25: 2519-24.
81. Dishman, J., Ball, K. and Burke, J. Central motor excitability changes after spinal manipulation, a transcranial magnetic stimulation study. Journal of Manipulative and Physiological Therapeutics. 2002. 25(1): 1-9.
82. Dishman, J. and Bulbulian, R. Comparison of effects of spinal manipulation and massage on motoneuron excitability. Electromyogr Clin Neurophysiol. 2001. 41(2): 97-106.
83. Dishman, J. and Burke, J. Spinal reflex excitability changes after cervical and lumbar spinal manipulation: a comparative study. Spine Journal. 2003. 3(3): 204-12.
84. Suter, E., McMorland, G. and Herzog, W. Short-term effects of spinal manipulation on H-reflex amplitude in healthy and symptomatic subjects. J Manipulative Physiol Ther. 2005. 28(9): 667-72.
85. Dishman, J., Dougherty, P. and Burke, J. Evaluation of the effect of postural perturbation on motoneuronal activity following various methods of lumbar spinal manipulation. The Spine J. 2005. 5(6): 650-9.
86. Fryer, G. and Pearce, A. The effect of lumbosacral manipulation on corticospinal and spinal reflex excitability on asymptomatic participants. J Manipulative Physiol Ther. 2012. 35(2): 86-93.
87. Dishman, J., Weber, K., Corbin, R. and Burke, J. Understanding inhibitory mechanisms of lumbar spinal manipulation using H-reflex and F-wave responses: A methodological approach. Journal of Neuroscience Methods. 2012. 210(2):169-77.
88. Murphy, B., Dawson, N. and Slack, J. Sacroiliac joint manipulation decreases the H-reflex. Electromyography and Clinical Neurophysiology. 1995. 35: 87-94.
89. Folland, J., Wakamatsu, T. and Fimland, M. The influence of maximal isometric activity on twitch and H-reflex potentiation, and quadriceps femoris performance. European Journal of Applied Physiology. 2008. 104: 739-48.
90. Güllich, A. and Schmidtbleicher, D. MVC-induced short-term potentiation of explosive force. New Studies in Athletics. 1996. 11: 67-81.
91. Peterson D, Bergmann T. Chiropractic technique: principles and procedures. 2nd ed. St. Louis: Mosby; 2002. Chapter 3, Joint assessment principles and procedures; p. 39-95.
92. Triano, J. Interaction of spinal biomechanics and physiology. In: Haldeman, S., Editor. Principles and practice of chiropractic. 3rd edition. Chapter 19. The McGraw-Hill Companies, Inc. 2005.

93. Hestbaek, L. and Leboeuf-Yde, C. Are chiropractic tests for the lumbo-pelvic spine reliable and valid? A systematic and critical literature review. Journal of Manipulative and Physiological Therapeutics. 23(4): 258-75. 2000.
94. Haas, M. and Panzer, D. Palpatory diagnosis of subluxation. in Gatterman, ed: Foundations of Chiropractic: Subluxation. (2nd Edition). 2005. 104-14. Elsevier Mosby. ISBN: 0-323-02648-6.
95. Murphy, D and Morris, C. Manual examination of the patient. In: Haldeman, S. Principles and Practice of Chiropractic. 3rd edition. The McGraw-Hill Companies, Inc. 2005. 593-610.
96. Morris C, Greenman P, Bullock M, Basmajian J and Kobesova A. Tribute to a master of rehabilitation. Spine. 2006. 31:1060–4.
97. Palmer, D. Text-book of the science, art and philosophy of chiropractic. Portland, Oregon: Portland Printing House Company; 1910.
98. Cleveland III, C. Neurobiologic relations and chiropractic applications. Chapter 8. In: Redwood, D. and Cleveland III, C. Fundamentals of Chiropractic. 2003. Mosby. ISBN: 0-323-01812-2.
99. Bove, G. Peripheral nerve biology and concepts of nerve pathophysiology. In: Haldeman, S. Principles and Practice of Chiropractic. 3rd edition. The McGraw-Hill Companies, Inc. 2005. 289-99.
100. Panjabi M, Takata K, Goel V. Kinematics of the lumbar intervertebral foramen. Spine. 1983. 8(4):348-57.
101. Kitago T, Mazzocchio R, Liuzzi G, Cohen L. Modulation of H-reflex excitability by tetanic stimulation. Clin Neurophysiol 2004. 115(4):858-61.
102. DeStefano, L. Chapter 6. Concepts of vertebral motion dysfunction. Greenman's Principles of Manual Medicine. 4th Ed. 2010. Lippincott Williams and Wilkins.
103. Coronado, R., Gay, C., Bialosky, J., Carnaby, G., Bishop, M. and George, S. Changes in pain sensitivity following spinal manipulation: A systematic review and meta-analysis. Journal of Electromyography and Kinesiology. 2012. 22: 752-67.
104. Korr, I. Somatic dysfunction, osteopathic manipulative treatment, and the nervous system: A few facts, some theories, many questions. J Am Osteopath Assoc. 1986. 86:109-14.
105. Korr, I. The spinal cord as organizer of disease processes IV. Axonal transport and neurotrophic function in relation to somatic dysfunction. Journal of the American Osteopathic Association. 80:451. 1981.
106. Seaman, D. A physiological explanation of subluxation and its treatment. California Chiropractic Association Journal. 21(3):32. 1996.
107. Mennel, J. Joint Pain. Little Brown and Company, 1983.
108. Seaman, D. and Winterstein, J. Dysafferentation: a novel term to describe the neuropathophysiological effects of joint complex dysfunction. A look at likely mechanisms to symptom generation. Journal of Manipulative and Physiological Therapeutics. 1998. 21(4):267.
109. Lantz, C. The vertebral subluxation complex. ICA Review. 1989. (Sep/Oct):37-61.
110. Rassier, D. and Herzog, W. Force enhancement following an active stretch in skeletal muscle. Journal of Electromyography and Kinesiology. 2002. 12(6): 471-77.
111. Herzog, W. The biomechanics of spinal manipulation. Journal of Bodywork and Movement Therapies. 2010. 14(3):280-86. Review.

112. Haavik-Taylor, H. and Murphy, B. The effects of spinal manipulation on central integration of dual somatosensory input observed following motor training: A crossover study. Journal of Manipulative and Physiological Therapeutics. 2010. 33: 261-272.
113. Haavik-Taylor, H. and Murphy, B. Altered somatosensory integration with cervical spine manipulation. Journal of Manipulative and Physiological Therapeutics. 2008. 31(2): 115-126.
114. Haavik-Taylor, H. and Murphy, B. Cervical spine manipulation alters sensorimotor integration: A somatosensory evoked potential study. Clinical Neurophysiology. 2007. 118(2): 391-402.
115. Haavik-Taylor, H. and Murphy, B. Altered central integration of dual somatosensory input after cervical spine manipulation. Journal of Manipulative and Physiological Therapeutics. 2010. 33(3): 178-188.
116. Haavik-Taylor, H. and Murphy, B. Transient modulation of intracortical inhibition following spinal manipulation. Chiropractic Journal of Australia. 2007. 37: 106-116.
117. Dishman, J., Ball, K. and Burke, J. Central motor excitability changes after spinal manipulation: A transcranial magnetic stimulation study. Journal of Manipulative and Physiological Therapeutics. 2002. 25(1): 1-9.
118. Dishman, J., Greco, D. and Burke, J. Motor-evoked potentials recorded from lumbar erector spinae muscles: A study of corticospinal excitability changes associated with spinal manipulation. Journal of Manipulative and Physiological Therapeutics. 2008. 31(4): 258-270.
119. Pickar, J. & Bolton, P. Spinal manipulative therapy and somatosensory activation. Journal of Electromyography and Kinesiology. 2012. 22: 785-794.
120. Pickar, J. Neurophysiological effects of spinal manipulation. The Spine Journal. 2002. 357-371.
121. Korr, I. and Goldstein, M. Abstract: Dermatomal autonomic activity in relation to segmental motor reflex threshold. In Korr, I., editor: The collected papers of Irvin M. Korr, Colorado Springs, Colorado. 1979. American Academy of Osteopathy.
122. Korr, I. The concept of facilitation and its origins. In Korr, I., editor: The collected papers of Irvin M. Korr, Colorado Springs, Colorado. 1979. American Academy of Osteopathy.
123. Korr, I., Wright, H., and Thomas, P. Effects of experimental myofascial insults on cutaneous patterns of sympathetic activity in man. In Korr, I., editor: The collected papers of Irvin M. Korr, Colorado Springs, Colorado. 1979. American Academy of Osteopathy.
124. Korr, I. Sustained sympathicotonia as a factor in disease. In Korr, I., editor: The collected papers of Irvin M. Korr, Colorado Springs, Colorado. 1979. American Academy of Osteopathy.
125. Travell, J., Rinzler, S and Herman, M. Pain and disability of the shoulder and arm. Treatment by intramuscular infiltration with procaine hydrochloride. Journal of the American Medical Association. 1942. 120:417-422.
126. Bogduk, N. and Aprill, C. The sources of back pain. In Liebenson, C., editor: Rehabilitation of the spine: A practitioner's manual. 2nd edition. Lippincott Williams & Wilkins. 2007. 112-121.

127. Seaman, D. Joint complex dysfunction, a novel term to replace subluxaton/subluxation complex: etiological and treatment considerations. Journal of Manipulative and Physiological Therapeutics. 1997. 20:634.
128. Haavik, H. & Murphy, B. The role of spinal manipulation in addressing disordered sensorimotor integration and altered motor control. Journal of Electromyography and Kinesiology. 2012. 22: 768-776.
129. Shekelle, P., Adams, A., Chassin, M., Hurwitz, E., Phillips, R. and Brook, R. The appropriateness for spinal manipulation for low-back pain: project overview and literature review. Santa Monica, CA: RAND Corporation. 1991. RAND document no R4025/1-CCR/FCER.
130. Bialosky, J., Bishop, M., Robinson, M., Zeppieri, G and George, S. Spinal manipulative therapy has an immediate effect on thermal pain sensitivity in people with low back pain: a comprehensive model. Manual Therapy. 2009. 14:531-538.
131. Henderson, C. Three neurophysiologic theories on the chiropractic subluxation. In: Gatterman, M. editor, Foundations of chiropractic: subluxation. St. Louis: Elsevier Mosby. 2005. 296-303. Chapter 13.
132. Andersen E. Periaqueductal gray and cerebral cortex modulate responses of medial thalamic neurons to noxious stimulation. Brain Research. 1986. 375: 30-36.
133. Melzack, R. and Wall, P. Pain mechanisms: A new theory. Science. 1965. 150:971-979.
134. Bove, G. and Swenson, R. Nociceptors, pain and chiropractic. Chapter 9. Redwood, D. and Cleveland III, C. editors, in: Fundamentals of Chiropractic. 2003. Mosby. ISBN: 0-323-01812-2.
135. Haavik-Taylor, H. and Murphy, B. Altered sensorimotor integration with cervical spine manipulation. Journal of Manipulative and Physiological Therapeutics. 2008. 31(2): 115-26.
136. Haavik Taylor, H., Holt, K. & Murphy, B. Exploring the neuromodulatory effects of vertebral subluxation and chiropractic care. Chiropractic Journal of Australia. 2010. 40: 37-44.
137. Gillette, R. A speculative argument for the coactivation of diverse somatic receptor populations by forceful chiropractic adjustments. Manual Medicine. 1987. 3: 1-14.
138. Potter, L., McCarthy, C. & Oldham, J. Physiological effects of spinal manipulation: A review of proposed theories. Physical Therapy Reviews. 2005. 10: 163-170.
139. Trontelj, J., Pecak, F. and Dimitrijevic, M. Segmental neurophysiological mechanisms in scoliosis. Journal of Bone and Joint Surgery – British Volume. 1979. 61:310-313.
140. Matre, D., Sinkjaer, T., Svensson, P. and Arendt-Nielsen, L. Experimental muscle pain increases the human stretch reflex. Pain. 1998. 75: 331-339.
141. Bishop MD, Beneciuk JM, George SZ. Immediate reduction in temporal sensory summation after thoracic spinal manipulation. The Spine Journal. 2011.
142. Fernandez-Carnero J, Fernandez-de-las-Penas C, Cleland JA. Immediate hypoalgesic and motor effects after a single cervical spine manipulation in subjects with lateral epicondylalgia. Journal of Manipulative and Physiological Therapeutics. 2008. 31(9):675–81.

143. George S, Bishop M, Bialosky J, Zeppieri Jr G, Robinson M. Immediate effects of spinal manipulation on thermal pain sensitivity: an experimental study. BMC Musculoskelet Disord 2006; 7:68.
144. Bialosky JE, Bishop MD, Robinson ME, Zeppieri Jr G, George SZ. Spinal manipulative therapy has an immediate effect on thermal pain sensitivity in people with low back pain: a randomized controlled trial. Physical Therapy. 2009b;89(12):1292–303.
145. Thomson O, Haig L, Mansfield H. The effects of high-velocity low-amplitude thrust manipulation and mobilisation techniques on pressure pain threshold in the lumbar spine. Int J Osteopath Med 2009;12(2):56–62.
146. Shearar KA, Colloca CJ, White HL. A randomized clinical trial of manual versus mechanical force manipulation in the treatment of sacroiliac joint syndrome. Journal of Manipulative and Physiological Therapeutics. 2005. 28(7): 493–501.
147. Ruiz-Saez M, Fernandez-de-las-Penas C, Blanco CR, Martinez-Segura R, Garcia-Leon R. Changes in pressure pain sensitivity in latent myofascial trigger points in the upper trapezius muscle after a cervical spine manipulation in pain-free subjects. J Manipulative Physiol. Ther. 2007;30(8):578–83.
148. Oliveira-Campelo NM, Rubens-Rebelatto J, Marti NVFJ, Alburquerque-Sendi NF, Fernandez-de-Las-Penas C. The immediate effects of atlanto-occipital joint manipulation and suboccipital muscle inhibition technique on active mouth opening and pressure pain sensitivity over latent myofascial trigger points in the masticatory muscles. J Orthop Sports Phys Ther 2010;40(5):310–7.
149. Maduro de Camargo V, Alburquerque-Sendin F, Berzin F, Stefanelli VC, De Souza DP, Fernandez-de-Las Penas C. Immediate effects on electromyographic activity and pressure pain thresholds after a cervical manipulation in mechanical neck pain: a randomized controlled trial. J Manipulative Physiol Ther 2011.
150. Hamilton L, Boswell C, Fryer G. The effects of high-velocity, low-amplitude manipulation and muscle energy technique on suboccipital tenderness. Int J Osteopath Med 2007;10(2–3):42–9.
151. Orakifar, N., Kamali, F., Pirouzi, S. and Jamshidi. F. Sacroiliac joint manipulation attenuates alpha-motoneuron activity in healthy women: a quasi-experimental study. Archives of Physical Medicine and Rehabilitation. 2012. 93(1):56-61.
152. Fryer G, Carub J, McIver S. The effect of manipulation and mobilisation on pressure pain thresholds in the thoracic spine. J Osteopath Med 2004;7(1):8–14.
153. Fernandez-de-las-Penas C, Perez-de-Heredia M, Brea-Rivero M, Miangolarra-Page JC. Immediate effects on pressure pain threshold following a single cervical spine manipulation in healthy subjects. J Orthop Sports Phys Ther 2007. 37(6): 325–9.
154. Terrett ACJ, Vernon H. Manipulation and pain tolerance: a controlled study of the effect of spinal manipulation on paraspinal cutaneous pain tolerance levels. Am J Phys Med 1984;63(5):217–25.
155. Vincenzino, B., Collins, D. and Wright, A. An investigation of the interrelationship between manipulative therapy-induced hypoalgesia and sympathoexcitation. Journal of Manipulative and Physiological Therapeutics. 1998. 21: 448-453.
156. Savva, C., Giakas, G. and Efstathiou. The role of the descending inhibitory pain mechanism in musculoskeletal pain following high-velocity, low amplitude thrust manipulation. A review of the literature. Journal of Back and Musculoskeletal Rehabilitation. 2014. 27: 377–382.

157. Korr, I. Proprioceptors and somatic dysfunction. Journal of the American Osteopathic Association. 1975. 74: 638-650.
158. Cramer, G., Tuck, N., Knudsen, J. and Fonda, S. Effects of side posture positioning and side posture adjusting on the lumbar zygapophyseal joints as evaluated by magnetic resonance imaging: A before and after study with randomization. Journal of Manipulative and Physiological Therapeutics. 2000. 23:380-394.
159. Cramer, G., Ross, K., Raju, P., Cambron, J., Cantu, J., Bora, P., Dexheimer, J., McKinnis, R., Habeck, A., Selby, S., Pocius, J. and Gregerson, D. Quantification of cavitation and gapping of lumbar zygapophyseal joints during spinal manipulative therapy. Journal of Manipulative and Physiological Therapeutics. 2012. 35:614-621.
160. Cramer, G., Cambron, J., Cantu, J., Dexheimer, J., Pocius, J., Gregerson, D., Fergus, M., McKinnis, R. and Grieve, T. Magnetic resonance imaging zygapophyseal joing spaces (gapping) in low back pain patients following spinal manipulation and side-posture positioning: A randomized controlled mechanisms trial with blinding. Journal of Manipulative and Physiological Therapeutics. 2013. 36(4):203-217.
161. Cramer, G., Gregerson, D., Knudsen, J., Hubbard, B Ustas, L. and Cantu, J. The effects of side-posture positioning and spinal adjusting on the lumbar Z joints: A randomized controlled trial with sixty-four subjects. Spine. 2002. 27: 2459-66.
162. Cramer, G., Gregerson, D., Knudsen, J., Hubbard, B. Ustas, L. and Cantu, J. The effects of side-posture positioning and spinal adjusting on the lumbar z joints. Spine. 2002. 22: 2459-2466.
163. Cramer, G., Ross, K., Pocius, J., Cantu, J., Laptook, E., Fergus, M., Gregerson, D., Selby, S. and Raju, P. Evaluating the relationship among cavitation, zygapophyseal joint gapping, and spinal manipulation: an exploratory case series. Journal of Manipulative and Physiological Therapeutics. 2011. 34(1): 2-14.
164. Lehman, G. and McGill, S. The influence of a chiropractic manipulation on lumbar kinematics and electromyography during simple and complex tasks: a case study. Journal of Manipulative and Physiological Therapeutics. 1999. 22:576-581.
165. Cao, D., Reed, W., Long, C., Kawchuk, G. and Pickar, J. Effects of thrust amplitude and duration of high-velocity, low-amplitude spinal manipulation on lumbar muscle spindle responses to vertebral position and movement. Journal of Manipulative and Physiological Therapeutics. 2013. 36: 68-77.
166. Tinazzi, M., Priori, A., Bertolasi, L., Frasson, E., Mauguiere, F. and Fiaschi, A. Abnormal central integration of a dual somatosensory input in dystonia. Evidence for sensory overflow. Brain. 2000. 123(Part 1): 42-50.
167. Haavik-Taylor, H. and Murphy, B. Cervical spine manipulation alters sensorimotor integration: A somatosensory evoked potential study. Clinical Neurophysiology. 2007. 118(2): 391-402.
168. Haavik-Taylor, H. and Murphy, B. Transient modulation of intracortical inhibition following spinal manipulation. Chiropractic Journal of Australia. 2007. 37: 106-116.
169. Whaley, Mitchell H., Peter H. Brubaker, Robert M. Otto, and Lawrence E. Armstrong. ACSM's Guidelines for Exercise Testing and Prescription. 8th ed. Philadelphia, PA: Lippincott Williams & Wilkins. 2010.
170. Marshall P, Murphy B. The effect of sacroiliac joint manipulation on feed-forward activation times of the deep abdominal musculature. J Manipulative Physiol Ther. 2006. 29(3): 196–202.

171. Marshall P, Murphy B. Delayed abdominal muscle onsets and self-report measures of pain and disability in chronic low back pain. J Electromyogr Kinesiol. 2010. 20(5): 833–839.
172. Leinonen V, Kankaanpää M, Luukkonen M, Kansanen M, Hänninen O, Airaksinen O, Taimela S. Lumbar paraspinal muscle function, perception of lumbar position, and postural control in disc herniation-related back pain. Spine. 2003. 28(8): 842-8.
173. Marshall P, Murphy B. Muscle activation changes after exercise rehabilitation for chronic low back pain. Arch Phys Med Rehabil. 2008. 89(7): 1305–1313.
174. Grindstaff, T., Hertel, J., Beazell, J., Magrum, E., Kerrigan, D. and Ingersoll, C. Lumbopelvic joint manipulation and quadriceps activation of people with patellofemoral pain syndrome. Journal of Athletic Training. 2012. 47(1): 24-31.
175. Indahl, A., Kaigle, A., Reikeras, O. and Holm, S. Interaction between the porcine lumbar intervertebral disc, zygapophyseal joints, and paraspinal muscles. Spine. 1997. 22:2834-40.
176. Colloca, C., Keller, T. and Gunzberg, R. Neuromechanical characterization of in vivo lumbar spinal manipulation. Part II. Neurophsiological response. Journal of Manipulative and Physiological Therapeutics. 2003. 26: 579-91.
177. Herzog, W., Scheele, D. and Conway, P. Electromyographic responses of back and limb muscles associated with spinal manipulative therapy. Spine. 1999. 15; 24(2):146-52.
178. Dunning, J. and Rushton, A. The effects of cervical high-velocity low-amplitude thrust manipulation on resting electromyographic activity of the biceps brachii muscle. Manual Therapy. 2009. 14(5): 508-13.
179. DeVocht, J., Pickar, J. and Wilder, D. Spinal manipulation alters electromyographic activity of paraspinal muscles: a descriptive study. Journal of Manipulative and Physiological Therapeutics. 2005. 28(7): 465-71.
180. Ritvanen, T., Zaproudina, N., Nissen, M., Leinonen, V and Hänninen, O. Dynamic surface electromyographic responses in chronic low back pain treated by traditional bone setting and conventional physical therapy. Journal of Manipulative and Physiological Therapeutics. 2007. 30(1): 31-7.
181. Colloca, C.J., Keller, T.S., 2001. Electromyographic reflex responses to mechanical force, manually assisted spinal manipulative therapy. Spine. 2001. 26(10): 1117-24.
182. Harvey MP, Descarreaux M. Short term modulation of trunk neuromuscular responses following spinal manipulation: a control group study. BMC Musculoskeletal Disorders. 2013. 13;14:92.
183. Clark, B., Goss, D., Walkowski, S., Hoffman, R., Ross, A. and Thomas, J. Neurophysiologic effects of spinal manipulation in patients with chronic low back pain. BMC Musculoskeletal Disorders. 2011. 12:170.
184. Daligadu, J., Haavik, H., Yielder, P., Baarbe, J. and Murphy, J. Alterations in cortical and cerebellar motor processing in subclinical neck pain patients following spinal manipulation. Journal of Manipulative and Physiological Therapeutics. 2013. 36(8):527-37.
185. Zhu, Y., Haldeman, S., Hsieh, C., Wu, P. and Starr, A. Do cerebral potentials to magnetic stimulation of paraspinal muscles reflect changes in palpable muscle spasm, low back pain, and activity scores? Journal of Manipulative and Physiological Therapeutics. 2000. 23(7): 458-64.

186. Zhu Y, Haldeman S, Starr A, Seffinger M, Su S. Paraspinal muscle evoked cerebral potentials in patients with unilateral low back pain. Spine. 1993 18:1092-102.
187. Konrad. The ABC of EMG – A practical introduction to kinesiological electromyography. Version 1.0. 2005. Noraxon, Inc. USA.
188. Clark, B., Goss, D., Walkowski, S., Hoffman, R., Ross, A. and Thomas, J. Neurophysiologic effects of spinal manipulation in patients with chronic low back pain. BMC Musculoskeletal Disorders. 2011. 22;12:170.
189. Fryer, G. and Pearce, A. The effect of lumbosacral manipulation on corticospinal and spinal reflex excitability on asymptomatic participants. J Manipulative Physiol Ther. 2012. 35(2): 86-93.
190. Morita, H., Petersen, N., Christensen, L., Sinkjaer, T. and Nielsen, J. Sensitivity of H-reflexes and stretch reflexes to presynaptic inhibition in humans. Journal of Neurophysiology. 1998. 80(2): 610-20.
191. Rudomin, P. Presynaptic inhibition of muscle spindle and tendon organ afferents in the mammalian spinal cord. Trends in Neuroscience. 1990. 13(12): 499-505.
192. Kabashima N, Shibuya I, Ibrahim N, Ueta Y, Yamashita H. Inhibition of spontaneous EPSCs and IPSCs by presynaptic GABAB receptors on rat supraoptic magnocellular neurons. J Physiol. 1997. 504:113-26.
193. Pickar, J. and Wheeler, J. Response of muscle proprioceptors to spinal manipulative-like loads in the anesthetized cat. Journal of Manipulative and Physiological Therapeutics. 2001. 24(1): 2-11.
194. Pickar, J. and Kang, Y. Paraspinal muscle spindle responses to the duration of a spinal manipulation under force conrol. Journal of Manipulative and Physiological Therapeutics. 2006. 29: 22-31.
195. Pickar, J., Sung, P., Kang, Y. and Ge, W. Response of lumbar paraspinal muscle spindles is greater to spinal manipulative loading compared with slower loading under length control. Spine J. 2007. 7: 583-95.
196. Tillin, N. and Bishop, D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. Sports Medicine. 2009. 39(2):147-166.
197. Lowery, R. et al. The effects of potentiation stimuli intensity under varying rest periods on vertical jump performance and power. Journal of Strength and Conditioning Research. 2012. 26(12): 3320-3325.
198. French, D.N., Kraemer, W.J., & Cooke, C.B. Changes in dynamic exercise performance following a sequence of preconditioning isometric muscle actions. Journal of Strength and Conditioning Research. 2003. 17(4): 678-685.
199. Hilfiker, R., Hübner, K., Lorenz, T. and Marti, B. Effects of drop jumps added to the warm-up of elite sport athletes with a high capacity for explosive force development. Journal of Strength and Conditioning Research. 2007. 21(2): 550-5.
200. Rixon, K., Lamont, H. and Bemben, M. Influence of type of muscle contraction, gender, and lifting experience on postactivation potentiation performance. Journal of Strength and Conditioning research. 2007. 21(2): 500-5.
201. Jones, P. and Lees, A. A biomechanical analysis of the acute effects of complex training using lower limb exercises. Journal of Strength and Conditioning Research. 2003. 17(4): 694-700.

202. Scott, S. and Docherty, D. Acute effects of heavy pre-loading on vertical and horizontal jump performance. Journal of Strength and Conditioning Research. 2004. 18(2): 201-5.
203. Cabrera, C., Morales, J., Greer, F. and Pettitt, R. Exercise bouts at three different intensities fail to potentiate concentric power. International Journal of Exercise Science. 2009. 2(1): 38-47.
204. Duthie, G., Young, W. and Aitken, D. The acute effects of heavy loads on jump squat performance: An evaluation of the complex and contrast methods of power development. Journal of Strength and Conditioning Research. 2002. 16: 530-38.
205. Hrysomallis, C. and Kidgell, D. Effect of heavy dynamic resistance exercise on acute upper body power. Journal of Strength and Conditioning Research. 2001. 15(4): 426-30.
206. Jensen RL, Ebben WP. Kinetic analysis of complex training rest interval effect on vertical jump performance. Journal of Strength and Conditioning Research. 2003. 17(2): 345-9.
207. Robbins, D and Docherty, D. Effects of loading on enhancement of power performance over three consecutive trials. Journal of Strength and Conditioning Research. 2005. 19: 898-902.
208. Gouvea, A., Fernandes, I., Cesar, E., Silva, W. and Gomes, P. The effects of rest intervals on jumping performance: A meta-analysis on post-activation potentiation studies. Journal of Sports Sciences. 2013. 9;31(5): 459-67.
209. Patikas, D., Bassa, H. and Kotzamanidis, C. Changes in the reflex excitability during and after a sustained, low-intensity muscle contraction. Int J Sports Med. 2006. 27(2):124-30.
210. Enoka, R., Hutton, R. and Eldred, E. Changes in excitability of tendon tap and Hoffmann reflexes following voluntary contractions. Electroencephalography and Clinical Neurophysiology. 1980. 48: 664-672.
211. Trimble, M. and Harp, S. Postexercise potentiation of the H-reflex in humans. Medicine and Science in Sports and Exercise. 1998. 30(6): 933-41.
212. Hultborn, H. and Nielsen, J. Comments: methodological problems of comparing F responses and H reflexes. Muscle and Nerve. 1996. 19(10): 1347-8.
213. Crone C, Nielsen J. Methodological implications of the post activation depression of the soleus H-reflex in man. Experimental Brain Research. 1989. 78(1): 28-32.
214. Floeter, M. and Kohn, A. H-reflexes of different sizes exhibit differential sensitivity to low frequency depression. Electroencephalography and Clinical Neurophysiology. 1997. 105: 470-5.
215. Misiaszek, J. The H-reflex as a tool in neurophysiology: its limitations and uses in understanding nervous system function. Muscle and Nerve. 2003. 28(2): 144-60.
216. Zehr, P. Considerations for the use of the Hoffmann reflex in exercise studies. European Journal of Applied Physiology. 2002. 86(6): 455-68.
217. Sale, D. Postactivation potentiation: role in human performance. Exercise and Sport Sciences Reviews. 2002. 30(3): 138-43.
218. Mitchell CJ, Sale DG (2011) Enhancement of jump performance after a 5-RM squat is associated with postactivation potentiation. European Journal Of Applied Physiology 111: 1957-63.

219. Fletcher, I. An investigation into the effect of a pre-performance strategy on jump performance. Journal of Strength and Conditioning Research. 2013. 27(1): 107-15.
220. Knapik, J., Wright, J., Mawdsley, R. and Braun, J. Isometric, isotonic, and isokinetic torque variations in four muscle groups through a range of joint motion. Phys Ther.1983 Jun;63(6):938-47.
221. Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior Research Methods,39, 175-191.
222. Drouin JM, Valovich-mcLeod TC, Shultz SJ, Gansneder BM, Perrin DH. Reliability and validity of the Biodex system 3 pro isokinetic dynamometer velocity, torque and position measurements. Eur J Appl Physiol 2004;91(1):22-9.
223. Todd G, Gorman RB, Gandevia SC. Measurement and reproducibility of strength and voluntary activation of lower-limb muscles. Muscle Nerve 2004;29:834-42.
224. Akebi T, Saeki S, Hieda H, Goto H. Factors affecting the variability of the torque curves at isokinetic trunk strength testing. Arch Phys Med Rehabil 1998;79:33-5.
225. Frost LR, Gerling ME, Markic JL, Brown SH. Exploring the effect of repeated-day familiarization on the ability to generate reliable maximum voluntary muscle activation. J Electromyogr Kinesiol 2012;22:886-92.
226. Krishnan C, Williams GN. Variability in antagonist muscle activity and peak torque during isometric knee strength testing. Iowa Orthop J 2009;29:149-58.
227. Comyns, T., Harrison, A., Hennessy, L. and Jensen, R. Identifying the optimal resistive load for complex training in male rugby players. Sports Biomechanics. 2007. 6(1): 59-70.
228. Ratamess, N. Adaptations to Anaerobic Training Programs. Chapter 5. Baechle, T. and Earle, R., eds: Essentials of Strength Training and Conditioning. (3rd Edition). 2008. 414-17. National Strength and Conditioning Association. ISBN-10: 0-7360-5803-6.
229. Rippetoe, M. Programming. Chapter 8. Starting Strength: Basic Barbell Training. (3rd Edition). 2013. The Aasgaard Company. ISBN-10: 0-9825-2273-8.
230. Winter D. Biomechanics and motor control of human movement. 4th ed. John Wiley & Sons, Inc. Hoboken, NJ 2009 Chapter 10, Kinesiological electromyography. p. 250-80.
231. Hodgson, M., Docherty, D. and Zehr, E. Postactivation potentiation of force is independent of h-reflex excitability. International Journal of Sports Physiology and Performance. 2008. 3(2): 219-31.
232. Waters, K. and Boone, W. The relationship of spinal misalignment elements to muscle imbalance in dance performance. Chiropractic. 1988. 1(2): 2-8.
233. Grimston, S., Engsberg, J., Shaw, L. and Vetanze, N. Muscular rehabilitation prescribed in coordination with prior chiropractic therapy as a treatment for sacroiliac subluxation in female distance runners. Chiropr Sports Med. 1990. 4(1):2–8.
234. Schwartzbauer, J. Kolber, J. Schwartzbauer, M., Hart, J. and Zhang, J. Athletic performance and physiological measures in baseball players following upper cervical chiropractic care. Journal of Vertebral Subluxation Research. 1997. 1(4): 1-7.
235. Costa S, Chibana Y, Giavarotti L, Compagnoli D, Shiono A, Satie J, Bracher E. Effect of spinal manipulative therapy with stretching compared with stretching alone on full-swing performance of golf players: a randomized pilot trial. Journal of Chiropractic Medicine. 2009. 8(4):165-70.

236. Bergmann, T. Chiropractic technique. Chapter 7 in Gatterman, ed: Foundations of Chiropractic: Subluxation. (2nd Edition). 2005. Elsevier Mosby. ISBN: 0-323-02648-6.
237. Lougee H, Johnston RG, Thomson OP. The suitability of sham treatments for use as placebo controls in trials of spinal manipulative therapy: A pilot study. Journal of Bodywork and Movement Therapies. 2013. Jan;17(1):59-68.
238. Brolinson P, Smolka M, Rogers M, Sukpraprut S, Goforth M, Tilley G, Doolan K. Precompetition manipulative treatment and performance among Virginia Tech athletes during 2 consecutive football seasons: a preliminary, retrospective report. J Am Osteopath Assoc. 2012. 112(9):607–15.
239. Hallgren K. Computing inter-rater reliability for observational data: An overview and tutorial. Quant Methods Psychol. 2012. 8(1):23-34.
240. Hoch M, Krause B. Intersession reliability of H:M ratio is greater than the H-reflex at a percentage of M-max. International Journal of Neuroscience. 2009. 119:345-52.

Vita

Grant Sanders

Education

New York Chiropractic College — Seneca Falls, NY
Doctor of Chiropractic — July 2010

Baldwin-Wallace College — Berea, OH
B.A. Fitness Management, Minor in Health Promotion — May 2006

Professional Positions

Wellness Guide, University of Kentucky — August 2014 - May 2015
Health and Wellness Program

Graduate Assistant, University of Kentucky — May 2013 - August 2014
Health and Wellness Program

Teaching Assistant, University of Kentucky — August 2012 - May 2013
Department of Kinesiology and Health Promotion

Clinical Internship, New York Chiropractic College — September 2009 - August 2010
Levittown Health Center, Long Island, NY

Conditioning Instructor, Baldwin Wallace University — August 2005 - May 2006
Women's basketball and volleyball teams

Internship, Key Bank Health and Fitness Center — May - August 2005
Cleveland, OH

Certifications

First Aid/CPR/AED two year recertification — December 2014 - Present
NSCA Certified Strength and Conditioning Specialist — July 2013 - Present
Kentucky Chiropractic License — October 2011 - Present

Awards

Research Grant, Arvle and Ellen Turner Thacker Research Fund — March 2014
University of Kentucky, College of Education

Conference Travel Award, University of Kentucky — February 2013
Department of Kinesiology and Health Promotion

Ezra Gillis Graduate Tuition Scholarship, University of Kentucky — August 2010
Department of Kinesiology and Health Promotion

Libero A. Violini Distinguished Service Award July 2010
Levittown Health Center, Long Island, NY

Memberships

American Chiropractic Association
Kentucky Association of Chiropractors
National Strength and Conditioning Association
Southeast Chapter of the American College of Sports Medicine

Peer-Reviewed Manuscripts

Sanders G, Nitz A, Abel M, Symons T, Shapiro R, Black W, Yates JW (in press). The effects of lumbosacral manipulation on isokinetic strength of the knee extensors and flexors in healthy subjects: A randomized, controlled, single-blind crossover trial. *Journal of Chiropractic Medicine*.

Abstracts

Accepted for 2016 Combined Sections Meeting February 2016
American Physical Therapy Association
Anaheim Convention Center, Anaheim, CA
Croft E, Nitz A, Sanders G, Bazrgari B
Spinal manipulation does not improve balancing performance of healthy individuals on an unstable seat.

10th Annual Spring Conference March 2015
University of Kentucky Center for Clinical and Translational Science
Lexington Convention Center, Lexington, KY
Croft E, Nitz A, Sanders G, Bazrgari B
Mechanical changes in the lower back following six sessions of spinal manipulation - Preliminary results.

Poster Presentations

25th Annual Spring Research Conference April 2014
Duke Energy Convention Center, Cincinnati, OH
Sanders G, Nitz A, Abel M, Symons T, Shapiro R, Black W, Yates J.W.
The effects of spinal manipulative therapy on postactivation potentiation: A pilot study.

24th Annual Spring Research Conference April 2013
Hilary J. Boone Center, University of Kentucky
Sanders G, Nitz A, Abel M, Symons T, Shapiro R, Black W, Yates J.W.
The effects of lumbosacral manipulation on isokinetic strength of the knee extensors and flexors.

Southeast Chapter of the American College of Sports Medicine February 2013
Hyatt Regency Hotel, Greenville, SC
Sanders G, Nitz A, Abel M, Symons T, Shapiro R, Black W, Yates J.W.
The effects of lumbosacral manipulation on isokinetic strength of the knee extensors and flexors.