HALMSTAD UNIVERSITY

Bachelor's programme in Exercise Biomedicine, 180 credits

BACHELOR THESIS

The effect of lifting speed on factors related to resistance training

A study on muscle activity, amount of repetitions performed, and time under tension during bench press in young males

Gustav Mårtensson

Bachelor thesis in Exercise Biomedicine, 15 credits

Halmstad 2015-05-29

The effect of lifting speed on factors related to resistance training

A study on muscle activity, amount of repetitions performed, and time under tension during bench press in young males

Gustav Mårtensson

2015-05-29

Bachelor Thesis 15 credits in Exercise Biomedicine

Halmstad University

School of Business and Engineering

Thesis supervisor: Eva Strandell

Thesis examiner: Emma Haglund

Acknowledgements

Thanks to Idrottscentrum for providing equipment for testing on multiple occasions.

Thanks to Adam Sahlén for assisting during testing

Contents

Abstract

Background Many different variables are important to consider when creating resistance training programs. However the lifting speed that exercises are performed with has not been studied as extensively as many of the other factors. Some research has indicated that training with specific lifting speeds results in improved strength or hypertrophy adaptations compared to other lifting tempos, but more research is needed to reach better knowledge on what lifting speeds are optimal for specific goals.

Aim The aim of this study was to analyze the effect of various lifting speeds on different factors known to influence resistance training. The measured variables were muscle activity, maximum amount of repetitions performed and time under tension during bench press.

Method Thirteen males performed bench press at their individual 6 RM. The exercise was performed to fatigue with three different lifting tempos (4 second repetitions, 6 second repetitions and repetitions intentionally performed as fast as possible). Number of repetitions performed and total time under tension for each test was recorded in seconds. Surface electromyography (EMG) was used to register muscle activity of pectoralis major and deltoideus anterior. Reference values were gathered using MVIC (Maximum voluntary isometric contraction) tests.

Results EMG amplitudes were higher in pectoralis major when a fast lifting speed (60.1 ± 7.3 % of MVIC) was used compared to the medium (54.8 ± 10.2) and slow (54.3 ± 7.1) conditions. More repetition were performed with faster lifting speeds. The time under tension was longer for the slow and medium lifting tempos than for the fast lifting tempo.

Conclusion The result from this study can be considered when designing resistance training programs. Based on the increased performance and muscle activity associated with the fast lifting tempo, faster lifting speeds may be beneficial when the training goal is to increase strength levels. It is difficult to draw any conclusions regarding the optimal lifting tempo for specific training designed to increase hypertrophy, but the time under tension appears to be longer for slower lifting speeds.

Introduction

Resistance training is a common type of training for athletes, as well as for improving health and fitness for the general population. A lot of different variables can be considered when creating a resistance training program in order to manipulate the result from the training. Training volume, intensity and exercise selection are often focused on and have been thoroughly researched (Bird, Tarpenning & Marino, 2005; Kraemer et al., 2002). One factor that is sometimes overlooked regarding resistance training is the lifting speed (also known as tempo or cadence) of the movement performed. A light resistance can be lifted with a large variety of speeds. As the resistance increases however, the options of lifting speeds decrease (McArdle, Katch & Katch, 2015).

Fast, explosive movements are generally used to improve an individual's power (Baechle & Earle, 2008). Power is defined as the rate of doing work (force x velocity) (McArdle et al., 2015). Slow lifting speeds on the other hand can be caused by two factors. Slow-velocity contractions can be intentional or a result of fatigue. Intentional slow-velocity contractions are sometimes recommended to individuals who are inexperienced with resistance training. A drawback to slower contractions is that they have been shown to produce lower amounts of force and neural activity (Kraemer et al., 2002). This study examined the effect of various lifting speeds on time under tension, maximum amount of repetitions performed and muscle activity during bench press using electromyography. The purpose was to analyze potential benefits of different lifting speeds.

Background

Resistance training programs can be used for a variety of purposes and causes a number of different adaptations in the body. A few examples would be increased muscular strength, hypertrophy and power. Increased strength can be a result of adaptations in the neuromuscular system, as well as hypertrophy. Hypertrophy means an enlargement in the muscular tissue, which is predominantly caused by an increased cross-sectional area of the muscle fibers (Baechle & Earle, 2008).

The muscular system

Each muscle consists of a large amount of muscle cells, which are commonly referred to as muscle fibers. Each muscle fiber consists of myofibrils located in the membrane of the muscle fiber (sarcolemma) (Baechle & Earle, 2008). The muscle action is produced by myofilaments inside the myofibrils named myosin and actin. Together myosin and actin make up a unit called sarcomere, responsible for contraction. When a muscle contraction takes place, actin will slide along the myosin towards the middle of the sarcomere (Baechle & Earle, 2008). Muscle contractions are controlled by the regulation of calcium ions. The release of calcium is signaled by an action potential, which causes a contraction in the muscle (Baechle & Earle, 2008). The amount of force produced from a muscle contraction is influenced by a number of factors. The maximum amount of force a muscle can produce is limited by its size. A muscle with a larger cross-sectional area can produce greater amounts of force (Hammil & Knutzen, 2009). The force production is also related to the velocity of a muscle contraction. At higher velocities, lower amounts of force can be produced from a muscle contraction. This is due to cross-bridges being cycled at a higher rate, resulting in a lower amount of cross-bridges connected at one time(Hammil & Knutzen, 2009). Rahmani et al. (2001) examined the relationship between force and velocity in the squat exercise and found a linear relationship with lower velocities capable of producing higher amounts of force.

Activation of muscle fibers

Nerve cells, also called motor neurons are responsible for innervating muscle fibers. A motor neuron and all muscle fibers connected to it make a motor unit. The motor neuron sends out impulses called action potentials and thereby activates all the muscle fibers that it innervates (Baechle & Earle, 2008). The action potential is a result of the membrane potential and the semi-permeable membrane of the cell. The resting potential is maintained at approximately -80 to -90 mV by ion pumps embedded in the cell membrane. This means that the internal part of the cell is negatively charged compared to the outside of the cell (Konrad, 2006). An activation of the alpha-motor neuron by a reflex or by the central nervous system causes an action potential to travel along the axon of the motor neuron until it reaches the nerve terminal, where it causes acetylcholine to be released. Once an adequate amount of acetylcholine has diffused through the neuromuscular junction, the characteristics of the membrane will change, causing Na^+ ions to diffuse into the muscle cell. As a result, the membrane potential changes, which is referred to as depolarization (Konrad, 2006). If the change in membrane potential surpasses a threshold, the depolarization will cause an action potential to occur. The difference in membrane potential is measured when estimating the muscle activity using electromyography (Konrad, 2006). The action potential is an electrical spike, resulting in a drastic change in membrane potential up to roughly +30mV. Immediately afterwards a repolarization of the membrane potential will occur as the ions travel back out of the cell through ion pumps. The action potential will travel across the sarcolemma, causing the muscle fiber to contract (Konrad, 2006).

Motor unit recruitment

Individual muscle fibers are for the most part activated by a single motor neuron. Each motor neuron on the other hand innervates a large amount of muscle fibers. Motor units are divided into fast twitch and slow twitch motor units depending on the twitch and tension capabilities of the innervated muscle fibers, as well as the resistance to fatigue (McArdle et al., 2015). The force produced by a muscle contraction depends on a few factors related to motor units. Increased force production can be achieved by increased motor unit recruitment, meaning the number of motor units that are recruited (McArdle et al., 2015). The amount of generated force is also related to the firing frequency of the activated motor units. An increased firing rate results in a greater force production in the muscle(McArdle et al., 2015). Motor unit recruitment is affected by the speed of a movement. Slow movements with a moderate effort mainly activate slow-twitch motor units, whereas faster movements progressively activate fast twitch motor units to a larger degree. Fast twitch motor units are less resistant to fatigue, which means exercising at high velocities results causes fatigue to occur faster (McArdle et al., 2015).

Lifting speed

A fast lifting speed is generally used for plyometric exercises, where the objective is to produce very high amounts of force in the shortest time possible (Baechle & Earle, 2008). The plyometric training mode is intended to improve the lifters power production (McArdle et al., 2015). A faster lifting tempo in the eccentric portion of the lift allows for a greater power output (Pryor, Sforza & King, 2011). The higher velocity in the eccentric part of the movement allows for more force to be produced by taking advantage of the stretch shortening cycle (SSC) (McArdle et al., 2015). The SSC is a combination of several factors. The elastic energy in the muscles and tendons involved in an exercise increases if they are stretched rapidly during the eccentric portion of the lift and is stored for a limited time frame. If a concentric contraction is initiated immediately following the eccentric phase, the stored energy will be released, resulting in a more powerful contraction (Baechle & Earle, 2008). The stretch reflex is an involuntary reaction and another component involved in the stretch shortening cycle. Muscle spindles are proprioceptive organs made of modified muscle fibers and are capable of detecting the speed and extent of a stretch. After experiencing a stretch, the muscle spindles will send a signal to the spinal cord through afferent nerve fibers. Alpha motor neurons located in the ventral root of the spinal cord will receive the signal and send signals intended to activate the agonist muscle group (Baechle & Earle, 2008). These signals are sent during the amortization phase of a movement, which is the delay between the eccentric and concentric phase of the movement. In order to take advantage of the stretch shortening cycle, this delay has to be as short as possible. Otherwise the energy will dissipate. By taking advantage of the stored elastic energy, as well as the increased activation of the agonist muscle, the stretch shortening cycle allows maximal muscle recruitment and force production for a limited amount of time (Baechle & Earle, 2008).

A slower tempo may be used for example when aiming to increase the time that the muscle is under tension. Some research has suggested that a longer time under tension may be beneficial for inducing hypertrophy (Bird et al., 2005; Burd et al., 2011). Multiple studies have shown that performing exercises at very slow lifting speeds consisting of five or six second eccentric and concentric phases results in a significantly longer time under tension for the musculature (Burd et al., 2011; Keogh, Wilson & Weatherby, 1999). The amount of repetitions performed at a given intensity is also affected by the lifting velocity. Lifting at higher velocities requires more force to be produced in order to accelerate the bar quicker. On top of that, the maximal force production is lower at higher velocities according to the muscles force-velocity relationship (Baechle & Earle, 2008). Based on these factors, lifters should be performing fewer repetitions with faster lifting speeds. However, the increased performance associated with utilizing the stretch shortening cycle might change the outcome. According to Sakamoto and Sinclair (2006), faster lifting speeds allows for more repetitions to be performed at a given % of 1RM, compared to if the same movement was performed at a slower speed. Headley et al (2011) tested 1 RM at two different lifting speeds and showed that a faster lifting tempo resulted in a higher 1RM, which again suggests that more work/force can be performed with faster lifting speeds. Both studies used bench press to test their hypothesis.

Bench press is a common resistance training exercise used in training to increase strength in the upper extremity (Coburn & Malek, 2012). The primary muscles involved in moving the bar during bench press is Pectoralis major, anterior deltoid, triceps brachii, serratus anterior and pectoralis minor (Coburn & Malek, 2012). The bar should be grabbed with a pronated and closed grip. Five-point body contact should be maintained at all time during performance of the exercise. This means that the back of the head, upper back and buttocks should have contact with the bench and both feet should remain on the ground. The bar should touch the chest at the end of the eccentric phase at around nipple level before it is returned to the starting position (Coburn & Malek, 2012). Wagner et al. (1992) examined the effect various grip widths had on bench press performance. All the test subjects performed 1RM tests with six different grip widths on separate occasions. The result showed that most test subjects performed better with moderate grip widths, which were measured to be 165% and 200 % of biacromial breadth. Lehman (2005) found that a wider grip caused the bar path to decrease, which may be one of the factors affecting the performance during bench press. The same study found that the muscle activation varied depending on the grip width. For example the activation of the sternoclavicular portion of pectoralis major was significantly lower with a narrow grip compared to a wider grip width.

A few studies have examined how the muscle activity varies depending on the lifting tempo used when performing an exercise (Burd et al., 2011; Sakamoto and Sinclair, 2012). The result showed that higher lifting speeds in general resulted in higher muscle activity. However the muscle activity for the faster lifting speeds declined more towards the end of a set compared to slower lifting speeds (Burd et al., 2011; Sakamoto and Sinclair, 2012).

Electromyography

To measure muscle activity a method called Electromyography (EMG) is used. Electromyography is a common method to use and previous studies have found it to have a high reliability (Ahern et al., 1986; Ochia & Cavanagh, 2007). The muscle activity is tested by measuring the difference in the membrane potential as a result of the depolarization and repolarization processes involved in the action potential. The location of the depolarization changes as it moves along the muscle fiber and is detected when it passes by the location of the electrodes. EMG signals contain both positive and negative amplitudes and therefore the signal needs to be rectified, which means converting all negative amplitudes to positive amplitudes. Generally a root mean square (RMS) algorithm is used to make the data smoother and easier to analyze (Konrad, 2006). The amplitude of the EMG signal is affected by a variety of factors and there is not a linear relationship between the amplitude of the signal and the amount of force produced by the muscle (Hammil & Knutzen, 2009). The method is useful when attempting to determine what muscle or which muscle groups are activated during a specific movement or activity. The size of the electrical activity can also be measured but cannot be used to compare the results of different individuals (Konrad, 2006). EMG signals are registered through the use of electrodes. The most common type of EMG is surface electromyography, meaning surface electrodes are attached to the skin. This method is effective when measuring the activity of large superficial muscles but cannot be used when the objective is to measure the activity of smaller muscles located deep under the surface of the skin (Hammil & Knutzen, 2009). Generally two electrodes are used to register the electrical activity and a third electrode is placed perpendicular to the others and used as a reference. The two main electrodes have to be placed parallel to each other and in the direction of the muscle fibers to get a clear and correct signal. They should be located approximately 1.5-2.0 cm apart from each other (Hammil & Knutzen, 2009). Another important factor to consider when using electromyography is the resistance of the skin. The resistance of the skin has to be low for a signal to be registered. To achieve this, the skin has to be prepared properly prior to placing the electrodes. This means removing any hair by shaving the area and cleaning it with alcohol (Hammil & Knutzen, 2009).

One of the main issues associated with using Electromyography is that the result depends on a large variety of factors. The test subject’s anatomy, physiology and the technology in the measuring device all have an influence on the end result of an EMG measurement (De Luca, 1997). To efficiently take advantage of the information provided by an EMG signal it is therefore essential to have a good understanding regarding the factors that could have an impact on the signal. An example of such a factor is the electrode configuration. This includes the size and form of the electrodes as well as how they are positioned in relation to the motor units in the musculature as well as in what direction they are placed in comparison to the direction of the muscle fibers (De Luca, 1997).

Normalizing EMG data

Raw EMG data can be compared in specific cases, but when comparing data from different individuals, the EMG values have to be normalized prior to making a comparison. In general this process is done by dividing the values received from EMG signals during a task with a reference value. The reference value has to be tested with the same testing conditions that are used during the regular tests. For example the electrode configuration has to be the same and the reference test has to be performed on the same day to have a high reliability. The most frequently used test for normalizing EMG data is a Maximum Voluntary Isometric Contraction (MVIC) test. The idea behind a MVIC is to create a maximum contraction in the targeted muscle. In order to achieve a reliable result, the test should be repeated a minimum of 3 times (Halaki & Ginn, 2012).

One of the main issues is identifying a MVIC test where the individual can elicit a maximum activation of the targeted muscle. Studies have examined various alternatives; however there is no agreement on which tests that generates maximal activation in specific muscle groups for all individuals (Halaki & Ginn, 2012). Another downside to MVIC tests is the necessity to use healthy and trained test subjects, due to the strain put on the body when performing maximal tests. Apart from this, if the test subjects is not used to engaging the muscle in a similar fashion, the test subject might not be able to fully activate the targeted muscle, resulting in an inaccurate MVIC value (Konrad, 2006). Although many factors can affect the result of a MVIC test, the method has been shown to have a high reliability if performed on the same individual on the same day (Halaki & Ginn, 2012).

The effect of lifting speed

More research needs to be done to determine potential benefits of exercising with different velocities. Previous research has shown that slower lifting speeds results in a greater muscle time under tension (Burd et al., 2011; Keogh et al., 1999). However, the tests were either performed with a lower intensity than what is typically used when resistance training (Baechle & Earle, 2008) or a set number of repetitions were completed rather than performing the exercise until fatigue (Burd et al., 2011; Keogh et al., 1999).

Whether he lifting speed assigned to a resistance training exercise affects the muscle activity has been tested in a previous study, however the amount of test subjects was relatively low (Sakamoto and Sinclair, 2012) and more research is needed to gain a deeper knowledge. The effect of training with a traditional lifting speed, which was defined as two second concentric phase and a four second eccentric phase, compared to using a super slow lifting speed on increasing strength has been tested previously (Keeler, Finkelstein, Miller & Fernhall, 2001). The study showed that a traditional lifting speed resulted in much greater increases in strength for the test subjects. Although it is important to consider that the super slow lifting speed consisted of 10 second concentric contractions and 5 second eccentric contractions, which is not commonly used for resistance training.

Aim

The aim of this study was to determine the effect of different lifting speed on muscle activity using EMG, maximum amount of repetitions performed and time under tension during bench press in young males.

Research questions

1. Does the muscle activity assessed with EMG vary depending on the lifting speed?

2. Are the maximum amounts of repetitions that can be performed at a given intensity (% of 1RM) affected by the lifting speed?

3. Is the time under tension at a given intensity (% of 1RM) affected by the lifting speed?

Method

Subjects

The test subjects included in the study were university students gathered through social media. All participants had to be familiar with the exercise that was performed (bench press). Sixteen males participated in the study, but after a few subjects dropped out due to injuries or didn't show up at the testing occasions, only thirteen completed all the tests. All test subjects had at least one year of resistance training experience. None of the test subjects had any injuries that affected their ability to safely perform bench press without pain. Prior to participating in the study, all test subjects gave informed consent.

Testing procedure

A 6RM bench press test was performed for all test subjects prior to the EMG measurements. Both the 6RM test and the EMG tests were performed at the biomechanics lab at Halmstad University during daytime (between 8 a.m and 5 p.m). Before the testing began, test subjects age, weight and height was measured and registered. All testing was performed by the author and a fellow student. A general warm-up consisting of five minutes on a Monark cycle ergometer with 50 W resistances was performed before the 6RM test. The test subjects started performing bench press with a light weight as a warm-up and then gradually increased the weight based on the perceived exertion of the test subject until a 6 RM was determined (Taylor and Fletcher, 2012). The test subjects were instructed to perform the exercise with maximal effort in order to achieve a true 6 RM. Two to three minutes of rest was provided between each attempt and a 6RM was determined within 1-3 attempts for all test subjects (Taylor and Fletcher, 2012). A 2/0/2 tempo was used when determining the 6RM, meaning the eccentric part of the lift lasted 2 seconds, followed by a 2 second concentric movement without a pause in the transition between the muscle actions. A metronome was used in combination with verbal cues to ensure that the exercise was performed with the correct tempo.

EMG testing

The EMG experiment was performed approximately one week after the 6 RM test. Before the test a general warm-up consisting of five minutes on a Monark cycle ergometer with 50 W resistances was performed. Afterwards as many sets of bench press warm up sets as the test subject required was completed. For the actual experiment the 6RM weight was used. Surface EMG was used to measure the muscle activity during the experiment. A portable surface EMG (ME6000, Kuopio, Finland) was used in combination with MegaWin Software (700046 Version 3.0, Mega Electronics LTD Kuopio, Finland). Electrodes (Ambu Blue Sensor M, M-00-s/50) were placed in the centre of the muscle bellies of pectoralis major and deltoideus anterior on the right side of the body. For deltoideus anterior the electrodes were placed 3.5 cm below the anterior angle of the acromion (Boettcher, Ginn & Cathers, 2008). The pectoralis major electrodes were placed on the sternocostalis portion of the muscle (Konrad, 2006). Before placement of electrodes, the areas had been shaved using a hand razor and cleaned with alcohol. EMG signals were recorded throughout the experiment.

Three different lifting speeds were evaluated. The tempos used were 2/0/2, 3/0/3 and one set where the test subject attempted to lift the weight as fast as possible. Prior to testing, proper lifting technique was instructed. Five-point body contact had to be maintained at all time and the bar was lowered to approximately nipple height. The width of the grip was just wide enough that the elbow angle was 90 degrees when the upper arm was parallel to the floor in order to make sure the exercise was performed with the same grip for all attempts (Lehman, 2005; Wagner et al., 1992).

Two different MVIC tests were performed, one for each muscle group that was tested. For the pectoralis major test (Konrad, 2006; Hislop & Montgomery, 2007) the subjects were instructed to lay down on the bench and press up against a bar that was placed at the height where the subjects upper arm was parallel to the floor. The bar was loaded heavy enough that the test subject was not able to move it. The test subject was instructed to press up against the bar with maximal force for 5 seconds. Three attempts were performed with a rest period of one minute in between (Konrad, 2006). The same procedure was repeated with another MVIC test for the anterior deltoid (Boettcher et al., 2008). The test subject was in a seated position with the shoulder flexed to 125 degrees, which was measured using a goniometer. The test subject was instructed to attempt to further flex the shoulder while the test leader prevented it by applying force just above the elbow and at the lower part of the scapula. Afterwards bench press was performed until fatigue with the 6RM load. Fatigue was defined as the point where the test subjects could no longer perform the exercise throughout the full range of motion. Verbal cues as well as a metronome were used to ensure that the correct lifting cadence was used. The metronome was set to 60 beats per minute (bpm) and the test subjects were instructed that each phase of the lift should last two beats for the medium tempo and three for the slow tempo. The medium velocity (2/0/2) was performed first followed by the slow velocity (3/0/3) and the fast lifting speed was tested last. The rest period in between sets was four minutes. The time under tension was measured in seconds from the point where the test subject began the decent of the first repetition until the last repetition was completed and was measured using MegaWin Software by looking at the spikes in electrical activity for each repetition and marking the time from the initiation of the first repetition until the completion of the last repetition.

Ethical and social considerations

Prior to deciding to perform any type of study, it is important to consider whether the research could have a positive impact, as an injury could potentially occur to the test subjects. The risk of injury for the test subjects should always be minimized. The test subjects are not obliged to complete their participation in the study and can drop out at any point in time. The test leader should abort the test immediately if it appears as if the test subject is likely to experience an injury. All test subjects should be provided information regarding the tests that will be involved in the study and an informed consent is a necessity (Vetenskapsrådet, codex 2015).

Before participating in this study, all the test subject were provided information about the test through an information letter regarding the purpose of the study, the study design, what not to do in preparation for the test and any potential risks associated with participating in the study. All test subjects were given the opportunity to ask any questions they had regarding the study and they were provided with the test leaders contact information. All test subjects were required to sign an informed consent (see appendix 1), to make sure that they were aware of their rights and that they understood all the potential risks of participating. All personal information that was gathered, such as the individuals names, age, height and weight was stored on a USB device to guarantee that the information did not reach anyone other than the test leader and supervisor (World Medical Association, 2013).

The result from this study could be useful in a larger perspective. It may be beneficial for example coaches or anyone with an interest in resistance training in the process of creating and planning training programs. By investigating the effect of performing exercises with different tempos on various adaptations related to resistance training, the optimal lifting speed for achieving specific training goals could be determined.

Statistical analyses

The average electrical activity was registered after the RMS value of the amplitudes had been calculated. The EMG values were normalized using the MVIC values before the data was analyzed. Statistical analysis was performed to determine if a statistical significance was found between different lifting speeds. The Statistical Package for the Social Sciences (IBM, SPSS Statistics, Version 20) was used in order to perform the statistical analysis. A Shapiro-Wilk test (Shapiro & Wilk, 1965) was used to test the data for normality. The EMG data was normally distributed and the number of repetitions performed as well as the time under tension was normally distributed apart from the medium lifting tempo. It was therefore assumed that the data was normally distributed and a paired sample t-test was used. Two lifting tempos were compared at a time for each of the tested variables (muscle activity, repetitions performed and time under tension). Since a parametric statistical test was used, the result is presented as mean and standard deviation (SD). The significance level was set to $\alpha=0.05$, meaning that any result with a p-value of 0.05 or lower was considered statistically significant.

Results

All thirteen test subjects participating in the study were males. As university students were asked to take part in the study, they were all relatively young. The mean age, body mass index (BMI) and 6 RM of the test subjects is presented in table 1.

Table 1: Test subject descriptive.

Age (years)	23 ± 4.0
BMI	24 ± 1.8
6RM (kg)	75.8 ± 14

Explanation of abbreviations: BMI = Body mass index. RM = repetition maximum.

For pectoralis major, RMS amplitude was significantly higher for the fast lifting speed compared to the slow lifting speed (p= 0.003) and the fast lifting speed compared to the medium lifting speed (p=0.013) (see table 3,4 & figure 1). The mean RMS amplitude was higher for the anterior deltoid when the fast lifting speed was used compared to the slow and medium lifting speeds, however the difference was not significant (see table 3,4 & figure 2). There was no statistical significant difference between the slow and medium lifting tempos (see table 2).

Table 2: Mean activity of pectoralis major and deltoideus anterior during bench press with slow and medium lifting speeds.

Muscle	Lifting tempo	% of MVIC ± SD	P-value
Pectoralis major	Slow	54.3±7.1	0.75
	Medium	54.8±10.2	
Deltoideus anterior	Slow	60.0±18.6	0.98
	Medium	60.0±18.2	

Explanation of abbreviations: SD = standard deviation. MVIC = Maximum voluntary isometric contraction, a test used to normalize data for electromyography. Slow tempo is equal to three second eccentric and concentric phases. Medium tempo is equal to two second eccentric and concentric phases.

Table 3: Mean activity of pectoralis major and deltoideus anterior during bench press with slow and fast lifting speeds.

Muscle	Lifting tempo	% of MVIC ± SD	P-value
Pectoralis major	Slow	54.3±7.1	0.00
	Fast	60.1±7.3	
Deltoideus anterior	Slow	60±18.6	0.12
	Fast	65.8±24.2	

Explanation of abbreviations: SD = standard deviation. MVIC = Maximum voluntary isometric contraction, a test used to normalize data for electromyography. Slow tempo is equal to three second eccentric and concentric phases. Fast tempo refers to the test subject attempting to perform the exercise as fast as possible.

Table 4: Mean activity of pectoralis major and deltoideus anterior during bench press with medium and fast lifting speeds.

Muscle	Lifting tempo	% of MVIC ± SD	P-value
Pectoralis major	Medium	54.8±10.2	0.01
	Fast	60.1±7.3	
Deltoideus anterior	Medium	60.0±18.2	0.11
	Fast	65.8±24.2	

Explanation of abbreviations: SD = standard deviation MVIC = Maximum voluntary isometric contraction, a test used to normalize data for electromyography. Medium tempo is equal to two second eccentric and concentric phases. Fast tempo refers to the test subject attempting to perform the exercise as fast as possible.

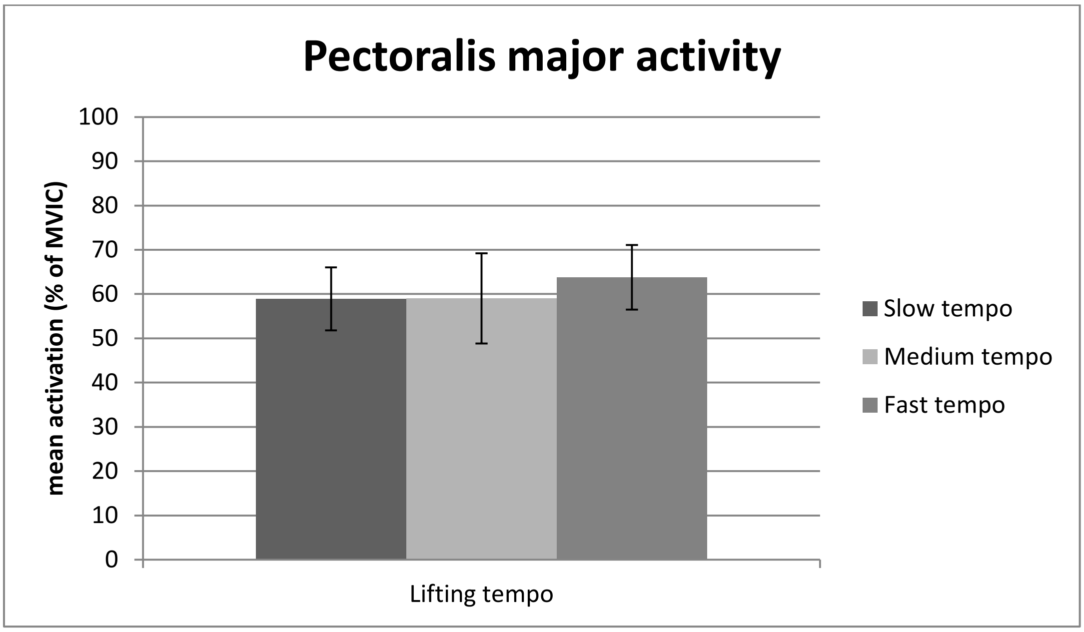

Figure 1: Activity of the pectoralis major during bench press compared to MVIC. MVIC = Maximum voluntary isometric contraction. Slow tempo is equal to three second eccentric and concentric phases. Medium tempo is equal to two second eccentric and concentric phases. Fast tempo refers to the test subject attempting to perform the exercise as fast as possible.

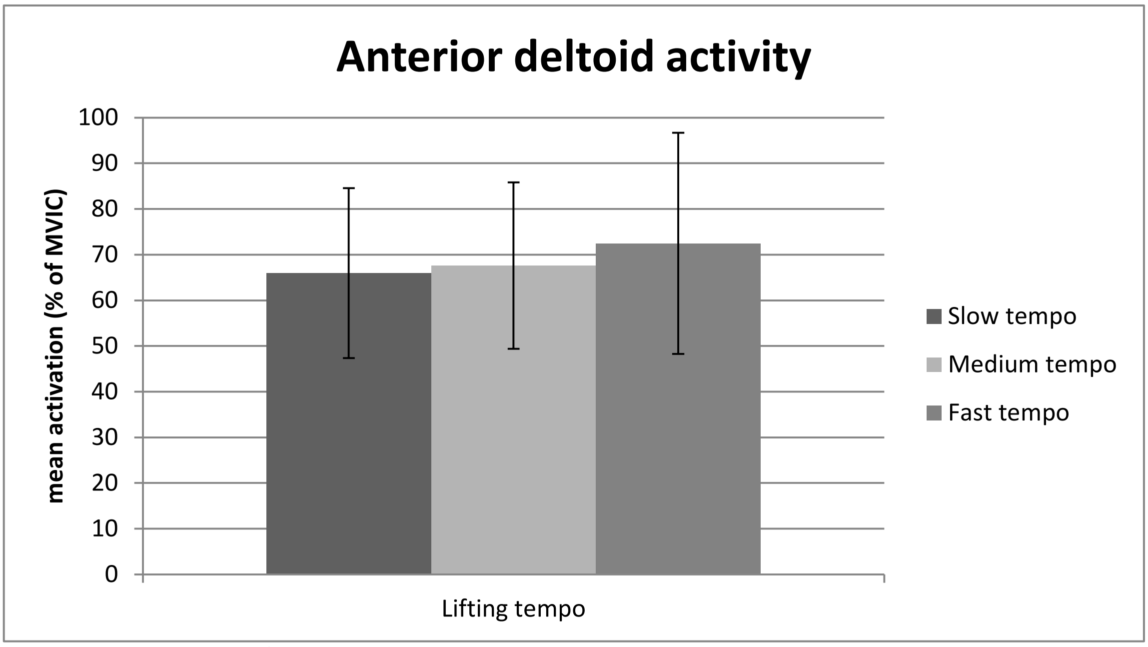

Figure 2: Activation of the anterior deltoid during bench press compared to MVIC. MVIC = Maximum voluntary isometric contraction. Slow tempo is equal to three second eccentric and concentric phases. Medium tempo is equal to two second eccentric and concentric phases. Fast tempo refers to the test subject attempting to perform the exercise as fast as possible.

Table 5 shows the number of repetitions performed by the test subjects at different lifting tempos using their individual 6RM. The average amount of repetitions was highest for the fast tempo (7.9 ± 3) and lowest for the slow tempo (3.7 ± 1). The average amount of repetitions performed with the medium tempo was 6.0 ± 1, which is equal to the amount of repetitions performed with the medium lifting speed during the 6RM test prior to the main experiment.

Table 5: Number of repetition performed with various lifting tempos.

Test subject	Repetitions performed		
	Slow tempo	Medium tempo	Fast tempo
1	5	8	15
2	5	7	10
3	2	6	3
4	4	6	8
5	3	6	4
6	5	6	12
7	5	6	8
8	4	6	9
9	2	6	7
10	4	6	8
11	4	6	6
12	3	5	7
13	2	4	6
Mean	3.7 ± 1*	6.0 ± 1*	7.9 ± 3*

Slow tempo is equal to three second eccentric and concentric phases. Medium tempo is equal to two second eccentric and concentric phases. Fast tempo refers to the test subject attempting to perform the exercise as fast as possible.* = Indicates that the difference between this result and the result from other lifting tempos is statistically significant.

The time under tension also varied depending on lifting speed. The time under tension was longest for the medium lifting tempo (26 ± 3) and shortest for the fast lifting tempo (20 ± 6). For the slow lifting speed the average time under tension was 24 ± 7. The difference in time under tension was statistically significant for the fast lifting tempo compared to the slow ($p = 0.02$) and medium ($p = 0.01$) lifting speed.

Discussion

Results discussion

The results indicated that lifting speed affects various factors related to resistance training. For both pectoralis major and deltoideus anterior, the muscle activity was slightly higher when a fast lifting tempo was used compared to a medium or slow lifting tempo. This result is similar to what has been found in previous studies (Burd et al., 2011; Sakamoto and Sinclair, 2012). However, the difference was only statistically significant for pectoralis major. Considering that the difference in muscle avtivity was relatively small in this study as well as a previous one (Sakamoto and Sinclair, 2012), it is difficult to decide if it has an actual impact on strength and hypertrophy adaptations from resistance training. Therefore research could look at the effect of lifting speed on these factors after a longer training period. The higher EMG amplitude associated with a faster lifting tempo may be explained by the greater force production for fast-velocity contractions compared to slow-velocity contractions (Kraemer et al., 2002) and the accompanying greater recruitment of motor units and activation of fast twitch muscle fibers associated with accelerating the bar to higher velocities (McArdle et al., 2015). Another potential explanation is the increased activation of the agonist muscle group caused by the stretch reflex, as a result of a fast stretch (eccentric action) followed by an immediate concentric contraction (Baechle & Earle, 2008).

The result also indicates that the maximum amount of repetitions that an individual can perform at a given intensity, in this case at 6RM, is affected by the lifting speed used. The average amount of repetitions performed with the fast lifting tempo was higher compared to the medium lifting tempo and in general more repetitions were performed with the medium lifting tempo than the slow variation. This finding is in line with what has been shown in a previous study (Sakamoto and Sinclair, 2006). The increased performance shown at higher lifting velocities is likely caused by the greater utilization of the stretch shortening cycle, which results in a higher force production and motor unit recruitment (Baechle & Earle, 2008). However a few of the test subjects performed fewer repetitions with the fast lifting speed than with the medium speed, which is almost certainly due to fatigue from the previous sets of bench press performed. The difference in EMG amplitude between the fastest lifting speed and the two slower speeds could also have been affected by fatigue. On the other hand there was almost no difference in muscle activity between the two slower lifting speeds, which makes it less likely that fatigue significantly affected the outcome.

The time under tension was highest for the medium lifting speed and lowest for the fast lifting speed. However that was the identical order that the tests were performed in, making it likely that fatigue affected the outcome. The difference in time under tension between lifting tempos was also relatively small (see table 5). It is therefore hard to draw any conclusions regarding the effect of lifting speed on time under tension based on the result of this study, even though the differences were statistically significant and corresponded with previous research (Burd et al., 2011; Keogh et al., 1999). Fast twitch muscle fibers associated with faster lifting velocities are less fatigue resistant (McArdle et al., 2015), which is a potential explanation of the shorter time under tension for the fast lifting tempo.

Method discussion

The reason that a 6 RM was used for the experiment was to test the effect of lifting velocity at a higher intensity compared to previous studies where intensities of 30-50% of 1 RM was prescribed (Burd et al. 2011; Keogh et al., 1999), which is significantly lower than what is typically recommended for resistance training with the goal of increased hypertrophy or strength (Beachle & Earle, 2008). Six repetitions is also commonly used in resistance training, whether the goal is to increase strength or hypertrophy (Baechle & Earle, 2008). Multiple repetition maximum tests have been shown to have a high reliability (Taylor and Fletcher, 2012). The grip width was chosen because it is easy to keep consistent and the grip width can influence the muscle activity (Lehman, 2005). A previous study has shown that in general the greatest strength levels are seen with a medium grip (Wagner et al. 1992), which is why a similar grip width was used in this study. The fast tempo was selected to compare the difference between utilizing the stretch shortening cycle effectively by lifting a weight as fast as possible and using an intentionally slow contraction velocity (Kraemer et al., 2002). The 2/0/2 is a common lifting tempo and similar lifting speeds have been studied previously (Headley et al., 2011; Sakamoto & Sinclair, 2012). Extremely slow repetition speeds such as 5 or 6 second eccentric and concentric muscle actions have been evaluated before (Burd et al., 2011; Keogh et al., 1999), however done at a significantly lower intensities than a 6RM. Therefore the tempo 3/0/3 was selected to ensure that the test subject would be able to complete at least a few repetitions.

One obvious issue with the study design is the fact that fatigue appears to have affected the outcome. The tests were performed in combination with a different study using the same test subjects. The other study investigated muscle activity during bench press performed at various angles, which meant an additional 2 sets of bench press were completed, increasing the fatigue experienced by the test subjects. Four minutes of rest was used between sets, which is a standard rest period to use when resistance training at a high intensity to ensure decent recovery in between sets (Baechle & Earle, 2008). But based on the results, at least a few of the test subjects performed at a significantly lower capacity during the latter part of the experiment. Even longer rest periods may have been a solution to this problem, however due to time constraints, that was not a possibility. The different tests could have been done at separate occasions, but because of limited access to testing equipment, as well as a lack of test subjects willing to participate on multiple testing occasions, this was not an option either. A final alternative solution would have been for the test subjects to perform the tests in a randomized order. But because of the separate study done simultaneously with this study and that only some of the tests were shared between the studies, a randomized testing order would have been complicated and not necessarily better because the test from the different studies would have affected each other nonetheless. If a different testing procedure was done to eliminate or minimize the effect of fatigue, the difference in the amount of repetitions performed may have been even greater and the result even more apparent.

This study only investigated the muscle activity of pectoralis major and deltoideus anterior. Several other muscle groups are involved when bench pressing, for example the triceps brachii (Coburn & Malek, 2012). On the other hand, the aim of the study was not to analyze differences between muscle groups. Further research could test the muscle activity in other muscles and determine if there are any differences. Since previous studies have shown that the muscle activity varies throughout a set depending on what lifting speed the exercise is performed with(Burd et al., 2011; Sakamoto and Sinclair, 2012), this study focused on evaluating how the mean activity of an entire set is affected by different lifting speeds.

A few test subjects experienced discomfort in connection with the MVIC test for deltoideus anterior. The discomfort might have prevented the test subjects from producing maximal force, leading to a sub maximal activation in the targeted musculature. This may have been the reason that a few outliers had EMG values above 100 % of MVIC. This is likely the reason that the standard deviations for muscle activity was much greater for deltoideus anterior than pectoralis major (see table 1-3).

More research is essential to make any reliably conclusion regarding the effect of performing exercises with a variety of lifting speeds on adaptations related to resistance training. The group of test subjects involved in this study was small and could only look at variables related to adaptation rather than examining how actual adaptations such as strength and hypertrophy are affected during a longer training period. The group of test subjects that participated in the study was relatively homogenous. They were healthy young males with an average age of 23 ± 4 years. Further research could be done to determine if the result would differ if a different group of test subjects such as a group of females or a group of older test subjects repeated the same testing procedure.

Conclusion

Based on the result of this study, lifting speed does affect variables related to resistance training. The muscle activity was greater in pectoralis major when using a fast lifting speed, although the difference was relatively small. The maximum amount of repetitions performed was also greater for faster lifting tempos compared to slower lifting tempos. Based on this result, there appears to be benefits of using faster lifting speeds compared to intentionally performing an exercise slowly. A potential benefit of using a slower lifting speed is an increased time under tension. The time under tension was longer for moderate lifting speeds compared to the fast lifting speed. However this result may have been influenced considerably by fatigue. The result from this study can be considered when designing resistance training programs. However, more research need to be done on the effect of lifting speed on various adaptations associated with resistance training, such as strength and hypertrophy, to determine optimal lifting speeds for specific training goals.

References

Ahern, D. K., Follick, M. J., Council, J. R. & Laser-Wolston, N. (1986). Reliability of lumbar paravertebral EMG assessment in chronic low back pain. *Archives of physical medicine and rehabilitation,* 67(10) 762-5.

Baechle, T. R. & Earle, R. W. (2008). *Essentials of strength and conditioning – National Strength and Conditioning Association* (3rd Ed). Champaign, IL: Human Kinetics.

Bird, S. P., Tarpenning, K. M. & Marino, F. E. (2005) Designing resistance training programmes to enhance muscular fitness: A review of the acute programme variables. *Sports Medicine,* 35, 841-851.

Boettcher, C. E., Ginn, K. A. & Cathers, I. (2008). Standard maximum isometric voluntary contraction tests for normalizing shoulder muscle emg. *Journal of Orthopaedic Research*, 26(12), 1591-7.

Burd, N. A., Andrews, R. J., West, D. W., Little, J. P., Cochran, A. J., Hector, A. J., ... Philips, S. M. (2011). Muscle time under tension during resistance exercise stimulates differential muscle protein sub-fractional synthetic responses in men. *The journal of physiology*, 590(2), 351–362.

Coburn, J. W. & Malek, M. H. (2012). *NSCA´s essentials of personal training conditioning – National Strength and Conditioning Association* (2nd Ed). Champaign, IL: Human Kinetics.

Codex. (2015, 3 19). *Codex regler och riktlinjer för forskning*. Retrieved 05-13, 2015, from Codex regler och riktlinjer för forskning: http://codex.vr.se/forskningmanniska.shtml

De Luca, C. J. (1997). The use of surface electromyography in biomechanics. *Journal of Applied Biomechanics*, 13(2), 135-163.

Mark Halaki and Karen Ginn (2012). Normalization of EMG Signals: To Normalize or Not to Normalize and What to Normalize to?, Computational Intelligence in Electromyography Analysis - A Perspective on Current Applications and Future Challenges, Dr. Ganesh R. Naik (Ed.), ISBN: 978-953-51-0805-4, InTech, DOI: 10.5772/49957. Available from: http://www.intechopen.com/books/computational-intelligence-in-electromyography-analysis-a-perspective-on-current-applications-and-future-challenges/normalization-of-emg-

Hamill, J. & Knutzen, K. M. (2009). *Biomechanical basis of human movement* (3rd Ed). Baltimore: Lippincott Williams and Wilkins.

Headley, S. A., Henry, K., Nindl, B. C., Thompson, B.A., Kraemer, W. J. & Jones, M. T. (2011). Effects of lifting tempo on one repetition maximum and hormonal responses to a bench press protocol. *Journal of strength and conditioning research*, 2, 406-13.

Hislop, H.L. & Montgomery, J. (2007). *Muscle Testing Techniques of Manual Examination* (8th Ed). Philadelphia: Saunders

Keogh, J. W.L., Wilson, G. J. & Weatherby, R. P. (1999). A cross-sectional comparison of different resistance training techniques in the bench press. *Journal of Strength and Conditioning Research*, 13(3), 247–258.

Konrad, P. (2006). The ABC of EMG A practical introduction to kinesiological electromyography. Retrieved 02-08, 2015, from www.noraxon.com.

Kraemer, W. J., Adams, K., Cafarelli, E., Dudley, G. A., Dooly, C., Feigenbaum, M. S., ... Triplett-McBride, T. (2002). Progression models in resistance training for healthy adults. *Medicine and Science in Sports and Exercise*, 34, 364-380.

Keeler, L. K., Finkelstein, L. H., Miller, W. & Fernhall, B. (2001). Early-phase adaptations of traditional-speed vs. superslow resistance training on strength and aerobic capacity in sedentary individuals. *Journal of strength and conditioning research*, 15(3), 309-314.

Lehman, G. J. (2005). The influence of grip width and forearm pronation/supination on upper-body myoelectric activity during the flat bench press. *Journal of strength and conditioning research*, 19(3), 587–591.

McArdle, W.D., Katch, F.I. & Katch, V.L. (2015). *Exercise Physiology: Nutrition, Energy and Human Performance* (8th Ed). Philadelphia: Lippincott Williams & Wilkins.

Ochia, R. S. & Cavanagh, P. R. (2007). Reliability of surface EMG measurements over 12 hours. *Journal of electromyography and kinesiology*, 17(3), 365-371.

Pryor, R. R., Sforza, G. A. & King. D. L. (2001). Optimizing power output by varying repetition tempo. *Journal of strength and conditioning research*, 25(11), 3029-34.

Rahmani , A., Viale, F., Dalleau, G. & Lacour, J. R. (2001). Force/velocity and power/velocity relationship in squat exercise. *European journal of applied physiology,* 84, 227-232.

Sakamoto, A. & Sinclair, P. J. (2006). Effect of movement velocity on the relationship between training load and the number of repetitions of bench press. *Journal of strength and conditioning research*, 20(3), 523-7.

Sakamoto, A. & Sinclair, P. J. (2012). Muscle activations under varying lifting speeds and intensities during bench press. *European journal of applied physiology,* 112(3), 1015-25.

Shapiro, S. S. & Wilk, M. B. (1965). An analysis of variance test for normality. *Biometrika,* 52(3,4):, 591-611.

Taylor, J. D. & Fletcher, J. P. (2012). Reliability of the 8-repetition maximum test in men and women. *Journal of science and medicine in sport,* 15(1), 69-73.

Wagner, L. L., Evans, S. A., Weir, J. P., Housh, T. J. & Johnson, G. O. (1992). The Effect of Grip Width on Bench Press Performance. *International Journal of Sport Biomechanics,* 8, 1-10.

World Medical Association. (2013). Ethical Principles for Medical Research Involving Human Subjects. *The Journal of American Medical Association,* 310(20), 2191-2194.

Appendix 1.

Information om test

Kontaktuppgifter
Gustav Mårtensson
Telefonnummer: 070-385 23 16
Mail: gustav.martensson93@gmail.com

Syfte

Syftet med studien är att undersöka skillnaden i muskelaktivering i samband med att bänkpress genomförs med olika hastigheter.

Allmän information

För att delta i studien får du som försöksperson inta ha någon typ av skada som förhindrar dig från att säkert genomföra övningen bänkpress. Du får heller inte ha någon historik av hjärt- och kärlsjukdomar. Personlig information(namn, längd och vikt) kommer att registreras. Informationen kommer hanteras konfidentiellt och inga namn kommer att presenteras någonstans. Som försöksperson är det viktigt att veta att du har rätt att avbryta och hoppa av studien när som helst.

Genomförande

Studien kommer att innehålla två separata testtillfällen. Båda kommer att genomföras på Halmstad Högskola. Under det första tillfället kommer 6RM testas, det vill säga den maximala vikt som du som försöksperson kan genomföra 6 repetitioner med. Under det andra testtillfället kommer bänkpress att genomföras med olika hastigheter och muskelaktiviteten kommer att mätas. Detta sker med hjälp av elektromyografi (EMG). Det sker genom att elektroder placeras på huden ovanpå den muskel som ska mätas. Elektroderna kopplas sedan till en mätutrustning. För att mätningarna ska kunna utföras måste huden där elektroderna ska placeras först rakas och tvättas med alkohol. Elektroderna kommer att placeras på bröstmuskulaturen, framsidan av axeln och triceps. Innan testerna påbörjas kommer en generell uppvärmning att genomföras. De mätvärden som erhålls med hjälp av EMG är individuella och kan inte jämföras mellan testpersoner. Därför måste ett så kallat MVIC värde (Maximal volontär isometrisk kontraktion) testas för att kunna analysera resultatet. Detta sker genom att testpersonen ligger på rygg och håller en skivstång över bröstet i 90°armbågsflektion. Skivstången är låst och går inte att förflytta uppåt. Testledaren ger klartecken och testpersonen trycker med full kraft uppåt i 3-5 sekunder. Proceduren upprepas ytterligare två gånger.

Risker

Det finns alltid en skaderisk när bänkpress eller andra övningar utförs med tung belastning. Men riskerna skiljer sig inte från om bänkpress skulle utföras i ett annat sammanhang. Huden där elektroderna placerats kan vara lite öm och irriterad en kort tid efter testet.

Inför testtillfällen

Undvik att genomföra någon typ av bänkpress eller andra övningar som påverkar samma muskelgrupper samma dag och dagen innan testerna. Inta ingen typ av tillskott innan testet samma dag som det genomförs.

Informerat samtycke

Härmed intygar jag att jag har tagit del av informationen kring testerna och förstår dess syfte. Jag är medveten om att jag deltar i studien frivilligt och att jag kan avsluta min medverkan när som helst utan förklaring. Jag är även medveten om de risker som studien medför.

Namnteckning

____

Namnförtydligande

____

Ort/datum

____

My name is Gustav Mårtensson. I am currently 22 years old. This paper is the examination for my Bachelor degree in Exercise Biomedicine. I am a certified personal trainer by the National Strength and Conditioning Association (NSCA).

HALMSTAD UNIVERSITY

PO Box 823, SE-301 18 Halmstad
Phone: +35 46 16 71 00
E-mail: registrator@hh.se
www.hh.se