Corticospinal mechanisms for muscle activation in resistance-trained and non-trained males

- A cross-sectional study

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AND HEALTH SCIENCE
Master Degree Project 91:2014
Master program: 2013-2015
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Abstract

Aim

The purpose of this study was to compare resistance-trained (RT) and non-trained (NT) males regarding mechanisms for neural activation during isometric muscle contractions of the soleus muscle. Further the plantar flexor strength of the two groups were compared.

Method

Ten males that had been resistance training for at least 3 years (RT) and 10 who did not train regularly (NT) participated in the study. The participants performed isometric contractions of their right plantar flexors against an isokinetic dynamometer at 15, 25, 50, 80 and 100% of maximal voluntary contraction. Five contractions were performed for each level in two different conditions; one where the participants were stimulated using transcranial magnetic stimulation over the left motor cortex and one in which they were stimulated electrically over the tibial nerve. Stimulations were also delivered at rest. The resulting soleus muscle motor evoked potentials (MEPs) and V-waves were normalized to a maximal M-wave (Mmax). Plantar flexor strength was measured and voluntary activation estimated using the twitch interpolation technique.

Results

No significant difference was found between the RT and the NT group for voluntary activation, V/Mmax ratio or MEP/Mmax at any level of maximal voluntary contraction (MVC). The RT group was significantly stronger than the NT group.

Conclusions

The study showed that the RT group was stronger than the NT group. Despite the difference in strength there was no significant group difference between the two groups in MEPs, V/Mmax or voluntary activation. This indicates that there is no, or a very small difference in corticospinal excitability of the soleus muscle between the chronic RT males and the NT males.

Keywords: electromyography, isometric contraction, m. soleus, resistance training, transcranial magnetic stimulation, V-wave.

List over short titles

AMT – Active motor threshold

EMG – Electromyography

LOA – Level of activation

MEP – Motor evoked potential

Mmax – Maximal M-wave

MVC – Maximal voluntary contraction

NT – Non-trained

RM – Repetition maximum

RT – Resistance trained

TMS – Transcranial magnetic stimulation

Table of content

1. Introduction

Resistance training is a commonly used exercise method to achieve strength gains in the general population as well as in athletes. It is used in rehabilitation settings as well as in wellness settings. Much is known on the effects of resistance training on the muscle itself but considerably less is known on how the nervous system controlling the muscle adapts to resistance training.

Resistance training of sufficient intensity causes improvements in strength that are believed to occur due to neural and muscular adaptations. The first increase in strength when beginning to resistance train occurs before muscle hypertrophy can be measured (Akima, Takahashi, Kuno, Masuda, Masuda, Shimojo, Anno, Itai & Katsuta 1999), muscle hypertrophy has been seen after only a few days at a time when the hypertrophy is to small to explain the increases in strength (Seynnes, de Boer & Narici 2007). Strength gains from training regimes consisting of concentric, eccentric and isometric training cannot be solely explained by increased cross-sectional muscle area (Jones & Rutherford 1987). A decrease in activation of antagonist muscles have been shown in trained individuals compared to sedentary (Amiridis, Martin, Morlon, Martin, Cometti, Pousson & van Hoecke 1996). Furthermore a period of resistance training increases the ability to voluntarily activate the agonist muscle fully (Del Balso & Cafarelli 2007), although contrasting evidence, i.e. no change in voluntary activation has been demonstrated when young men participate in resistance training at up to 85% of RM (Walker & Häkkinen 2014). There is also evidence of resistance training resulting in cross-education, i.e. unilateral training improves strength in the contralateral limb (Farthing JP, Borowsky R, Chilibeck, Binsted & Sarty 2007; Lepley & Palmieri-Smith 2014; Magnus, Arnold, Johnston, Dal-Bello Haas, Basran, Krentz & Farthing 2013).
Among the neural adaptions that have been proposed to underpin improvements in neural activation are changes in the firing rate of the motor unit, enhanced synchronization of motor unit activity, spinal reflex alterations and changes in corticospinal excitability and inhibition (Carrol, Selvanayagam, Riek & Semmler 2011).
What is less known is if the acute responses observed after a brief period of resistance training remain after a longer period of training or if they are transient. When studying how a period of resistance training is affecting the spinal motoneurons and spinal reflexes researchers can either evoke the Hoffman reflex (H-reflex) or the V-wave. The H-reflex is measured during rest and the V-wave is measured during maximal voluntary contraction (MVC) which makes

the V-wave more suitable if enhanced neural drive is to be taken into consideration. (Folland & Williams 2007) To study if the changes arise from the motor cortex there is primarily two methods used, transcranial electrical stimulation (TES) and transcranial magnetic stimulation (TMS). Both of the methods can be used to stimulate the motor cortex directly in a similar way. Today TES is rarely used compared to TMS due to the fact that TES is painful, TMS can produce similar results but with little or no pain. (Hallet 2007)

1.2 Transcranial magnetic stimulation

TMS is a commonly used method to assess the corticospinal excitability and its contribution to neural adaptations following strength training. TMS is a noninvasive method to stimulate the motor cortex through the use of a high-intensity magnetic field. (Hallett 2007). TMS excites somas and dendrites of neural cells in the tissue underlying a coil held over the head. Direct and indirect action potentials are induced in the motor neurons in the primary motor cortex. These action potentials travel down the corticospinal tract, excite the motor neurons in the spinal cord and then activate the muscle in the limb contralateral to the stimulation. The amplitude of the motor evoked potential (MEP) in the muscle is believed to reflect the level of corticospinal activation of the spinal motoneuron pool. (Kidgell, Stokes, Castricum & Pearce 2010b) TMS is used both in a clinical context as a therapy tool and when researching diseases as stroke and Parkinson´s disease (Machado, Arias-Carrión, Paes, Vieira, Caixeta, Novaes & Nardi 2013), TMS have also been used to assess if and how much of the neurological changes due to strength training that is contributed to the motorcortex (Hallet 2007).

1.3 Motor neuron activation

Another method to assess the role of the motor cortex is to measure the voluntary wave (V-wave) in comparison to the M-max. The V-wave is measured by stimulating the peripheral nerve with a supramaximal electrical stimulation (Figure 1). The stimulation will evoke action potentials that travels in the alpha motor axon to the muscle and is recorded as an M-max. The electrical stimulation will also elicit antidromic action potentials that will travel toward the spinal cord and on the way there collide with orthodromic action potentials that stems from the descending voluntary signals. The electrical stimulation will also elicit action potentials travelling towards the spinal cord in Ia afferents that will stimulate a reflex from the spinal cord and send action potentials back through alpha motor axons. As a consequence, the bigger the voluntary drive, the bigger the cancellation of antidromic signals will be and the bigger the V-wave amplitude will be from the evoked reflex. The V-wave is therefore elicited in the same way as the H-reflex with the difference of a voluntary contraction when eliciting the V-wave. Although the V-wave is also affected by the presynaptic inhibition of Ia afferents and motoneurone excitability, this means that V/Maximal M-wave (Mmax) may be used as evidence of the extent of the alpha motor neurone output during voluntary activation. (Aagaard, Simonsen, Andersen, Magnusson & Dyhre-Poulsen 2002)

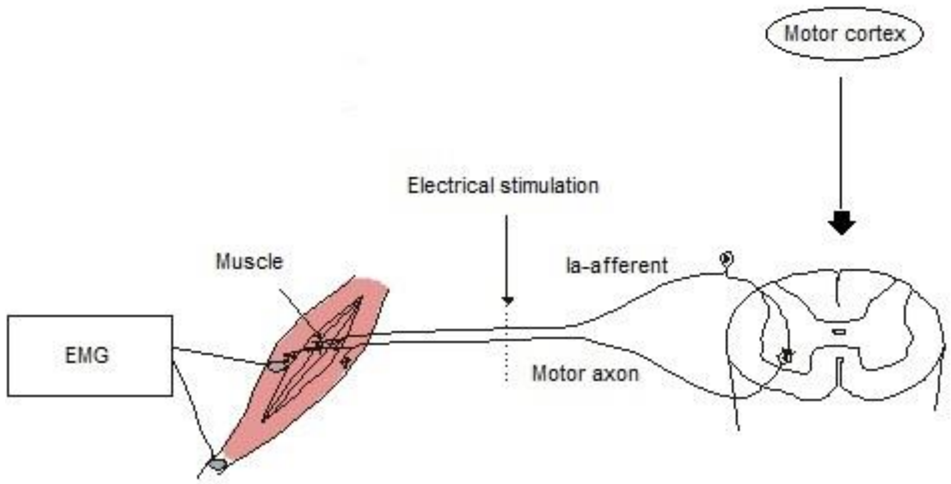

Figure 1. The peripheral electrical stimulation

1.4 Short term adaptations to resistance training

There has been a large amount of studies using the TMS to evaluate shorter bouts of resistance training (Beck, Taube, Gruber, Amtage, Gollhofer & Schubert 2007; Carroll, Barton, Hsu & Lee 2009, Carroll, Riek & Carson 2002; Griffin & Cafarelli 2006; Jensen, Marstrand & Nielsen 2005; Kidgell & Pearce 2010a; Kidgell 2010b). The results have been inconsistent, with some studies reporting a higher MEP amplitude at different MVC levels or during rest (Carrol et al. 2009; Griffin & Cafarelli 2006; Kidgell et al. 2010b) and other studies demonstrate the opposite or no difference (Beck et al. 2007; Carrol, Riek & Carson 2002; Jensen, Marstrand & Nielse 2005; Kidgell & Pearce 2010a).

Resistance training of the index finger during five weeks has led to a reduction of the MEP amplitude at MVC levels of 40, 50 and 60% (Carrol, Riek & Carson 2002). The index finger has also been studied by Kidgell and Pearce (2010a) which compared the MEP amplitude after resistance training of the index finger. In their study they found no significant differences when comparing MEP amplitude before and after the intervention. A muscle group of the upper limb which also has been studied, is the radial deviator muscles. A larger amplitude of MEP at low MVC levels was found after four weeks of resistance training, whereas MEP amplitude at higher levels were not altered. (Carrol et al. 2009) MEP/Mmax (MEP amplitude expressed as a percentage of the corresponding M-wave) at rest has been reported to decrease after 4 weeks of resistance training of the m. biceps brachii. At different levels of voluntary contraction no changes could be found. (Jensen, Marstrand & Nielsen 2005) In contrast to this result, Kidgell et al. (2010b) found a much higher MEP amplitude after four weeks of resistance training of the m. biceps brachii. The large-sized difference between corticospinal excitability in studies comparing the same muscle can be attributed to training on different levels of repetition maximum (RM) and how well controlled the training is (Kidgell et al. 2010b). In the study by Kidgell et al. (2010b) they also required the participants to do the resistance training in a controlled pace, which might increase the skill requirements and therefore could affect the result. Skill training has been seen to alter the MEP amplitude (Jensen, Marstrand & Nielsen 2005). The effect of short-term resistance training has also been investigated at lower limb muscles although not to the same extent. Ballistic strength training of the ankle for four weeks did not alter the MEP size in neither m. tibialis anterior or m. soleus (Beck et al. 2007). The m. tibialis anterior has also been tested after regular resistance training by Griffin and Cafarelli (2006), who found that four weeks of training resulted in significantly higher MEP amplitudes assessed at 10% MVC but not when assessed at rest.

The inconsistent results might be due to the different muscles being trained, the way the resistance training were conducted and the different ways of performing the TMS testing (Kidgell et al. 2010b). Griffin and Cefarelli (2006) concluded that findings of their and previous studies indicate that a few weeks of progressive resistance training results in an increased corticospinal excitability that likely is a manifestation of higher initial firing frequencies of motor neurons and lower recruitment threshold resulting in a higher rate of rise of the torque and higher overall torque development.

V-wave measuring has also been used to evaluate the effect of short term resistance training. V/Mmax has been increased in participants who resistance train for a short period of time (Aagaard et al. 2002; Del Balso & Cafarelli 2007; Fimland, Helgerud, Gruber, Leivseth &

Hoff 2009a; Fimland, Helgerud, Solstad, Iversen, Leivseth & Hoff 2009b; Nordlund Ekblom 2010; Vila-Chã, Falla, Correia & Farina 2012). The results of a period of rather heavy resistance training for 3-14 weeks seem to result in an increase of V/Mmax ratio of between 53% (Fimland et al. 2009a) and 109% (Fimland et al. 2009b). The results are rather consistent although the studies uses similar but different training regimens.

1.5 Chronic adaptation to resistance-training

So far, only a few studies have examined the long term effects of resistance training on corticospinal excitability using TMS (Del Olmo, Reimunde,Viana, Acero & Cudeiro 2006; Pearcey, Power & Button 2014; Tallent, Goodall, Hortobágyi, St Clair Gibson & Howatson 2013). Del Olmo et al. (2006) compared the evoked force and MEP amplitude at different levels of MVC when activating the m. biceps brachii. They did not find any significant differences in MEP amplitude between resistance-trained (RT) men or non-trained (NT) men. What they found was a difference between the two groups when comparing TMS evoked force. The NT group had a higher evoked force at every activation level, indicating a lower voluntary activation for the NT group. The group of Pearcey, Power and Button (2014) investigated the difference in corticospinal excitability between RT men and NT when activating m. biceps brachii. They found that the RT group had a ~15% lower MEP amplitude compared to the NT group on activation levels of 60% MVC and higher. The authors suggest that this change might be due to an altered function on a spinal level, with a higher firing frequency of the motoneurons as the main reason. In the only study where the muscle studied is of the lower limb, (Tallent et al. 2013) the authors compared the activation of the tibialis anterior muscle between RT men and NT men. There were no significant difference between the two groups either when comparing MEPs. The authors conclude themselves that the lack of difference might be lacking due to the fact that m. tibialis anterior is seldom a specifically targeted muscle when resistance training.

The effect of chronic resistance training on V-wave has only been investigated in a few studies (Sale, Upton, McComas & MacDougall 1983, Tallent et al. 2013). Weight-lifters and bodybuilders have been compared to men with no experience of weight training (Sale et al. 1983). The experienced weight-trainers had a 70% higher V/Mmax compared to the control group. Tallent et al. (2013) found no significant differences in V/Mmax between RT men and NT men.

The only muscle of the lower extremity were chronic adaptations of resistance training has been studied with TMS is a muscle which is seldom trained during resistance training. Therefore there is a need to evaluate if the corticospinal and/or spinal excitability is different between RT and NT individuals in muscles that are more commonly engaged in resistance training. The soleus muscle is a muscle that fit this description, and has a good accessibility to the peripheral nerve in comparison to the quadriceps and hamstring muscles. With all this in mind the following purpose were formed.

The purpose of this study was to compare RT and NT males regarding responses evoked by TMS and peripheral nerve stimulation, measured during isometric muscle contractions of the soleus muscle. The main research questions were:
Is there a group difference in strength and voluntary activation between RT men and NT men?
Is there a group difference in V/Mmax at MVC between RT men and NT men?
Is there a group difference in MEP/Mmax-ratio between RT men and NT men at different levels of MVC?

2 Method

2.2 Participants

Twenty male adults participated in the study. Ten participants were RT (age 25.4 SD=3.6) and ten were NT (age 23.9 SD=3.9) males. The participants in the RT group had to have a history of at least three years of resistance training, consisting of three or more training sessions per week. The participants in the NT group were not performing resistance training on a regular basis nor participated at any kind of training at a high level. The test was performed on the right leg, which for all the participants was the dominant leg. The left motor cortex were stimulated in all participants. The participants were recruited through advertisement (attachment 1) and by mouth to mouth. Each participant gave written conformed consent to participate (attachment 2) and completed the GIH (The Swedish School of Sport and Health Sciences) health survey. Exclusion criteria’s were: epilepsy, having a pace-maker, hypotension, having a heart disease or having a psychiatric illness.

2.3 Study design

The participants completed the test-protocol (attachment 3) over two hours in one day in the laboratory at GIH. TMS responses and M- and V-waves were recorded at both rest and during isometric contractions of the plantar flexors at 15%, 25%, 50%, 80% and 100% of MVC. The test-protocol was standardized and the participants performed the different contractions at a randomized order. The reason for the choice of the plantar flexors is the good accessibility to the peripheral nerve and that the plantar flexors probably is more commonly resistance trained than the other muscles of the lower leg. The participants were instructed to not perform resistance training during the last 24 hours before participation and not ingest coffee during the day of the experiment.

2.4 Test-protocol

The participants were positioned laying on their back, with straps over their shoulders, arms and the dominant leg to maintain the same body position during the whole test-protocol. The ankle was locked in a 90 degrees position with the right foot placed on a metal plate attached to an isokinetic dynamometer (IsoMed 2000, D. & R. Ferstl, Hemau, Germany) and with the knee in full extension (figure 2). Participants were provided with visual feedback of their ongoing plantar flexor torque and the MVC percentage level they were supposed to achieve. A horizontal cursor in the same data window indicated the requested torque level. Participants initially performed warm-up contractions to familiarize with the task. Subsequently, participants were verbally encouraged to perform a maximal isometric contraction against the footplate and to hold the contraction for 2-3 seconds. The participants performed two maximal contractions from which the highest torque value was selected as the MVC. Verbal encouragement and visual feedback of ongoing torque was provided. The torque level achieved during this effort was used for calculating torque levels used in the following protocol.

The participants performed five contractions per MVC percentage level, allowing a resting period of 30 seconds between every isometric contraction at the 15%, 25% and 50% of MVC and a resting period of 60 seconds between contractions at 80% and 100%. The same protocol were used for both TMS and peripheral nerve stimulation. The order of the contractions and TMS or peripheral stimulation were randomized and mirrored so that one person in each group had exactly the same test-protocol as one in the other group. After half of the protocol (i.e. either the TMS or the peripheral nerve stimulation) the participants were allowed a few minutes rest in a seated position before proceeding. When all the isometric plantar flexor contractions in the test-protocol were completed, a MVC of the dorsal flexors were recorded in the same fashion as the plantar flexors.

Figure 2. The isometric contraction was performed with the knee in extension and the ankle in 90 degrees position. Electrodes were placed over m. soleus, m. tibialis anterior, m. gastrocnemius, the head of the fibula and the medial aspect of the knee joint.

2.5 Electromyography recording and evoked potentials

EMG was recorded over the soleus muscle, the tibialis anterior muscle and the medial gastrocnemius muscle (of which the results of the tibialis anterior and gastrocnemius muscle are not presented in the present study) using bipolar surface electrodes (Ag-AgCl, Blue M-00-A, electrode sensor area: 13.2 mm^2, Ambu, Olstycke, Denmark) that were placed according to ABC of EMG with an inter electrode distance of 1.5 cm (Konrad 2005). The reference electrodes were placed over the head of the fibula and over the medial aspect of the knee joint. The skin over the muscles was shaved and cleansed with an alcohol wipe. The EMG-signals were amplified 1000 times, filtered between 10-1000 Hz and sampled at 5 kHz (1401, Cambridge Electronic Design). The M-wave, V-wave and MEP of the m. soleus were measured as peak-to-peak, and calculated as the mean of all five contractions at each level of MVC. Surface EMG measurements of the soleus muscle have previously shown to represent muscle group activity rather than single muscle activity (De Luca & Merletti 1988; Perry, Easterday & Antonelli 1981) but showing a high reliability for repeated measurements over time (Ochia & Cavanagh 2007).

2.6 Transcranial stimulation procedure

A Magstim 200 magnetic stimulator (The Magstim Company Ltd, Carmarthenshire, UK) with a double cone coil was used to evoke MEPs. The coil was placed over the contralateral motor cortex and the optimal location for coil placement was marked on the scalp with ink. The optimal location for motor cortex stimulation (hot spot) was defined as the location where the lowest TMS-stimuli would generate a MEP of 0.1-0.2 mV when performing a contraction of 20% of MVC. The TMS-stimuli that was sufficient to create a MEP of 0.1-0.2 mV was defined as the active motor threshold (AMT). Once the hot spot was established, the participant was asked to perform isometric contractions at the different percentages of MVC in a randomized order while being stimulated at an intensity of 1.2* AMT. (figure 3) During the whole experiment, the coil was handled by one of the researchers trying to keep the coil in the same position throughout the test-procedure. TMS have not been validated in the context of resistance training but is widely used to study the human primary motor cortex and its role in strength gains (Kidgell & Pearce 2011). TMS has been reported to have the highest reliability for assessment of corticospinal excitability when the number of consecutive stimulations reach 30 or more (Cuypers, Thijs & Meesen 2014).

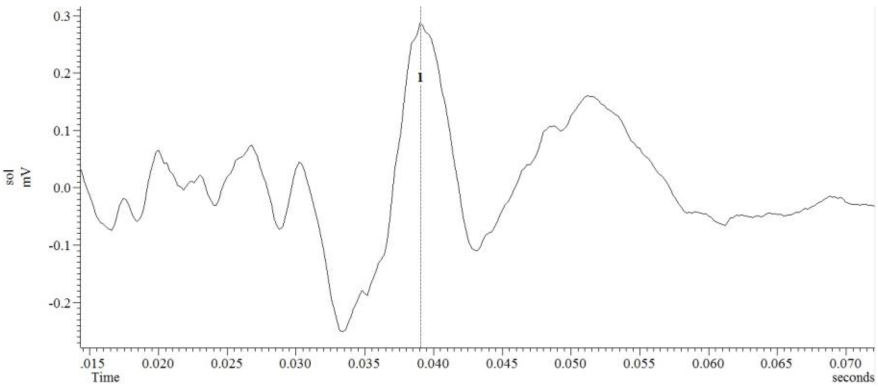

Figure 3. An example of a TMS. The mean of the five trials at 50% of MVC from a RT individual. Cursor 1 is situated at the peak of the MEPs.

2.7 Peripheral electrical stimulation procedure

Current pulses were delivered via a constant current stimulator (Digitimer DS7A, Digitimer, Hertfordshire, UK), through an anode (carbon rubber electrode, 100 × 50 mm, CEFAR Medical, Malmö, Sweden) placed proximal of the patella and a cathode (Ag-AgCl, Blue M-

00-A, electrode sensor area: 13,2 mm², Ambu) positioned at the optimal stimulating site in the popliteal fossa over the tibial nerve. To determine the stimulus intensity to be used in the protocol, the stimulation intensity was started at a subliminal level and was increased until there was no increase to the M-wave or twitch torque despite increasing the intensity of the stimulation. The intensity of the stimulation was set at 1.2 times the intensity required to evoke the maximal M-wave. The peripheral nerve stimulation was then administered in the same way as the TMS-stimulation, for isometric contractions at every MVC percentage level and at rest. Measuring of the V-wave (figure 4) has been shown to have substantial reliability when measured in the soleus muscle (Solstad, Fimland, Helgerud, Iversen & Hoff 2011).

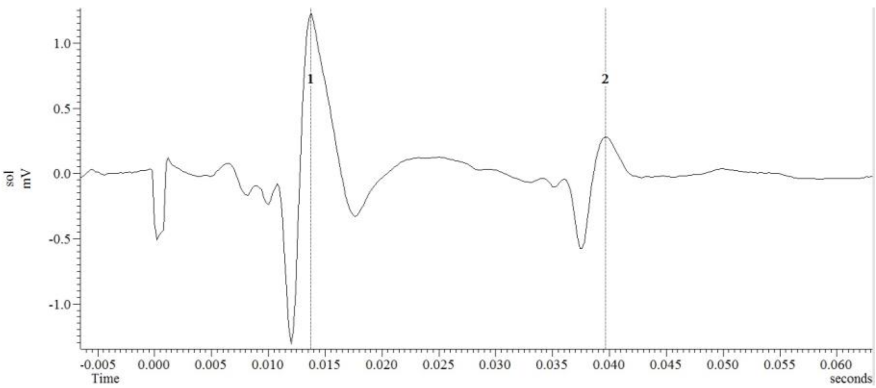

Figure 4. An example of a V-wave. The mean of the five trails at 50% of MVC from a RT individual. Cursor 1 is situated at the peak of the M-wave and cursor 2 at the peak of the V-wave.

2.8 Torque measurements

Torque signals were analog to digital converted at 5 kHz using a CED 1401 data acquisition system and Signal software (Cambridge Electronic Design, Cambridge, UK).

The MVC of the participants was calculated taking the baseline value during the MVC and subtracting the baseline value during rest. The twitch interpolation technique was used to assess the level of activation (LOA) of the participants. This technique uses the ratio between the amplitude of the interpolated twitch and the resting twitch using the formula: voluntary activation = 100*[1-(interpolated twitch /resting twitch)]. The interpolated twitch is the twitch seen after electrical supramaximal stimulation during MVC and was calculated by using the difference between the baseline 50 ms before stimulation and the peak from stimulation and up to 250 ms after. Resting twitch was measured in the same way but with no voluntary activation. In the present study the interpolated twitch was calculated using the mean from the 5 contractions at 100% of MVC.

2.9 Statistics and data analysis

After checking the normal distribution of the data using Shapiro Wilks W-test, maximal strength, maximal LOA, V/M ratio and MEP/Mmax ratio was compared between groups using the independent samples t-test for normally distributed data and Mann Whitney U-tests for non-normally distributed data. Normally distributed data are described as mean (SD) and non-normally distributed data as median (25^{th} and 75^{th} percentile). The level of significance was set at $p<0.05$. All statistical procedures were performed using the Statistica software package (version 12.0, Statsoft).

2.10 Ethical considerations

The participants were given oral and written information about the study and the experimental setup before deciding to participate. Before entering the study the participants were screened for contraindications. Participation was voluntary and the participants were informed that they could cancel their participation at any given moment without having to explain themselves. The TMS can be perceived to be unpleasant but does usually not cause pain. The peripheral nerve stimulation can cause pain and discomfort but the pain is only temporary. TMS is generally considered to be very safe and can be used with a minimal risk (Kidgell 2011).

3. Results

3.2 Torque measurements

The MVC of the RT group (260.2± 19.9 N) was significantly (p=0.033) higher than that of the NT group (226.6± 41.5 N).

The LOA of the RT group (96.0, Q1=95.2 Q3=99%) did not differ significantly (p=0.473) from that of the NT group (94.3, Q1=91.8 Q3=98.3%).

3.3 Evoked potentials

There was no significant difference (p=0.724) in normalized soleus V-wave amplitude (V/Mmax) between the RT 0.349 (SD=0.1) and the NT 0.326 (SD=0.1) group (p=0.494). (Figure 5).

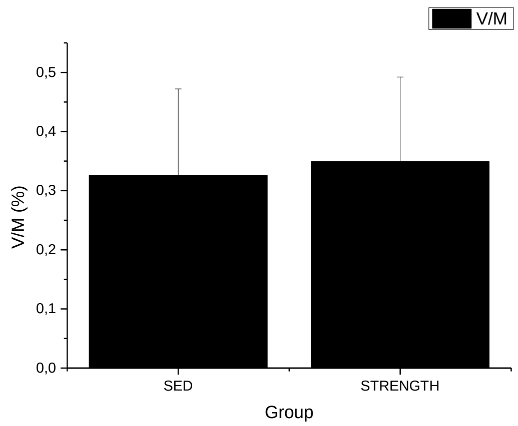

Figure 5. Mean (SD) V/Mmax at 100% MVC for the NT (SED) and RT (STRENGTH).

Since the MEP/Mmax were non-normally distributed, differences between the RT and the NT group were tested using Mann Whitney U-tests for each MVC level. There was no significant difference (ranging p=0.241 - p=0.791) in soleus MEP/Mmax ratio between the RT group and the NT group at any of the 6 tested levels of activation. (Figure 6)

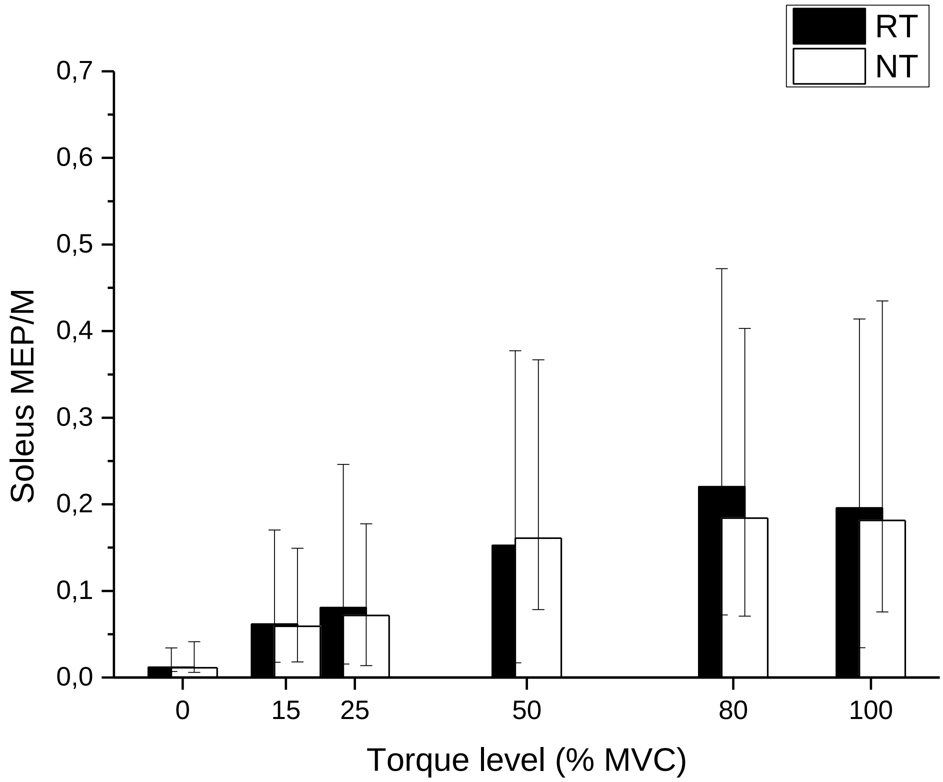

Figure 6. Median (25th and 75th percentile) of m. Soleus gastrocnemius MEPs normalized to the M-wave at different levels of activation for resistance trained (RT, in black) and non-trained (NT, in white) individuals.

The stimulator output level (1.2* AMT) of the RT group was 49.8 (SD=13.3) and the NT group 54.0 (SD=13.6).

4. Discussion

The purpose of this study was to compare RT and NT males regarding corticospinal and spinal responses to TMS and peripheral nerve stimulation, measured during isometric muscle contractions of the soleus muscle. This is the first study that has compared TMS and V-wave responses in the soleus muscle in chronic RT men and NT men.

The main findings of the study were that there were no significant difference between the RT and the NT men in LOA, V/Mmax or MEP/Mmax ratio, despite a significant difference in their training experience as also substantiated by a significant difference in the MVC of the RT men and the NT men.

The current study demonstrated that the RT group did not have a significantly higher normalized V-wave amplitude as compared to the NT group. Previous studies found an increase of V-wave amplitude after resistance training interventions (Aagaard et al. 2002; Nordlund Ekblom 2010; Del Balso & Cafarelli 2007). Higher V/Mmax ratios are usually interpreted as a sign of elevated motoneuronal output, but can also be caused by decreases in presynaptic inhibition of the Ia afferents or increased motoneurone excitability. If the V/Mmax is increased after an acute training intervention without any substantial change in the H-reflex however, the elevated V/Mmax is interpreted to be related to enhanced supra spinal input to the motoneurone pool. Studies where changes in V-waves and H-reflexes have been compared after resistance training interventions have presented conflicting results. Most studies show an increase of the V-wave and no change in resting H-reflex (Aagaard et al. 2002; Beck et al. 2007; Fimland et al. 2009a; Fimland et al. 2009b Nordlund Ekblom 2010), but there is at least one study were the authors have found increases in H-reflex during activation (Aagaard et al. 2002).

In the present study, the voluntary activation of the participants was higher than that found in some studies (Nordlund Ekblom 2010) and equal to or lower compared to other studies measuring voluntary activation of the plantar flexors (Del Balso & Cafarelli 2007; Scaglioni, Ferri, Minetti , Martin, Van Hoecke, Capodaglio, Sartorio & Narici 2002; Shima, Ishida, Katayama, Morotome, Sato & Miyamura 2002). There was a difference between the RT group and the NT group, but it was not significant. This is in line with previous studies that report a positive but rather small effect on voluntary activation after resistance training, (Scagliano et al. 2002; Shima et al. 2002; Del Balso & Cafarelli 2007) although there are also studies that has shown no effect (Lee, Gandevia & Carroll 2009) or a big increase in voluntary activation after a period of resistance training (Nordlund Ekblom 2010). Nordlund Ekblom (2010) discusses that neural adaptations to resistance training may be task specific, which could be one reason for the small difference in voluntary activation in the present study due to the isometric testing. There might also been a need for a larger sample size to detect any significant differences.

There has been studies showing that the MEP/Mmax ratio differ between RT and NT individuals (Pearcey, Power & Button 2014). In the present study group differences were not significant for any of the tested torque levels. In the present study, the MVC level at which the maximum MEP amplitude were leveling out appears to be lower for the RT group (Figure 2). Authors of previous studies (Carrol 2002, Griffin & Cafarelli 2006) have speculated that this effect might be due to a reduction in motor unit recruitment thresholds after training. Carrol, Riek & Carson (2002) found that the MEP peak occurred at a significantly lower level of contraction after a short period of resistance training and concluded that after resistance training, the level of contraction needed to recruit all the motor units was reduced. The lack of a significant difference in the present study could be because of the absence of screening for calf training in particular. If there would have been a bigger difference between the RT and the NT group in MVC this would have been an indication of a higher degree of resistance training of the calf muscles.

Although dynamic strength training can often be transferred into isometric strength (Cadore, González-Izal, Pallarés, Rodriguez-Falces, Häkkinen, Kraemer, Pinto, & Izquierdo 2014), it mainly increases the dynamic strength (Cadore et al. 2014, Folland, Hawker, Leach, Little & Jones 2005). Since strength training is usually performed in dynamic contractions there might be a bigger difference between strength trained individuals and sedentary individuals in dynamic strength than in isometric. There might also be a higher demand of movement skill when training with and testing dynamic versus isometric contractions.

In the present study the exclusion criteria regarding training were only based upon resistance training. This might not have been a problem since there is evidence that a short period of endurance training does not improve neuromuscular function (Zghal, Martin, Thorkani, Arnal, Tabka & Cottin 2014). The soleus muscle is otherwise a muscle that is highly activated during a range of different activities such as standing on one foot, walking, running and jumping (Duysens, Tax, van der Doelen, Trippel & Dietz 1991; Moritani, Oddsson & Thorstensson 1991). Although the individuals in the NT group did not participate in resistance training, the soleus muscle might be easier to activate compared to other lower limb muscles since it is activated in other activities than resistance training. Another factor that might influence the result is that the calf muscles is a muscle group that might not be trained to the same extent as other muscles during resistance training. This should be noted although which exact muscle of the lower limb that an individual does train may not be of as big of an importance as one believe, there has been suggestions that resistance training focusing on the upper leg can result in an increased V-wave for the lower leg (Fimland et al. 2009a). There is also evidence of elevated V-wave in the contralateral limb after a short period of resistance training (Fimland et al. 2009b). Furthermore the soleus muscle consists of mainly type 1 muscle fibers in comparison to the gastrocnemius muscle which consists of type 2 muscle fibers to a larger extent (Trappe, Trappe, Lee & Costill 2001). Type 1 muscle fibers are primarily trained with low intensity with long duration, which is typical for aerobic training (Zghal et al. 2014).

4.2 Methodological considerations

EMG-signals and reflexes are sensitive to body movement and inconsistent noises (Palmieri, Ingersoll & Hoffman 2004). Extra care was taken during the experiment to maintain the participant's body position in the same position during the entire test-protocol. The experiments were also conducted in a closed room which resulted in a quiet environment. The H-reflex is measured in approximately the same way as the V-wave and this kind of measurement have shown to be reliable between sessions (Hopkins, Ingersoll, Cordova & Edwards 2000; Palmieri, Hoffman & Ingersoll 2002).
Normalizing the V-wave to the supramaximal M-wave is a procedure that makes sure that any alterations in for example electrode impedance does not contaminate the data. In the present study, surface EMG were used. This method have limitations as it has proven sensitive to cross-talk from others muscles, especially when compared to fine-wire EMG (Byrne, Lyons, Donnelly, O´Keeffee, Hermens & Nene 2005). Even though there is a risk of cross-talk, surface EMG has a linear relationship to fine-wire EMG (Bouisset & Maton 1972).

Although there were two pilot tests performed, this might not have been sufficient to ensure that the researchers were familiar enough with the test procedure, especially since one of the test-leaders were novel to the methods used. Furthermore, up to 30 consecutive stimulations have been recommended for the most reliable estimate of corticospinal excitability (Cuypers, Thijs & Meesen 2014), whereas in the present study there were only 5 stimulations per torque level. This is far less than 30, but comparable to other studies measuring chronic adaptations to resistance training (Del Olmo et al. 2006; Pearcey, Power & Button 2014; Tallent et al. 2013). To use 30 stimulations at each level would be practically challenging due to the element of fatigue for the participants and the time demand.

4.3 Clinical implications

As this is a mechanistic study it is not possible to base clinical advice on the results. The results shall rather be seen as a basis for deeper understanding of the mechanisms of resistance training. A good understanding of the mechanism behind strength gains allows the clinician to better be able to design appropriate programs for both rehabilitation and performance enhancing in general.

4.4 Future research

Future research should be aimed towards muscles which might be trained more regularly when resistance training. Future research should also include assessing neural mechanisms for activation in isometric, concentric and eccentric muscle work to detect any possible differences in adaptations between action types. A larger sample size than in the present study might also warranted, to make sure that even subtle differences can be identified. Since no studies have investigated if there is differences between men and women, such studies would be welcome to further broaden the knowledge about corticospinal excitability.

4.5 Conclusion

The present study showed that the RT group was stronger than the NT group. Despite the difference in strength there was no significant group difference between the two groups for MEP/Mmax, V/Mmax or voluntary activation. This indicates that there is no, or a very small proportion of the acute neural adaptations to resistance training of the soleus muscle that persists over time. There might be a possibility that the chronic neural adaptations to resistance training are task specific and need to be tested in the same manner as they are trained.

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Attachment 1

Forskningspersoner sökes!

Studien syftar till att förstå mer om nervsystemets förmåga att aktivera benmuskulaturen i jämförelse mellan personer som tränar styrketräning regelbundet och personer som inte tränar regelbundet.

Vi söker dig som kan ingå i gruppen som inte tränar regelbundet. Du ska vara kille och mellan 20-32 år, fullt frisk och inte träna regelbundet, i synnerhet inte styrketräning.

Studien genomförs vid Gymnastik och idrottshögskolan (GIH) i Stockhom under 2014.

Vi kommer att be dig komma till GIH vid ett tillfälle om ungefär 2 timmar. Vi kommer att stimulera en ner i ditt knäveck för att utlösa reflexer i vadmusklerna. Du kommer att ligga på mage på en brits med högerfoten fäst mot en platta. Vi kommer sedan att stimulera nervsystemet med el eller magnetfält som skapar en svag urladdning i motorcortex medan du trycker olika hårt med foten mot plattan.

Målet med studien är att undersöka de eventuella neurofysiologiska skillnaderna i aktivering av benmuskulatur mellan styrketränade och icke-styrketränade män.

Om du vill delta kommer du att bli ombedd att underteckna ett samtycke om att delta i studien. Om du bestämmer dig för att delta i studien, är du fortfarande fri att när som helst, och utan att ange några skäl för ditt beslut, hoppa av studien.

Ersättning utgår vid deltagande.

Ytterligare upplysningar kan du få muntligt eller skriftligt av nedanstående försöksledare.

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Attachment 2

INFORMATION TILL DIG SOM ÄR INTRESSERAD AV ATT DELTA I STUDIEN

”Mätning av corticospinal excitabilitet med hjälp av transmagnetisk stimulering”

Inbjudan att delta

Du har blivit inbjuden till att delta i denna studie som syftar till att ge en ökad förståelse om nervsystemets förmåga att aktivera benmuskulaturen hos personer som styrketränar i jämförelse med personer som inte tränar regelbundet.

Ditt deltagande är frivilligt

Det är helt upp till dig att avgöra om du vill delta i denna studie. Innan du bestämmer dig är det viktigt för dig att förstå vad studien handlar om. Med denna information berättar vi om studien, varför forskningen görs, vad studien innebär och de eventuella fördelar, risker och obehag som studien kan innebära. Om du vill delta kommer du att bli ombedd att underteckna bifogat samtycke. Om du bestämmer dig för att delta i studien är du fortfarande fri att när som helst och utan att behöva ange några skäl för ditt beslut avsluta din medverkan. Om du inte vill delta behöver du inte ange något skäl till ditt beslut.

Ta dig tid att läsa följande information noggrant och fundera innan du bestämmer dig.

Vem genomför studien?

Denna studie genomförs av en student och forskare vid Gymnastik och idrottshögskolan (GIH) och Institutionen för Neurovetenskap vid Karolinska Institutet som en del i en magisteruppsats. Studien är finansierad av medel från GIH.

Bakgrund till studien

Vid styrketräning sker en ökning av styrka. En del av denna ökning härstammar från en neurologisk anpassning. Denna studie ämnar undersöka vilken del av den neurologiska anpassningen som kan härstamma från förändringar i delen av hjärnan som styr muskelarbete (motorcortex) och vilka förändringar detta kan vara.

Varför genomförs studien?

Studien genomförs för att få en ökad förståelse för den neuronala anpassningen som sker vid regelbunden styrketräning.

Vem kan delta i studien?

Du kan delta i denna studie om du:

- Är mellan 18-32 år gammal.
- Antingen styrketränar tre gånger i veckan och har gjort det senaste tre åren eller är fysiskt inaktiv
- är vid god hälsa.

Vem bör inte delta i studien?

Du bör inte delta i studien om något av följande stämmer in på dig:

- Du är gravid.
- Du har epilepsi.
- Du har elektroder implanterade i centrala eller perifera nervsystemet (såsom pacemaker eller hörselimplantat).
- Du har medicinska problem såsom lättutlöst autonom dysreflexi eller hypotoni.
- Du har hjärtsjukdomar (inklusive aneurysm)
- Du har psykisk sjukdom, psykiska problem (såsom depression) eller lider av sömnbrist.

Vad innebär ett deltagande i denna studie?

Studien genomförs vid Gymnastik och idrottshögskolan (GIH i Stockhom) under 2014. Om du väljer att delta kommer du att inkomma till Laboratoriet för Biomekanik och Motorisk Kontroll vid Gymnastik och Idrottshögskolan vid ett tillfälle. Du kommer att ligga på rygg på

en brits med din högra fot fastspänd vid en platta kopplad till en sensor som mäter hur hårt du trycker. Vi kommer att testa reflexer i ryggmärgen genom att elektriskt stimulera tibialisnerven i knävecket. Svaren mäts via små ytelektroder (små runda plattor som fästs på huden som ett plåster) som registrerar muskelaktivitet. Stimuleringen kan ibland orsaka momentan smärta och obehag som dock går över och inte är farligt. Totalt kommer nerven att stimuleras ca 50 gånger. Besöket tar ca 2 timmar varav merparten består av förberedelser.
Vi kommer även att använda transkraniell magnetstimulering, en slags spole som sätts på huvudet för att testa retbarheten i hjärnceller som ansvarar för att aktivera vadmusklerna. Stimuleringen kan orsaka visst obehag. Totalt kommer nervsystemet att stimuleras ca 50 gånger.

Vilka är mina uppgifter som forskningsperson?
Du kommer att bli ombedd att komma till laboratoriet vid 1 tillfälle. Väl där kommer du att i ryggliggande på en brits ombes aktivera dina vadmuskler för att försöka ställa dig på tå mot en fotplatta under din högra fot.

Vilka eventuella skador och biverkningar kan deltagandet i studien medföra?
Riskerna i den föreslagna studien är ringa. Ytelektroder vid registrering av muskelaktivitet används frekvent inom klinisk forskning. Du kan uppleva lätt irritation från elektroderna över registreringsområdet. Om lätt rodnad uppstår avtar irritationen i allmänhet inom 15-30 minuter. Transkraniell magnetstimulering används ofta inom klinisk forskning. Vid stimulering över huvudet kan du uppleva övergående huvudvärk, lokal smärta eller övergående hörselproblem men om dessa symtom uppstår kommer de i allmänhet snabbt att försvinna. I sällsynta fall när huvudvärken kvarstår kan en vanlig värktablett intas och vara till hjälp. Riskerna för att TMS (med enstaka stimulering som används i detta projekt) skall framkalla kramper är mycket små och har endast rapporterats hos patienter med depression som använder psykofarmaka. Elstimulering av nervsystemet är en vanlig metod vid klinisk forskning. Riskerna vid elstimulering är minimala. Stimuleringen kan orsaka övergående obehag eller smärta, men inga varaktiga negativa rapporter finns påvisade.

Vilka är de potentiella fördelarna med att delta i denna studie?

Du som deltar i studien kan via samtal med försöksledarna få ökad förståelse för hur ditt nervsystem aktiverar vadmusklerna. Du bidrar till forskning som kan vara användbar vid både frisk och sjukvård i framtiden.

Hur kan du få information om studiens resultat?

Resultaten från studien som du medverkar i kommer att vara en del av en magisteruppsats. Om du är intresserad av att ta del av de resultat och publikationer som eventuellt kommer publiceras så kan du ta kontakt med ansvarig student och forskare med hjälp av kontaktuppgifterna som finns i slutet av dokumentet.

Är du försäkrad och får du någon ekonomisk ersättning för din medverkan?

Ja, allmän patientförsäkring gäller när du deltar i denna studie. Denna försäkring ger ett ändamålsenligt försäkringsskydd för samtliga forskningspersoner som deltar. Den ekonomiska ersättningen som du erhåller för din medverkan är skattepliktig och utgör 400 kr.

Samtycke och vetskap om rätten att avbryta

Undertecknad forskningsperson intygar härmed att jag har erhållit utförlig muntlig och skriftlig information om bakgrund och syfte med forskningsprojektet samt om vad mitt deltagande innebär. Jag har även fått tillfälle att ställa frågor och har fått mina frågor besvarade och samtycker härmed till att delta i studien.

Mitt deltagande är helt frivilligt och jag har vetskap om möjligheten att kunna avbryta min medverkan när som helst utan krav på förklaring till detta.

Undertecknad uppfattar sig som fullt frisk och ser inga medicinska hinder för deltagande.

Stockholm den / År 2014.

____________________________ ____________________________

Namnteckning forskningsperson Namnförtydligande forskningsperson

_____________________________ _________________________

Namnteckning ansvarig forskare Namnförtydligande ansvarig forskare

Ytterligare upplysningar kan du få muntligt eller skriftligt av nedanstående försöksledare under genomförande av studien eller i efterhand om du så önskar.

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Attachment 3

Namn:

Baseline:

MVC:

Inställning för V-wave:

V-Wave 15% MVC antal försök:

V-Wave 100% MVC antal försök:

V-Wave 50% av MVC antal försök:

V-Wave 25% av MVC antal försök:

V-Wave rest antal försök:

V-Wave 80% av MVC antal försök:

TMS AMT (20% av MVC) 0.1-0.2 mV:

TMS 120% av AMT:

TMS 15% av MVC:	Antal försök:
TMS 25% av MVC:	Antal försök
TMS 100% av MVC:	Antal försök:
TMS rest:	Antal försök:
TMS 80% av MVC:	Antal försök:
TMS 50% av MVC:	Antal försök:

MVC Tib ant: