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Mechanisms of motor control and function are interesting to those from the medical, athletic training and sports performance professions primarily during the development of conditioning and rehabilitation programs. The aim of this study was to assess spinal control mechanisms in two groups of explosively trained, female athletes from a NCAA Division 1- A institution. Comparisons of motor control variables were made between softball and volleyball players using Hoffmann reflex (H-reflex) measurements including: extrinsic presynaptic inhibition (EPI), intrinsic presynaptic inhibition (IPI) and the H: M ratio. One-way t-test results revealed no significant difference ($p < .05$) between the two groups in EPI (0.74±0.28 vs. 0.77±0.57), IPI (0.09±0.17 vs. 0.16±0.35) or the H: M ratio (0.57±0.17 vs. 0.56±0.26). Although the two groups participated in different sport-specific tasks over the course of a competitive season, both groups demonstrated similar reflex characteristics at rest. Thus, there were no differences between the two explosively-trained groups with respect to adaptations along the motor control, reflex pathway despite the two groups being from different sports.

Spinal Control Mechanisms in Elite Level, Explosively Trained Athletes from Two Different Sports

by
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Marie E. Zidek, Author

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CONTRIBUTION OF AUTHORS

Jeffery Doeringer and Erica Perrier assisted with data collection of subjects. Dr. Mark Hoffman served to edit this manuscript and gave input in each section. Dr. Mark Hoffman also assisted with interpretation of this data.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1 – General Introduction

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In the development of strength and conditioning programs (anaerobic, aerobic, resistance, etc.), the nervous system is often overlooked in favor of pure muscular changes instead of acknowledging the sophisticated neural network that controls and regulates movement (Earles et al. 2002). The goal of strength and conditioning programs is to manifest a chronic physical adaptation through sport performance training in order to meet the physical demands placed upon the athlete by his/ her sport. Understanding the mechanisms that control muscle activation, i.e. integrative nervous system mechanisms, could have significant implications for the medical, athletic training and sport performance training fields.

All forms of motor control and muscle activation funnel through 0.01% of the central nervous system's (CNS) billion-neuron network (Wolpaw 2001). Although motor control operates within such a small percentage of the nervous system, it is still capable of adaptation to training. Despite the overwhelming evidence indicating a significant role for neural mechanisms in adaptations due to chronic physical activity, there has been less progress in identifying the specific mechanisms responsible for motor control adaptations (Enoka 1997). Knowledge identifying these specific adaptations and where they occur along the sensory-motor pathway could provide a clearer picture of how muscles are activated and inhibited. Such knowledge could be beneficial in satisfying the goals of injury prevention and sports performance development per strength and conditioning programs by providing insight into how gains are made along the nervous system pathways.

Motor control can be viewed as the integration between the sensory and motor nervous systems. Activity-dependent plasticity is known to occur along this CNS pathway. The challenge is to define exactly where the adaptation takes place and how this plasticity accounts for learned physical behaviors (Wolpaw & Chen 2006). A measurement tool used to illustrate acute and chronic adaptations to activity is Hoffmann-reflex (H-reflex) testing, in which many variables may be assessed. H reflex testing is non-invasive and can be used to assess training and/or other adaptations (i.e. aging) of the neuromuscular system (Koceja & Kamen 1992). Additionally, the H-reflex can be used to assess the response of the nervous system to various neurological conditions, musculoskeletal injuries, application of therapeutic modalities, pain, exercise training and performance of motor tasks (Palmieri et al 2004). Testing involves electrically stimulating a peripheral nerve at varying levels of stimulation intensity, which sends a signal up afferent nerves to the spinal cord, whereby that information is filtered and transmitted down the efferent pathway to establish a muscular reaction.

Reflexes have historically been thought to be "rigidly fixed" (Zehr 2006). However, in comparing endurance, explosive and/or non-trained groups, a decreased ratio of the maximum H reflex to motor response (H:M ratio) has been traditionally seen in explosively trained athletes (Casabona et al. 1990; Maffiuletti et al. 2001). Explosively trained athletes seemed to be able to activate higher percentages of their motoneuron pool with lowered sensory input.

Explosive movements can be described as athletic movement that utilizes quick and powerful contraction of the muscle. This type of muscular contraction usually lasts under six seconds due to limiting metabolic demands and incorporates major muscle groups that surround the ankle, knee and hip joints also termed "triple extension" (NSCA 2010). It is well established that explosively trained athletes produce stronger muscular twitches at faster development and relaxation compared to endurance athletes (Maffiuletti et al 2001). Previous research has also shown a positively correlated change between H-max and rate of force development amplitude after 3 weeks of resistance training, indicating that adaptation within the CNS had some relation to performance outcomes (Holtermann et al. 2007). Rate of force development refers to how quickly a muscle can reach peak force during voluntary activation.

As Zehr stated in 2006, "A principled basis for an intervention requires an understanding of the extent to which the nervous system can accommodate to increased or decreased use before a long-standing change in control and function occurs." While differences in reflex measurements are valuable in illustrating adaptation to varying training conditions, they do not offer insight as to where neural modulation is taking place. For instance, even though explosive athletes activate higher percentages of their motoneuron pool with less sensory input than do endurance athletes, (Zehr 2006) the location of these changes have not been identified. While explosive athletes from different sports are trained to produce similar reactions appropriate to their sport-specific movement, it is not clear if sport specific training causes adaptations or if it is the mode of movement itself that leads to these outcomes.

A variety of techniques exist that allow the investigation of the mechanisms responsible for spinal control/ input of movement. One such mechanism is presynaptic inhibition (PI). PI is a measure of the gating of sensory information to the spinal cord in order to assist in smooth execution of movement or motor task (Hultborn et al. 1987b). PI involves the use of interneurons, which serve to control/ filter the over-abundant amount of stimuli being sent to the spinal cord via Ia afferent sensory neurons. Interneurons comprise the major integrating elements of the nervous system, which allows a great deal of flexibility in the circuitry system (Earles 2002). Neural inhibitors, i.e. interneurons, act as high pass filters, which effectively "shut down" signals flowing through the reflex loop (Frerking et al. 2006). The functional consequences of this high pass filter during synaptic processing of behavior still remains allusive (Frerking et al. 2006). Generally speaking, PI alters the information at the synapse between neurons and ultimately the information that is filtered. This form of interneuron activity indirectly decreases post-synaptic transmitter release thereby affecting signals that the α-motoneuron pathway receives from the Ia afferent pathway; however, its role in determining motor behavior is still unknown (Rose and Scott 2003). There are two types of PI: extrinsic pre-synaptic inhibition (EPI) and intrinsic pre-synaptic inhibition (IPI). IPI represents the efficiency of synaptic transmission based on the availability of neurotransmitter. EPI is a measure of the gating of the sensory information at the level of the synapse. Research with trained athletes has demonstrated that when stimulating intensities increase, inhibition increases in both the power- and endurance- trained groups (Earles et al. 2002). To date, very little research has compared PI variables in subgroups of similar athletic populations, i.e. two groups of explosively trained athletes. This is of interest because, although the two sports require similar explosive training programming, sport specific tasks are very different and may cause further adaptations along the reflex pathway.

Volleyball and softball athletes are conditioned to produce explosive movements due to the nature of their respective sports. However, their sport-specific requirements are very different. The primary objective of this investigation was to measure levels of EPI, IPI and the H: M ratio in two groups of explosively trained elite level collegiate athletes in attempt to assess any sport specific adaptations, outside of the traditionally seen adaptations to mode of training, between the two groups.

Chapter 2 – Spinal Control Mechanisms in Elite Level, Explosively Trained Athletes from Two Different Sports

Cover Letter

“This manuscript contains material that is original and not previously published in text or on the Internet, nor is it being considered elsewhere until a decision is made as to is acceptability by the JSCR Editorial Review Board.”

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Title Page

Spinal Control Mechanisms in Elite Level, Explosively Trained Athletes from Two Different Sports

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Spinal Control Mechanisms in Elite Level, Explosively Trained Athletes from Two Different Sports

ABSTRACT

Mechanisms of motor control and function are interesting to individuals from the medical, athletic training and sports performance professions to further the development of efficient conditioning and rehabilitation programs. The aim of this study was to assess mechanisms of motor control in two groups of explosively trained, female athletes aged 18-25 years, from a NCAA Division 1- A institution. Comparisons in motor control mechanisms were made between softball and volleyball players using Hoffmann reflex (H-reflex) measurements including: extrinsic inhibition (EPI), intrinsic inhibition (IPI) and the H: M ratio. One-way t-test results revealed no significant difference ($p < .05$) between the two groups of softball vs. volleyball athletes in EPI (0.74 vs. 0.77), IPI (0.09 vs. 0.16) or the H: M ratio (0.57 – 0.56). Although the two groups participated in varying sport-specific tasks over the course of a competitive season (i.e. volleyball players jump trained while softball players did not receive any jump training), both groups demonstrated similar reflex characteristics. Thus, there were no differences between the two explosively-trained groups with respect to adaptations along the motor control, reflex despite the two groups being from different sports.

KEYWORDS Hoffmann reflex, neuromuscular adaptation, sensorimotor integration

INTRODUCTION

In the development of strength and conditioning programs (anaerobic, aerobic, resistance, etc.), the nervous system is often overlooked in favor of pure muscular changes instead of acknowledging the sophisticated neural network that controls and regulates movement (Earles et al. 2002). Mechanisms of motor control and muscle activation have been studied at length by those from the medical, athletic training and sport performance fields for the purpose of training, treatment, and/or rehabilitation program development. Despite the overwhelming evidence indicating a significant role for neural mechanisms in adaptations associated with changes in the levels of chronic physical activity, there has been less progress in identifying the specific mechanisms responsible for motor control adaptations (Enoka 1997). Knowledge surrounding these specific adaptations and where they occur along the sensory-motor pathway could illustrate a clearer picture of how muscles are activated and inhibited. Such knowledge could be beneficial in satisfying the goals of injury prevention and sports performance development per strength and conditioning programs by providing insight into how gains are made along the motor control pathway.

Despite the overwhelming evidence indicating a significant role for neural mechanisms in adaptations due to chronic physical activity, there has been less progress in identifying the specific mechanisms responsible for motor control adaptations (Enoka 1997). Knowledge identifying these specific adaptations and where they occur along the sensory-motor pathway could illustrate a clearer picture of how muscles are activated and inhibited. Such knowledge could be beneficial in satisfying the goals of injury prevention and sports performance development per strength and conditioning programs.

The H reflex testing, a common neurological resting tool, is the electrical equivalent of the tendon tap reflex, commonly used by physicians to assess nervous system function (Koceja & Kamen 1992). In both testing formats, there is activation of the sensory system that in turn activates the motor system to produce an observed motor response. These measurements can be used to assess the response of the nervous system to various neurological conditions, musculoskeletal injuries, application of therapeutic modalities, pain, exercise training and performance of motor tasks (Palmieri et al 2004).

Testing involves electrically stimulating a peripheral nerve at varying levels of intensity, which sends a signal up afferent neurons to the spinal cord, where that information is filtered and transmitted down the efferent pathway to produce a muscular reaction. The muscle response is measured as the peak-to-peak amplitude of the twitch contraction as measured by EMG. At smaller intensities, an electrical signal depolarizes the afferent nerves and proceeds to travel around the closed loop chain that produces a muscular activation response. This is termed the H-reflex. However, as the stimulation intensity increases, maximum H is reached and the electrical signal is large enough to depolarize the motoneurons directly. This is termed the M response and is thought to reflect the potential of the entire motoneuron pool of the muscle. The stimulation intensity is increased in step-wise fashion until maximum H and maximum M have been reached. Traditionally, maximum values of both variables and the H: M ratio are compared to illustrate differences between trained status and / or condition.

Reflexes had previously been thought to be “rigidly fixed” (Zehr 2006). However, research has shown trained-state, task dependent differences between groups in response to training programs. Positively correlated changes between H-reflexes and rate of force development (RFD) amplitude have been seen after 3 weeks of resistance training coupled with a decreased ratio when compared to non-trained individuals (Holtermann et al. 2007). Explosively trained athletes activated higher percentages of their motoneuron pool with lowered sensory input. A decreased H:M ratio has consistently been seen in explosively trained athletes when compared to endurance and non-trained groups (Casabona et al. 1990; Maffiuletti et al. 2001).

Explosive movements can be described as athletic movement that utilizes quick and powerful contraction of the muscle. This type of muscular contraction usually lasts under six seconds due to limiting metabolic demands and incorporates major muscle groups that surround the ankle, knee and hip joints also termed “triple extension” (NSCA 2010). It is well established that explosively trained athletes produce stronger muscular twitches at faster development and relaxation rates (Maffiuletti et al 2001). Previous research has also shown a positively correlated change between H-max and rate of force development amplitude after 3 weeks of resistance training indicating that adaptation within the CNS was related to performance outcomes (Holtermann et al. 2007). While this information is valuable in illustrating differences between groups and conditions, it does not offer insight into which of these changes are occurring in the spinal cord.

Pre-synaptic inhibition is critical in understanding the neural control of movement since it gates sensory afferent feedback to the spinal cord in order to assist in smooth execution of movement or motor task (Hultborn et al. 1987b). Generally speaking, presynaptic inhibition alters the information at the synapse of a neuron. This form of interneuron activity indirectly decreases post-synaptic transmitter release thereby affecting signals that the α-motoneuron pathway receives from the Ia afferent pathway; however, its role in determining motor behavior is still unknown (Rose and Scott 2003). The two regulating mechanisms of PI include extrinsic pre-synaptic inhibition (EPI) and intrinsic pre-synaptic inhibition (IPI). IPI refers to a stimulus being sent up the Ia afferent pathway only to be followed, only a few milliseconds apart, by another stimulus up the same pathway. EPI refers to a situation where a stimulus is sent up a antagonist sensory Ia pathway and followed almost simultaneously by a stimulus up the agonist Ia pathway. Research with trained athletes has demonstrated that when stimulating intensities increase, inhibition increases in both the power- and endurance- trained groups in similar amounts (Earles 2002). This supported the theory that training effects are modulated by changes in inhibition qualities along the sensory-motor pathway. To date, very little research has compared PI variables in subgroups of similar athletic populations, i.e. two groups of explosively trained athletes. This is of interest because, although the two sports require similar explosive training programming, sport specific tasks are very different and may cause further adaptation along the reflex pathway.

Volleyball and softball athletes are trained to produce explosive movements. Volleyball players also perform jump training whereas softball does not. To date, research has examined Hoffman reflex measurements in two opposing samples, i.e. endurance and explosive athletes, and not between like groups. As well, very little evidence has looked into how these athletes achieve explosive movements, i.e. how these athletes adapt to stimuli. The primary objective of this investigation was to measure levels of EPI, IPI and the H: M ratio in two groups of explosively trained elite level collegiate athletes in attempt to assess any trained-state difference in nervous system attenuation.

METHODS

Experimental approach to the problem

This was a cross sectional study that compared the PI values of elite level softball and volleyball athletes in order to determine if the utilize spinal control mechanisms in a similar way. Previous research has revealed a difference in how muscles are controlled in explosively trained (i.e. sprinters) and endurance trained (i.e. runners) athletes. However, there has not been a systematic investigation regarding the sub groups from these areas. For example, even though softball players and volleyball players undergo explosive training, the activities required during their sports are very different (i.e. volleyball requires repeated jumping where as softball does not). Therefore, we were interested in sub groups of the explosive-type athlete (explosively trained athletes in a jumping sport vs. explosively trained athletes in a non-jumping sport).

These measures allow us to more specifically investigate how neural information in the spinal cord moves from one neuron to another. These techniques are commonly used in the investigation of neuromuscular disorders such as: stroke, multiple sclerosis, etc. Information from this study could potentially contribute to the understanding of how best to train explosive athletes as well as how best to rehabilitate them should they become injured.

Subjects

NCAA Division I-A, elite level, female collegiate athletes from the softball and volleyball teams were recruited. There were a total of 20 athletes consisting of 11 softball players and 9 volleyball players aged 19.6 ± 1.4 years. Average ± SD height and mass for the group of softball players was 169.6±12.6cm and 74.9±15.6kg. Average height and mass for the group of volleyball players was 184.8±5.3cm and 74.2±8.4kg. This study was approved by the Institutional Review Board and all subjects gave consent prior to participation.

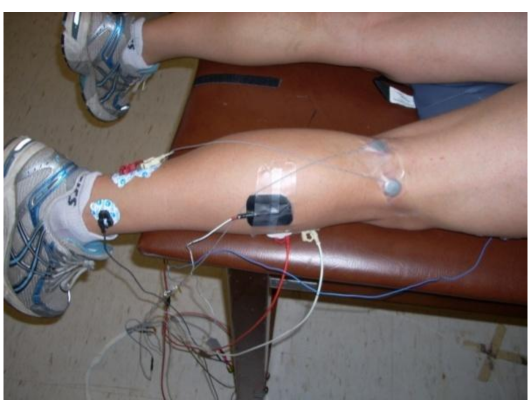
Procedures

An informational recruitment meeting was held with both groups. Following the meeting, subjects interested in participating were scheduled for a one-time data collection session. Upon arrival for data collection, the subjects completed a short screening questionnaire. Upon researcher approval of this questionnaire, subjects proceeded to data collection. Informed consent was read and vocally explained by the researcher before data collection, potential risks were addressed and all subject questions were answered.

All subjects completed one data collection session that lasted approximately 55 minutes. Subjects were instrumented with a total of 9 electrodes on their right leg that were used for reflex stimulation and data collection. Five lubricated bipolar (Ag/AgCl) surface electromyography electrodes were placed on the subject’s right leg. Two electrodes were placed linearly down the midline of the soleus muscle away completely from the gastrocnemius muscle. Two electrodes were placed on the tibialis anterior muscle over the middle of the muscle belly. One dispersal pad electrode was placed just above the patella on the front of the right knee. One stimulating electrode was placed in the back of the knee over the tibial nerve, which in most subjects ran just below the midline crease of the knee. One stimulating electrode was placed on the outside of the knee, just superior and medial to the head of the fibula, for stimulation of the tibialis anterior. One dispersal pad electrode was placed approximately 8cm inferior to the stimulating electrode on the side of the knee. The ground electrode was placed on the lateral malleolus of the right ankle.

The subject was asked to lie face down on a padded table in a fixed after EMG and dispersal pad electrodes were placed. Once the subject was on the table, proper placement for the stimulating electrodes was found by placing the electrode in an optimum position.

Figure 1. Example of data collection set-up.



Muscle responses were evoked by stimulating the tibial nerve in the back of the knee with a 1 ms pulse duration and were measured using peak to peak values of the EMG waveform readings. A Grass Product Group S88 stimulator was used (Warwick, Rhode Island) was used for stimulus of the subject. Stimulus intensity was increased in small increments until the data collection equipment detected a maximal muscle response. The same was done for the tibialis anterior stimulator. Once maximum reflex responses were gathered, stimulation for the tibialis anterior was set at motor threshold. This was determined by the researcher palpating the tendon of the tibialis anterior until the slightest motion was detected after low-intensity stimulus. This stimulus intensity served as the conditioning stimulus for the soleus during the extrinsic inhibition measurements. Soleus stimulation intensity was set at 20-30% of the maximal stimulus of H (i.e. H-max).

Approximately 30-50 total stimulations were collected. Inter-stimulus interval was approximately 10 seconds. Finding the appropriate stimulus location took 5-10 stimulations. Approximately 15 readings were taken using the TA conditioning stimulus in the EPI protocol and 10 using the pulse paired stimulus (IPI) protocol. During the EPI protocol, the delay between stimulus was set at 10ms. The IPI protocol required an 80ms delay. The ratio between conditioned and unconditioned responses was calculated by taking the average of each set of variables and dividing the conditioned by the unconditioned responses.

Statistical Analysis

Means and standard deviations of the H: M ratio, EPI and IPI measurements were calculated. Differences between groups in all of these variables were examined using t tests with the alpha level of significance set at $p < 0.05$. Non-parametric statistics were also calculated using SPSS software with a Mann-Whitney test.

RESULTS

Mean values between H:M ratios, EPI and IPI measurements were taken for each group. They are listed in Table 1.

Table 1. Group Statistics – Softball (0) and Volleyball (1)

Variable	Sport	Mean ± SD
H:M Ratio	SBALL	0.57±0.17
	VBALL	0.56±0.26
EPI	SBALL	0.73±0.28
	VBALL	0.77±0.57
IPI	SBALL	0.09±0.17
	VBALL	0.16±0.35

Comparisons between mean H: M ratio, EPI and IPI values in softball and volleyball players are shown in Table 2. There were no significant differences between groups with regard to any of the independent variables.

Table 2. Independent Samples Test – Comparison between group means

		F	Sig.	t	df	Sig. (2-tailed)
Hmax	Equal variances assumed	6.70	0.02	-0.70	18.00	0.50
	Equal variances NA			-0.64	9.25	0.54
Mmax	Equal variances assumed	0.04	0.85	-0.78	18.00	0.45
	Equal variances NA			-0.76	14.91	0.46
HMratio	Equal variances assumed	6.38	0.02	0.13	18.00	0.90
	Equal variances NA			0.13	13.24	0.90
EPI	Equal variances assumed	6.60	0.02	-0.18	18.00	0.86
	Equal variances NA			-0.17	11.11	0.87
IPI	Equal variances assumed	1.57	0.23	-0.62	18.00	0.54
	Equal variances NA			-0.58	11.01	0.57

Statistical power was 0.061 for the H: M ratio, 0.067 for EPI and 0.14 for IPI as calculated by the DSS researcher's toolkit.

Non-parametric statistics were also calculated because of the concern of a non-evenly distributed statistical output between the two samples. Results are displayed in Table 3.

Table 3. Non parametric Mann-Whitney U test.

Mann Whitney U	46.00	49.00	47.50
Wilcoxon W	112.00	115.00	113.50
Asympt. Sig.	0.79	0.97	0.88
Exact Sig.	0.82	1.00	0.88

DISCUSSION

Mechanisms of motor control and function are of interest to individuals in the medical, athletic training and sport performance fields for the continued development of efficient conditioning and rehabilitation programs. Motor control is achieved by the finely-tuned organization of the body's afferent (sensory) nervous system, which collects information from the body and transports it to the spinal cord to produce a muscular reflex. Electrical stimulation of the peripheral nerve elicits different measurements of this reflex and allows bypass of the Golgi tendon organs and muscle spindles, and by doing so, bypasses the influence that these may have on sensory integration at the spinal cord level (Ross et al 2001). The afferent neurons carry nerve impulses from sense organs towards the spinal cord whereupon the impulse travels through a motoneuron pool to eventually innervate the corresponding muscle fibers (Palmieri et al. 2004). The H-reflex is a major probe for the non-invasive study of sensorimotor integration, plasticity of the central nervous system in humans and used in excitability assessments of interneuronal circuits during a variety of conditions (Knikou 2008).

The excitability of the motor-neuron pool under-goes adaptive changes in response to various factors including: long-term physical training, sudden trauma and/or change of type of activity (Ogawa et al. 2009). H reflex amplitudes reveal a difference at equivalent EMG levels in walking, standing and running, suggesting there to be activity dependent modifications to

Hoffmann reflex measurements. Indeed, parallel increases in strength and rate of force development (RFD) are common outcomes after the initial phase of strength training but the extent of nervous system modulation in these increases is unknown. Early neural modulation research has primarily studied forms of resistance training while using non-resistant trained individuals as controls. Previous research has also revealed a difference in how muscles are controlled in explosively trained (i.e. sprinters, weight lifters, etc.) and endurance trained (i.e. runners, etc.) athletes.

Perot et al (1991) measured tendon reflexes as well as H-reflexes before and after an eight week endurance training program performed by 20 healthy college subjects, and reported a significant increase in the H: M ratio. Koceja and Kamen (1992) measured controlled and conditioned reflexes between endurance trained and non-trained groups. The researchers concluded that motor-neuron excitability was changed by varying the conditioning status, further supporting the argument for nervous system modulation. Ogawa et al. (2009) recently investigated the effects of long-term participation in a regimented swimming program and concluded that spinal reflex excitability in experienced swimmers was “far more enhanced” than that of non-trained individuals as they found a higher H:M ratio.

Suggesting that H reflex measurement is a reflection of excitability fails to take into account the sophisticated network of filtering that goes on at the CNS level. Research has failed to identify where this modification is taking place along the reflex pathway and therefore limits application of these measures. New evidence suggests that, while the H-reflex is a valuable measuring tool, is it insufficient at explaining the more complex interactions that take place between interneurons, which are now viewed to have more of an “attenuating” role in the communication between sensory and alpha motoneuron fibers in spinal and supraspinal centers. The CNS is continuously exposed to a barrage of afferent impulses coming from the various sense organs such that exceed overall processing capabilities (Rudomin & Schmidt 1999). To help with processing, interneurons are responsible for excitatory and inhibitory control in other neurons and account for 99% of all neurons (Earles 2002). It is the method by which “surplus” afferent impulses are reduced or abolished by inhibition (Rudomin & Schmidt 1999). Deseilligny et al. (1997) found PI to be decreased on the Ia afferents projecting onto the motoneurons of a contracting muscle versus increased on Ia afferents projecting on motor nuclei not contracted, which revealed that changes in H-reflex amplitude do not reflect changes in MN excitability thus making a case for examining interneurons and their function. There is limited research using refined reflex measuring techniques – namely those that reflect what is going on at a inter-neuronal (i.e. EPI and IPI).

PI is critical to understanding the neural control of movement since it gates sensory afferent feedback to the spinal cord in order to assist in smooth execution of movement or motor task (Hultborn et al. 1987b). PI is divided into two different types based on the location of the inhibition related to the synapse. Research on trained athletes has demonstrated that when stimulating intensities during conditioned testing increase, inhibition increases in both the power- and endurance- trained groups but EPI increases more in explosively trained athletes (Earles et al. 2002). The change in neural information, combined with trained status of an individual, has indicated that knowledge of metabolic demands is only part of creating an optimal periodized training schedule. To date, very little research has compared pre-synaptic inhibition in differing subgroups of athletes trained to produce similar reactions with regard to their required sporting movements.

Volleyball and softball athletes are trained to produce explosive movements. However, volleyball players have added jump training to their sport conditioning whereas softball does not. The primary objective of this investigation was to measure levels of EPI, IPI and the H: M ratio in two groups of explosively trained elite level collegiate athletes in attempt to assess any trained-state difference in nervous system attenuation.

Interneurons comprise the major integrating elements of the nervous system, which allows a great deal of flexibility in the circuitry system (Earles 2002). Neural inhibitors act as high pass filters, which effectively “shut down” signals flowing through the reflex loop (Frerking et al. 2006). The functional consequences of this high pass filter during synaptic processing of behavior still remains allusive (Frerking et al. 2006). For example, even though softball players and volleyball players undergo explosive training via strength &

conditioning practices, the activities required during their sports are very different (i.e. volleyball players require repeated jumping as softball does not). Avela et al. (2006) tested H-reflex measurements on two subgroups of explosively-trained athletes, sprinters versus high jumpers and found no difference in resting measurements but a significant difference between groups when testing the H-reflex during jumping movement. These results suggest that the two groups used different spinal control mechanisms.

In attempt to further investigation beyond H and M values, PI was tested with the aim to study neural-adaptive mechanisms. The primary objective of this investigation was to measure levels of EPI, IPI and the H: M ratio in two groups of explosively trained elite level collegiate athletes in attempt to assess any trained-state difference in nervous system attenuation. There was no significant different in mean H: M ratio, EPI and IPI between softball and volleyball players. There were a few limitations to this study. First, the athletes were not performing sport-related movement during testing; they were tested at rest. Research has suggested attenuation to specific trained tasks occur only during the performance of these tasks (Beck et al. 2007; Schubert et al 2008). Second, while participants were encouraged to perform no physical activity immediately prior to testing, the conflict of practice schedules made this challenging to enforce.

PRACTICAL APPLICATIONS

Neural adaptations are of specific interest to the strength and conditioning community, because they play an integral role how bodies move and adapt. The study of the nervous system in this community is limited to a plethora of tests (i.e. counter movement jump, top weights and speeds of Olympic lifts, etc.) but do not illustrate specific adaptations taking place within the reflex loop. Understanding, at a more mechanistic level, specific adaptations to chronic activity may provide insight in the program development in both the clinical and applied sports medical fields. Results indicated no difference between softball and volleyball players, thus it can be suggested that the mode of training (i.e. training explosively in strength and conditioning) is important. This is not to suggest that specific exercise during sport is of little importance; on the contrary, it is tremendously important for sport specific success. However, when examining the CNS at a mechanistic level, the two explosively trained groups did not differ even though their sport-specific training was drastically different. These results suggest that explosively trained athletes do not differ regardless of sport specific training.

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23. Zehr PE. Training-induced adaptive plasticity in human somatosensory reflex pathways. *J Appl Physiol* 101: 1783-1794, 2006.

Figure Legends

FIGURE 1. Example of data collection set-up.

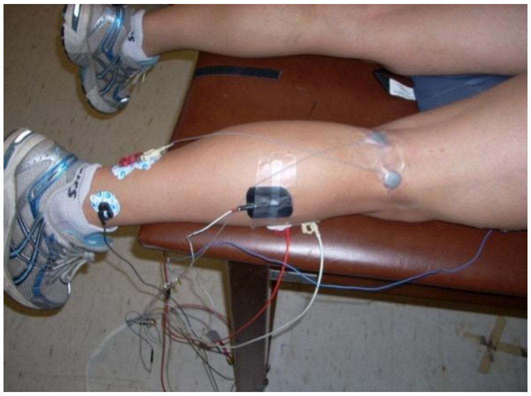

Table Captions

TABLE 1. Group Statistics – Softball (0) and Volleyball (1)

TABLE 2. One-way t test measurements of the independent variables between groups.

TABLE 3. Non parametric Mann-Whitney U test.

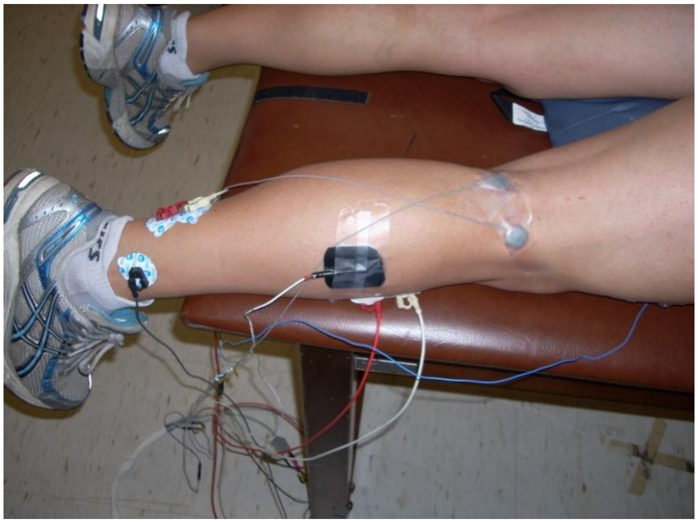

Figure 1

Table 1. Group Statistics – Softball (0) and Volleyball (1)

Variable	Sport	Mean ± SD
H:M Ratio	SBALL	0.57±0.17
	VBALL	0.56±0.26
EPI	SBALL	0.73±0.28
	VBALL	0.77±0.57
IPI	SBALL	0.09±0.17
	VBALL	0.16±0.35

Table 2. Independent Samples Test – Comparison between group means

		F	Sig.	t	df	Sig. (2-tailed)
Hmax	Equal variances assumed	6.73	0.02	-0.70	18.00	0.50
	Equal variances NA			-0.64	9.25	0.54
Mmax	Equal variances assumed	0.04	0.85	-0.78	18.00	0.45
	Equal variances NA			-0.76	14.91	0.46
HMratio	Equal variances assumed	6.38	0.02	0.13	18.00	0.90
	Equal variances NA			0.13	13.24	0.90
EPI	Equal variances assumed	6.62	0.02	-0.18	18.00	0.86
	Equal variances NA			-0.17	11.10	0.87
IPI	Equal variances assumed	1.57	0.23	-0.62	18.00	0.54
	Equal variances NA			-0.58	11.01	0.57

Table 3. Non parametric, Mann-Whitney U test.

	HM	EPI	IPI
Mann Whitney U	46.00	49.00	47.50
Wilcoxon W	112.00	115.00	113.50
Asympt. Sig.	0.79	0.97	0.88
Exact Sig.	0.82	1.00	0.88

Chapter 3 – General Conclusion

General Conclusion

Neural adaptations are of specific interest to the strength and conditioning community, because they play an integral role how bodies move and adapt. The study of the nervous system in this community is limited to a plethora of tests (i.e. counter movement jump, top weights and speeds of Olympic lifts, etc.) but do not illustrate specific adaptations taking place within the reflex loop. Understanding, at a more mechanistic level, specific adaptations to chronic activity may provide insight to the program development in both the clinical and applied sports medical fields. The change in the processing of neural information, combined with trained status of an individual, has indicated that knowledge of metabolic demands is only part of creating an optimal periodized training schedule. To date, very little research has compared pre-synaptic inhibition in differing subgroups of power trained athletes who participate in different sports. Results utilizing EPI and IPI testing from this study indicated no differences between softball and volleyball players, thus it can be argued that the mode of training (i.e. training explosively in strength and conditioning) is important. This is not to say specific exercise is of little importance, on the contrary, it is tremendously important for sport specific success. However, when examining the CNS at a mechanistic level, jumping did not lead to any additional adaptations in the reflex pathway not already altered by the mode of training. As long as the mode of exercise is trained, whether it is endurance or explosive in nature, adaptations relating to this reflex loop between like- groups should be similar.

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APPENDICIES

Review of Literature

Mechanisms of motor control and muscle activation have been studied at length by those from the medical, athletic training and sport performance fields for the purpose of training, treatment and/or rehabilitation program development. Adaptations of the nervous system to chronic physical activity have been a research area of interest due to the evidence of muscular strength gains without any noticeable hypertrophy early-on in a resistance training intervention (Gabriel et al. 2006). Muscle is activated via motor units, which are comprised of a single motor neuron and the muscle it innervates (Wolpaw 2001). Motor control funnels through 0.01% of the billion-neuron CNS network and the simplest to most complex movements are controlled by the interaction of descending commands, which depend upon peripheral inputs from spinal cord interneurons and motor neurons (Wolpaw 2001). Increases in muscular strength have been attributed to modified neural drive (Gabriel et al. 2006). Understanding the role of higher-up conditioning could lend a crucial knowledge component to the pathways that control movement in rehabilitation and/or training settings. In order to study potential neural adaptations by the body to interventions and/or injury, several techniques have been used, and one of those techniques begins with the CNS' control of basic muscle reflexes.

Muscular reflexes are under direct command of spinal and supraspinal centers, which function to receive information from sensory neurons (I-a afferents), filter and transfer information to motoneurons in order to produce a muscular response. Movement is a response to closed loop communication in which descending information is influenced directly by ascending peripheral input from the sensory nervous system (Wolpaw 2001). When looking for adaptable areas responsible for training/injury or disease-induced changes in the CNS, the peripheral side of central control (i.e. sensory neurons) are the neurons of interest. Even though supraspinal control is evident during plasticity in trained or diseased individuals, motor neuron discharges that underlie specific skilled movements are influenced by and depend upon peripheral input (Wolpaw 2001). Wolpaw (2001) underscored the role of peripheral input upon motor reflexes using the example of stepping on a nail: "Peripheral input excites a muscle's motor neurons as well as the inhibitory motoneurons of the antagonist muscle, which results in a production of muscle force that opposes stretch and restores a limb to normal position…when a person steps on nail, for instance, a resulting flexion withdrawal reflex (produced by peripheral input) occurs that pulls the body weight off the foot and onto the other leg..."

Morphological and functional adaptations of the body have been documented in assessing the performance capabilities of an individual's neuromuscular system; however, the specific mechanisms responsible for this chronic adaptation are still not well documented (Enoka 1997). A tool used to examine the closed loop reflex of the neuromuscular system is Hoffmann reflex (H reflex) testing. The Hoffmann reflex is commonly referred to as the monosynaptic reflex response, analogous to the tendon (i.e. stretch) reflex loop, elicited by electrical stimulation of the peripheral nerve, which bypasses Golgi tendon organs and muscle spindles that may influence the modulation of sensory information to spinal and supraspinal centers (Ross et al 2001). It is considered a major probe for the non-invasive study of sensorimotor integration, plasticity of the central nervous system in humans and used in excitability assessments of interneuronal circuits at rest as well as during movement; it is a highly sensitive reflex whose amplitude is a result of complex neural mechanisms that act synchronously (Knikou 2008). It is tested by artificially stimulating a peripheral nerve along the surface of the body and recording the muscular response to that stimulation. Variables examined traditionally include the maximum H value, maximum M value and the H: M ratio. The H-max measure reflects the maximum amount of motor units one can potentially activate during a muscular response while the M-max represents maximum muscle activation (Palmieri et al. 2004).

The H-reflex measures the efficacy of synaptic transmission through the motoneuron pool as the stimulus travels from the sensory, afferent (Ia) fibers to the corresponding muscle's efferent, gamma motoneuron fibers. The H-reflex is an artificial stimulation to what doctors normally conduct as the tendon tap reflex, which is more normally used in the clinical setting to assess training and/or other adaptations (i.e. aging) of the muscular system (Koceja & Kamen 1992). H-reflex amplitudes at equivalent EMG levels in walking, standing and running reveal a difference, which proves there to be an activity dependent attenuation of the nervous system in order to produce the proper muscular action in response to the task at hand. As stated by Palimeri et al. (2004) these measurements can be used to assess the response of the nervous system to various neurological conditions, musculoskeletal injuries, application of therapeutic modalities, pain, exercise training and performance of motor tasks. Descending regulation of spinal reflexes has been illustrated in differences between inhibition measurements during standing, walking and running (Wolpaw 2001).

Within the realm of intervention of adaptations, it is vital to compare and contrast like and unlike groups in order to get an idea which variables along this reflex loop seem to be responsible for training adaptations. Previous research has been geared towards figuring out what activity-dependent plasticity occurs within the CNS, whereas current research is lending to establish how this plasticity occurs as a result of trained/learned activity (Wolpaw and Chen 2006). The excitability of the motor-neuron pool undergoes adaptive changes in response to various factors including: long-term physical training, sudden trauma and/or change of type of activity (Ogawa et al. 2009). Early neural modulation research has primarily studied forms of resistance training using non-resistant trained individuals as controls. Indeed, parallel increases in strength and rate of force development (RFD) are common outcomes after the initial phase of strength training but the extent of nervous system modulation in these increases is unknown. The most common variable tested has been the H: M ratio, which has been interpreted to reflect the proportion of the entire motor neuron pool capable of being recruited (Palmieri et al. 2004).

In attempt to reveal if modulation played any role in RFD changes, Holtermann et al. (2007) studied neural adaptations before and after a resistance training program by splitting a group of 24 healthy subjects into one control group and one training group. Researchers found there to be positively correlated changes between H-reflex and RFD amplitude after 3 weeks of training as well as a decreased H: M ratio, which indicated neural attenuation associated with resistance training (the ratio decreased as a result of training when compared to control group). In comparing postural stability maintenance training to ballistic ankle strength training (i.e. a form of balance versus strength training), Beck et al. (2007) measured motor-evoked potentials (MEP), which consisted of transcranial stimulation (TMS) of the soleus and tibialis anterior in order to get a muscle reflex response and found there to be attenuation (i.e. a lowered ratio response) only during the assigned training tasks. Schubert et al. (2008) tested both during trained task and at rest for three groups: one randomly assigned group performed explosive training to the lower limb, the second group performed balance training and the control group performed no training. This study used TMS stimulation to evoke a motor response as did Beck (2007). However, in this study, the researchers used TMS to condition the soleus during performance of trained task. Spinal excitability, as defined in this study by H-reflex testing measures, was unchanged following 4 weeks of training. However, interesting to note was a change in the conditioned H-reflex responses during the trained motor task, which indicated a specific adaptation of corticospinal excitability during the performed task. Researchers concluded that adaptations occurred merely during task-related function (Beck et al. 2007).

Perot et al (1991) measured actual tendon reflexes as well as H-reflexes before and after an eight week endurance training program performed by 20 healthy college subjects. The researchers found a significant increase in the H: M ratio (maximal reflex response to mean value of muscular response), which indicated a nervous system attenuation in muscle function. This is also completely opposite to what the trends had been for resistance-trained groups where the ratio had been seen to decrease. Koceja and Kamen (1992) measured the controlled reflexes as well as the conditioned reflexes between two groups, endurance trained and non-trained. The researchers concluded that motor-neuron excitability can be changed by varying inputs (i.e. training and conditioned tasks) further supporting the argument for nervous system modulation. In attempt to reveal a difference in H-reflex measurements between explosive and non-trained subjects, Casabona et al. (1990) tested explosively-trained subjects (elite volleyball players and sprinters) vs. non-trained following their competitive season. The researchers found the explosively-trained athletes to have smaller H: M ratios as well as a significant difference in M amplitude (the maximum value that each individual participant's muscle can be artificially stimulated).

Previous research utilizing the Hoffman reflex has revealed a difference in how muscles are controlled in explosively trained (i.e. sprinters, weight lifters, etc.) versus endurance trained (i.e. runners, etc.) athletes. Maffiuletti et al. (2001) compared the H-reflex to the M-max response in explosively-trained to endurance trained and found the H: M ratio to be significantly lower in the explosively-trained group. Ozmedivenli et al. (2002) found a significance decrease in H-reflex measurements in two trained groups (long-distance and short distance athletes) versus non-trained individuals. Ogawa et al. (2009) recently investigated the effects of a long-term participation in a regimented swimming program. Researchers concluded that spinal reflex excitability in experienced swimmers was “far more enhanced” than that of non-trained individuals. This conclusion was supported by finding a larger H: M ratio in the long-term swimming group versus the non-trained group (Ogawa et al. 2009).

New evidence suggests that, while the Hmax, Mmax and H: M ratio are valuable measuring tools, they are insufficient at explaining the more complex interactions that take place between interneurons and therefore not adept to pick up fine modifications that may be occurring between groups of trained individuals. Previous research has only been able to identify differences between group measurements, but the measure is not able to go beyond illustrating those differences. It is also not well understood how specific these interneurons are to activity – for example, is the mode of training responsible regarding neural adaptations or does the specific type of sport-related activity modify these adaptations even further? The source of these modifications, i.e. interneurons, have been sought after in order to better understand how these modifications occur due to training.

Interneurons potentially have more of an “attenuating” role in the communication between sensory and alpha motoneuron fibers in spinal and supraspinal centers. In other words, although motoneurons serve as that final common pathway by which muscle is ultimately activated, interneurons comprise major integrating elements of the nervous system…they act as the filter through which sensory information is passed through (Earles et al. 2002). Interneurons participate in what is now recognized as pre-synaptic inhibition (PI), which has been shown to be capable of changing reflex amplitude during motor tasks regardless of excitation levels of alpha-motoneurons (Knikou 2008). Pre-synaptic inhibition has been said to be critical to the neural control of movement since it gates sensory afferent feedback to the spinal cord in order to assist in smooth execution of movement or motor task (Hultborn et al. 1987b). They act as high pass filters with the functional consequences during synaptic processing during behavior still remaining allusive (Frerking et al. 2006). Previous research has found that PI, which decreases the motor neuron response to I-a sensory neurons (afferent neurons), is greatest during running, less during walking and even less during standing (Wolpaw 2001). Its measurements in athletic individuals have been limited.

PI measures reveal how information flows through the nervous system (reflex loop), and allows a more specific investigation into how neural information in the spinal cord moves from one neuron to another. It is a form of activity-dependent neuromodulation. Two regulating mechanisms that can be estimated in humans by using non-invasive H-reflex methodology are extrinsic PI and intrinsic PI (Earles et al. 2002). In this study, they are termed EPI and IPI respectively.

Perez et al. (2005) tested H-reflex measurements and pre-synaptic changes during and 10 minutes following a learned visual-motor task. Researchers concluded that selective attenuation to pre-synaptic control of Ia afferents contributed significantly to the learning of a simple visual motor task by modulating sensory input, seeing that these significant changes returned to baseline after a 10 minute break. Earles et al. (2002) was one of the few studies to research pre and post synaptic control of motoneuron excitability in endurance and explosively trained athletes by gathering H-reflex, EPI and IPI values. Although inhibition increased in both groups, inhibition was significantly less in endurance-trained athletes during the EPI condition and significantly greater in the IP condition versus power-trained & un-trained subjects (Earles et al. 2002).

Despite the overwhelming evidence that indicates a significant role for neural mechanisms in the neuromuscular adaptations associated with changes in the level of chronic physical activity, there has been less progress in identifying specifically what these mechanisms are (Enoka 1997). The examination of interneurons has come of high interest due to its proposed abilities to examine beyond general training adaptations into the filters of the central nervous system that change according to chronic adaptation to specific sport activity. For example, even though softball players and volleyball players undergo explosive training via strength and conditioning practices, the activities required during their sports are very different (i.e. volleyball players require repeated jumping as softball does not). One of the few studies to compare two explosively-trained populations, Avela et al. (2006) tested H-reflex measurements on two groups, sprinters versus high jumpers. The researchers concluded there to be no difference in resting measurements but significant differences between groups when testing the H-reflex during movement…the sprinters had a decreased H-reflex during the drop-jump landing protocol. To current knowledge, no research protocol has examined two similarly conditioned groups utilizing EPI and IPI testing. Possible mechanisms of change may be apparent utilizing a more intimate method of testing for similarly trained groups.

Regarding procedure, most of the research has used a specific percentage of Mmax for conditioning during protocols dealing with pre-synaptic and post-synaptic potentials in order to make an even comparison. A percentage of a person's M max has traditionally been used as the conditioning value for the antagonist muscle during EPI testing. The problem with using this variable is that M max is reflective of a muscular response, which is affected by the amount of potential that a given person has. For example, 30% of a person's maximum M could be higher on the reflex curve and therefore need to be set at such high stimulus intensity that it causes complete inhibition. In Earles' et al. (2002) study, significant inhibition effect differences were seen between groups following a 10% threshold stimulus while no significant effect was seen using the 30% threshold stimulus, which begs to question if the 30% stimulation intensity was simply too high to detect any differences in inhibition even there were some (i.e. false negatives). This study used the motor threshold set at the intensity using light palpation of a subject's tibialis anterior tendon and set at first contraction in order to set a proper intensity reflective but not determinant of a muscular response.

Research on trained athletes has demonstrated that when stimulating intensities increase, inhibition increases in both the power- and endurance-trained groups; however, EPI is significantly less and IPI significantly more in endurance-trained group versus power- and un-trained groups during conditioning protocols (Earles et al. 2002).

The change in neural information, combined with trained status of an individual, has indicated that knowledge of metabolic demands is only part of creating an optimal periodized training schedule. To date, very little research has compared pre-synaptic inhibition in differing subgroups of athletes trained to produce similar reactions with regard to their required sporting movements.

Volleyball and softball athletes are trained to produce movement that is explosive in nature (under 6 seconds and encompass some form of triple extension/ trunk rotation) (NSCA 2010). However, volleyball players have added jump training to their sport conditioning whereas softball does not. The primary objective of this investigation was to measure levels of EPI, IPI and the H: M ratio in two groups of explosively trained elite level collegiate athletes in attempt to assess any trained-state difference in nervous system adaptation.

IRB Documents

Oregon State UNIVERSITY OSU Institutional Review Board
Office of Research Integrity

Initial Application

Please read through the entire application before beginning. *Requested information must be typed and submitted to the Human Protections Administrator, Office of Research Integrity, 308 Kerr Administration Bldg.* ***Be sure to allow adequate time for review and comments. Incomplete requests will delay the review process.*** *Applications will be returned without review if the application involves technical language without common explanations or if the application is poorly constructed grammatically. Send an email to IRB@oregonstate.edu or call (541) 737-8008 with any questions.*

Project Title: Muscle Activation Between Two Groups of Explosively-Trained Athletes			**IRB Application #:** Assigned by IRB Office
Principal Investigator: Mark A. Hoffman		**Department:** Nutrition and Exercise Science	
PI Email: mark.hoffman@oregonstate.edu			**PI Telephone:** 541-737-6787
Student Researcher: Marie E. Zidek		**Class or Degree Program (if requirement for student):** Masters of Science Degree - Thesis Requirement	
Primary Contact Person: Mark A. Hoffman	**Email:** mark.hoffman@oregonstate.edu		**Telephone:** 541-737-6787
Campus or US Mail Address (to send correspondence): Room 8 Women's Building			**Date:** 28 June 2009

1. **Level of Review Requested:**

   ☐ Exempt from Full Board — Allow a ***minimum of two weeks for the initial review*** and additional time for modifications, if required for approval.

   ☐ Expedited — Allow a ***minimum of one month for the initial review*** and additional time for modifications, if required for approval.

   ☒ Full Board — A schedule of upcoming Full Board meetings and submission deadlines can be found at: http://oregonstate.edu/research/osprc/rc/humansubjects.htm

2. **Method of Submission:**

   ☒ Via campus/US mail — Hard copy of application and appropriate materials (e.g., recruitment materials, informed consent document) sent in mail. ***For Exempt from Full Board applications submit 1 copy, for Expedited and Full Board applications submit 3 copies.***

   ☐ Via email — Submit application and appropriate materials as email attachments. ***The signature page (page 4) must be mailed or faxed to complete the application.***

3. **External Funding** (present or proposed):

   ☐ **Yes** Contract or grant title: _____
   Funding source: _____
   If funded by NIH, DHHS, PHS (including subcontracts), submit a copy of the grant.

   ☒ **No**

4. **Certification of Education:**

All research staff involved in this project must receive training in the ethical use of human participants in research. To document this training, the **Certification of Education form** must be submitted (available at: http://oregonstate.edu/research/osprc/rc/humansubjects.htm) . The Certification of Education form is **NOT** the confirmation issued by the educational tutorial. The Certification of Education form needs to be submitted only once for each researcher. ***Submission of all necessary certificates is a prerequisite to review.**

Research Staff Name	Role in Project	Certification of Education Submitted
Mark A. Hoffman	Principal Investigator	☒ Yes ☐ No*
Marie E. Zidek	Student Researcher	☒ Yes ☐ No*
Jeffrey Doeringer	Student Researcher	☒ Yes ☐ No*
Erica Perrier	Student Researcher	☒ Yes ☐ No*
		☐ Yes ☐ No*
		☐ Yes ☐ No*
		☐ Yes ☐ No*
		☐ Yes ☐ No*
		☐ Yes ☐ No*

Attach additional sheet if necessary.

5. **Project Start Date** (i.e., recruitment of human participants): 1 September 2009

6. **Expected Duration of the Study:** 180 days

7. **Does this study only involve de-identified data or samples?***

☐ **Yes** If "yes", then skip to Question 10.

☒ **No**

*Research involving the collection or study of existing data, documents, records, tissue culture cells, or pathological/diagnostic specimens, if these sources are publicly available or if the information is recorded by investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to subjects.

8. **Risk/Benefit Assessment:**

☒ Minimal risk

☐ Greater than minimal risk, but holds prospect of direct benefit to subjects

☐ Greater than minimal risk, no prospect of direct benefit to subjects but likely to yield generalizable knowledge about the subject's disorder or condition

☐ Research not otherwise approvable but presents an opportunity to understand, prevent, or alleviate a serious problem affecting the health or welfare of the subjects.

9. **Subject Population:**

Number of subjects that will be enrolled over the life of the study: 40
In order to enroll more than the number specified, a Project Revision request must be approved.

Participant age range (check all that apply):
Populations designated with an asterisk (*) are vulnerable populations and ineligible for exempt review.

- ☐ *0-7: Youth (include parental consent form)
- ☒ 18-65
- ☐ *8-17: Youth (include assent and parental consent)
- ☐ 65 and older

Populations targeted in this research (check all that apply):
Populations designated with an asterisk (*) are vulnerable populations and ineligible for exempt review.

- ☐ *Persons with mental/emotional/developmental disabilities
- ☐ *Pregnant women/fetuses/IVF
- ☒ Gender imbalances – all or more of one gender
- ☐ *Prisoners
- ☐ *Minority group(s) and non-English speakers
- ☐ Elderly subjects

10. **If the research involves any of the following, check the appropriate box:**

- ☐ Audio or videotaping
  Ineligible for Exempt review
- ☒ Survey/questionnaire
- ☐ Deception
  Requires review at Full Board level
- ☐ Behavioral observation
- ☐ Radiation
  Complete and submit Attachment A
- ☐ Study of existing data
- ☐ Human materials (i.e., blood or other bodily secretions)
  Complete and submit Attachment B
- ☐ Microorganisms or recombinant DNA
- ☐ Waiver of documentation (signature) of informed consent
  Include justification in the protocol
- ☐ Waiver of informed consent
  Include justification in the protocol
- ☐ Consent material in another language
  Include consent material in other language and an English translation; provide details regarding qualifications of translator and of research staff obtaining consent in other language
- ☐ Other research site (i.e. school, tribal reservation, etc)
  Provide documentation of the approval of the relevant IRB, school principal, tribal office, etc.
  Name of other research site(s): ______
- ☐ International research site
  Provide documentation of the approval of the relevant IRB, community leader, FWA, etc.
  Name of international research site(s): ______
- ☐ Submitted to another institution's IRB for review
  Name of institution: ______

11. Attachments (check all that apply):

- ☒ Protocol ***(required)***
- ☒ Consent Document
- ☐ Assent Document
- ☐ Attachment A: Radiation
- ☐ Attachment B: Human Materials
- ☐ Grant (required for NIH, DHHS, PHS funded projects)
- ☒ Recruiting tools (scripts for recruitment/screening)
- ☐ Test instruments (e.g., questionnaires, surveys)
- ☐ Material in other languages
- ☒ Additional information (e.g., debriefing materials)
- ☐ Approvals from other research sites (other IRB, school principal, tribal office, etc)

12. Will the study need to be registered with ClinicalTrials.gov?

☐ **Yes** For more information: http://www.oregonstate.edu/research/osprc/rc/humansubjects.htm

☒ **No**

13. Conflict of Interest:

Federal Guidelines require assurances that there are no conflicts of interest in research projects that could affect the welfare of human subjects. If this study presents a potential conflict of interest, additional information will need to be provided to the IRB. Examples of potential conflicts of interest may include, but are not limited to:

- A researcher or family member participating in research on a technology, process or product owned by a business in which the faculty member holds a financial interest
- A researcher participating in research on a technology, process or product developed by that researcher
- A researcher or family member assuming an executive position in a business engaged in commercial or research activities related to the researchers University responsibilities
- A researcher or family member serving on the Board of Directors of a business from which that member receives University-supervised Sponsored Research Support

For more information: http://oregonstate.edu/research/osprc/rc/conflictofinterest.htm

Conflict of Interest Statement:

Could the results of the study provide a potential financial gain to you, a member of your family, or any of the co-investigators that may give the appearance of a potential conflict of interest?

☐ **Yes** Please describe any potential conflicts of interest in a cover letter and disclose in the informed consent document.

Has this potential conflict been disclosed and managed? ☐ **Yes*** ☐ **No**

☒ **No**

IRB will confirm with Conflict of Interest Officer that potential conflicts of interest have been managed. Final IRB approval cannot be granted until all potential conflict matters are settled. The full IRB committee grants final approval regarding the disclosure of conflict statement in the consent form.

By signing below, I certify that the above information is accurate and complete. I understand that research involving human participants, **including recruitment**, may not begin until full approval has been granted by the IRB.

Signature______________________________ Date____________________

*Principal Investigator (required)**

***If submitting Initial Application via email, mail or fax this page with the PI's signature to the Human Protections Administrator.**

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 decide not to take part in this study, your decision will have no effect on the quality of care, services, athletic participation, etc. you receive. If you choose to withdraw from this project before it ends, the researchers may keep information collected about you and this information may be included in study reports.

WHAT IF I HAVE QUESTIONS?

If you have any questions about this research project, please contact: **Mark Hoffman, (541) 737-6787, mark.hoffman@oregonstate.edu; Marie Zidek, (541) 737-8252, marie.zidek@oregonstate.edu**

If you have questions about your rights as a participant, please contact the Oregon State University Institutional Review Board (IRB) Office, at (541) 737-8008 or by email at IRB@oregonstate.edu.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Participant's Name (printed): ____

______________________________ ______________________

(Signature of Participant) (Date)

Oregon State University • IRB Study #: 4379 Approval Date: 10/15/09 Expiration Date: 07/13/10

Nutrition and Exercise Science
Oregon State University, 101 Milam, Corvallis, Oregon 97331
Tel 541-737-2643 | **Fax** 541-737-6914 | Mendy.Gayler@oregonstate.edu | http://www.hhs.oregonstate.edu/home

INFORMED CONSENT DOCUMENT

Project Title: **Muscle Activation between two groups of explosively-trained athletes**
Principal Investigator: **Mark Hoffman, Nutrition and Exercise Science**
Co-Investigator(s): **Marie E. Zidek, Jeffrey Doeringer, Erica Perrier and Nutrition and Exercise Science**

WHAT IS THE PURPOSE OF THIS STUDY?

You are being invited to take part in a research study designed to determine if two groups of explosively-trained athletes that participate in different sports activate their muscles the same way. Our hypothesis is that the two sub-groups of explosively trained athletes (jumpers vs. non-jumpers) will have different activation patterns in their leg muscles. From this, we hope to have a better understanding of how best to train explosive athletes as well as how best to rehabilitate them should they become injured. The results and outcomes from this study are intended for publication. We are studying this, because further investigation is needed to understand if muscle activation is specific to sport played, not exclusive to the training and conditioning practiced.

WHAT IS THE PURPOSE OF THIS FORM?

This consent form gives you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask any questions about the research, the possible risks and benefits, your rights as a volunteer, and anything else that is not clear. When all of your questions have been answered, you can decide if you want to be in this study or not.

WHY AM I BEING INVITED TO TAKE PART IN THIS STUDY?

You are being invited to take part in this study because you are a healthy, female collegiate athlete between 18-25 years of age with no current lower extremity injury.

WHAT WILL HAPPEN DURING THIS STUDY AND HOW LONG WILL IT TAKE?

You will have an informational session in which you will sign this document as well as address any questions/ concerns. You will change into appropriate attire if necessary (which includes sneakers, shorts, and t-shirt). Following, you will have skin prepared for the application of 9 electrodes. Skin preparation includes cleaning the skin where the electrodes will be placed; should leg hair be thought to potentially interfere with testing, leg hair will be shaved. You will receive a series of electric stimuli that will gradually increase in strength until maximum muscle contraction is achieved. Approximately 30-50 stimulations will be given. Your muscles will be electrically stimulated using two machines in the Sports Medicine Lab. Individuals vary in their ability to tolerate the discomfort associated with this procedure. At any time, you may inform the researcher if the stimulus becomes uncomfortable for your tolerance and/or want to the procedure to stop and be discontinued. Although the possibility of a harmful stimulation is possible anytime electrical stimulation is being used no harmful occurrences have been documented in past and current literature. We will determine appropriate stimulus placement in order generate the proper reflex. You will then lie face down on a cushioned table for actual reflex testing. No more than 50 reflexes will be gathered. After all data is collected, we will remove the electrodes and you will be provided a towel to wipe the lubrication gel from your leg. Should you feel discomfort at any time, you may notify the researcher to stop data collection immediately.

If you agree to take part in this study, your involvement will last for about 55 minutes.

WHAT ARE THE RISKS OF THIS STUDY?

The possible risks and/or discomforts associated with the procedures described in this study include: the use of electrical stimulation, there may be a slight level of discomfort associated with the testing. This level of discomfort has been described as a sensation of a "carpet shock." Since you are connected to electrical equipment the possibility exists that you may receive a harmful shock if there were a malfunction with the equipment. Although the possibility of a harmful stimulation is possible anytime electrical stimulation is being used no harmful occurrences have been documented in past and current literature. Subjects will be encouraged and reminded to alert the investigator if any of these symptoms appear. If any of these symptoms do occur, the testing will be discontinued immediately and the subject will be screened for life threatening symptoms.

STUDIES INVOLVING POTENTIAL FOR PHYSICAL INJURY

Oregon State University and the researchers have no plan or fund to pay for medical treatment of research related injuries. If you think that you have been injured as a result of being in this study, please contact the researcher.

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study. However, we hope that, in the future, other people might benefit from this study because we will have a better understanding if subgroups of explosively trained populations activate their muscles differently with respect to different sport participation.

WILL I BE PAID FOR PARTICIPATING?

You will not be paid for being in this research study.

WHO WILL SEE THE INFORMATION I GIVE?

The information you provide during this research study will be kept confidential to the extent permitted by law. To help protect your confidentiality, we will use code numbers on all data forms. All documents will be filed safely in the Sports Medicine Lab office, a secured location.

If the results of this project are published your identity will not be made public.

DO I HAVE A CHOICE TO BE IN THE STUDY?

Institutional Review Board ▪ Office of Sponsored Programs and Research Compliance
Oregon State University, 312 Kerr Administration Building, Corvallis, Oregon 97331-2140
Tel 541-737-4933 | **Fax** 541-737-3093 | http://oregonstate.edu/research/osprc/rc/humansubjects.htm
IRB@oregonstate.edu

NOTIFICATION OF APPROVAL

Date: October 15, 2009

Principal Investigator: Mark A. Hoffman, Nutrition and Exercise Sciences
Study Team Members: Marie E. Zidek, Jeffrey Doeringer, and Erica Perrier (Student Researchers)

Re: 4379 - Muscle Activation Between Two Groups of Explosively-Trained Athletes

Review Category: Full Board

Approval Date: 07/14/09 Expiration Date: 07/13/10

Approved Number of Participants: 40

The above referenced project was reviewed and approved by the Oregon State University's Institutional Review Board (IRB).

The IRB has approved the: Initial Application

As principal investigator of the research, you are responsible for fulfilling the following requirements of approval:

1) All study team members should be kept informed of the status of the research.
2) Any changes to the research must be submitted to the IRB for review and approval prior to the activation of the changes.
3) Reports of unanticipated problems involving risks to participants or others must be submitted to the IRB within three calendar days.
4) Only consent forms with a valid approval stamp may be presented to participants.
5) Submit a continuing review application or final report to the IRB for review at least four weeks prior to the expiration date. Failure to submit a continuing review application prior to the expiration date will result in termination of the research, discontinuation of enrolled participants, and the submission of a new application to the IRB.

If you have any questions, please contact the IRB Office at IRB@oregonstate.edu or by phone at (541) 737-8008.

Data Table

Subject	ID	Hmax	Mmax	H:M ratio	EPI	IPI	Age	Height	Weight
1	0	3.87	6.66	0.51	0.78	0.59	21	172.72	86.36
2	0	2.34	3.26	0.72	0.35	0.03	21	175.26	75.91
3	0	3.60	5.60	0.64	0.77	0.04	21	187.96	85.45
4	0	6.60	10.70	0.62	0.74	0.06	18	175.26	81.82
5	0	4.33	5.20	0.83	0.91	0.02	19	180.34	95.45
6	0	6.16	11.15	0.55	0.06	0.02	21	162.56	56.82
7	0	5.75	7.85	0.73	1.01	0.11	18	157.48	53.64
8	0	2.92	11.05	0.26	0.85	0.06	18	167.64	65.91
9	0	4.78	7.30	0.65	0.93	0.01	19	180.34	97.73
10	0	4.05	10.52	0.38	0.84	0.01	21	143.00	65.91
11	0	6.12	15.20	0.40	0.85	0.00	19	162.56	59.09
12	1	7.50	9.53	0.79	1.22	0.05	21	187.96	75.00
13	1	3.40	8.20	0.41	1.16	0.03	21	182.88	63.64
14	1	4.81	6.47	0.74	1.86	1.09	21	193.04	90.91
15	1	2.54	11.26	0.22	0.43	0.02	18	187.96	79.55
16	1	8.57	12.96	0.66	0.19	0.00	18	185.42	77.27
17	1	2.88	9.31	0.30	0.95	0.19	20	176.53	65.91
18	1	2.01	2.51	0.81	0.26	0.02	20	187.96	68.18
19	1	16.12	18.70	0.86	0.20	0.03	18	182.88	77.27
20	1	2.57	10.71	0.24	0.66	0.02	18	177.80	70.00

Statistics

ID		Hmax	Mmax	HMratio	EPI	IPI
0	Mean	4.59	8.59	0.57	0.74	0.09
	N	11	11	11	11	11
	SD	1.41	3.45	0.17	0.28	0.17
1	Mean	5.60	9.96	0.56	0.77	0.16
	N	9	9	9	9	9
	SD	4.57	4.46	0.260	0.57	0.35
Total	Mean	5.05	9.21	0.57	0.75	0.12
	N	20	20	20	20	20
	SD	3.18	3.89	0.21	0.42	0.26

		F	Sig.	t	df	Sig. (2-tailed)
Hmax	Equal variances assumed	6.73	0.02	-0.70	18.00	0.50
	Equal variances NA			-0.64	9.25	0.54
Mmax	Equal variances assumed	0.04	0.85	-0.78	18.00	0.45
	Equal variances NA			-0.76	14.91	0.46
HMratio	Equal variances assumed	6.38	0.02	0.13	18.00	0.90
	Equal variances NA			0.13	13.24	0.90
EPI	Equal variances assumed	6.62	0.02	-0.18	18.00	0.86
	Equal variances NA			-0.17	11.11	0.87
IPI	Equal variances assumed	1.57	0.23	-0.63	18.00	0.54
	Equal variances NA			-0.58	11.01	0.57

Non- Parametric Ranks, Mann-Whitney U

	id	N	Mean Rank	Sum of Ranks
HM	0	11	10.18	112.00
	1	9	10.89	98.00
	Total	20		
EPI	0	11	10.45	115.00
	1	9	10.56	95.00
	Total	20		
IPI	0	11	10.32	113.50
	1	9	10.72	96.50
	Total	20		

Test Statistics[b]

	HM	EPI	IPI
Mann-Whitney U	46.000	49.000	47.500
Wilcoxon W	112.000	115.000	113.500
Z	-0.266	-0.038	-0.154
Asymp. Sig. (2-tailed)	0.790	0.970	0.878
Exact Sig. [2*(1-tailed Sig.)]	0.824[a]	1.000[a]	0.882[a]

a. Not corrected for ties.

b. Grouping Variable: id