Muscle activity in m.pectoralis major during bench press variations in healthy young males

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# Innehåll

Abstract ........................................................................................................................................... 1

Introduction ........................................................................................................................................ 2

1. Background .................................................................................................................................... 2

1.1 Skeletal muscle .............................................................................................................................. 2

1.1.1 Sarcomeres ................................................................................................................................. 2

1.1.3 Motor unit .................................................................................................................................. 3

1.2 Action potential ............................................................................................................................. 3

1.3 Muscle contraction ......................................................................................................................... 3

1.4 Resistance training ....................................................................................................................... 4

1.4.2 Muscle hypertrophy and atrophy ............................................................................................... 4

1.4.3 Muscle fatigue ............................................................................................................................ 5

1.5 Previous research in bench press .................................................................................................. 5

1.6 Electromyography ......................................................................................................................... 7

1.6.2 Maximal voluntary isometric contraction .................................................................................. 8

1.7 Aim ................................................................................................................................................ 8

1.7.2 Research questions ..................................................................................................................... 9

2. Method ............................................................................................................................................ 9

2.1 Subjects ......................................................................................................................................... 9

2.2 Muscle activity data collection ..................................................................................................... 9

2.3 Test procedures ........................................................................................................................... 10

2.3.2 Test day 1: Six repetition maximum test ................................................................................ 10

2.3.3 Test day 2: Muscle activity in m.pectoralis major .............................................................. 10

2.3.3 Maximal voluntary isometric contraction test ....................................................................... 11

2.3.4 Measurement activity in m.pectoralis major ....................................................................... 11

2.4 Ethical and social considerations ................................................................................................ 11

2.5 Statistical analyses ....................................................................................................................... 12

3. Results ........................................................................................................................................... 13

3.1 Exercise load ................................................................................................................................ 13

3.2 Muscle activity in different parts of m.pectoralis major ............................................................. 13

4. Discussion ...................................................................................................................................... 15

4.1 Result discussion ........................................................................................................................... 16

4.1.2 Muscle activity in Pars clavicularis ....................................................................................... 16

4.1.3 Muscle activity in Pars sternocostalis ............................................................................... 17
4.1.4 Muscle activity in Pars abdominals ................................................................. 17
4.2 Method discussion .............................................................................................. 17
5. Conclusion ............................................................................................................ 20
Abstract

**Background.** The bench press is a commonly used resistance training exercise for targeting the chest musculature. During hypertrophy training, different variations of bench press are often used to isolate different segments (pars clavicularis, pars sternocostalis and pars abdominals) of the chest muscle m.pectoralis major. Commonly used variations of the bench press are decline bench press (less than 0° from horizontal) and incline bench press (more than 0° from horizontal). Some research has been done into these variations of bench angle and their effect on muscle activation; however other commonly used bench angles is yet to be investigated. **Aim.** The aim of this study was to examine if there were any difference in muscle activity in the three segments of m.pectoralis majors while performing three different barbell bench press variations with different bench angles to obtain a greater understanding of m.pectoralis major activation and possibly optimize hypertrophy training in above mentioned muscles segments. **Method.** 13 healthy male (age: 23± 3.8 year and BMI: 24.3 ±1.8 kg/m²) participated in this single group study. EMG was used to measure muscle activity in m.pectoralis major's three segments. Test subjects performed 1 set of 6 repetitions on each bench press variation at a relative load of 6RM. An maximal voluntary isometric contraction (MVIC) test was performed and set as 100 percent reference value for comparison muscle activity in various angles. **Results.** While performing the decline bench press and the incline bench press, the muscle activity in pars clavicularis displayed a strong trend of a lower muscle activity (decline: p= 0.055 and incline: p=0.052) in comparison to the flat bench press. Muscle activity in pars sternocostalis while performing the incline bench press was significantly lower in comparison to the flat bench press (flat: p<0.001 and decline: p<0.001). Muscle activity in pars abdominals while performing the decline bench press was significantly higher (p=0.013) in comparison to the flat bench press. Muscle activity in pars abdominals while performing the incline bench press were significantly lower than both the flat and decline bench press (incline: p<0.001 and decline: p<0.001). **Conclusion.** For a better isolation of the pars abdominals segment, the decline bench press should be used. Muscle activity in pars sternocostalis did not show any significant difference between flat and decline bench press and could be isolated with either of these two exercises. The muscle activity in pars clavicularis showed a strong trend of higher activity while performing the flat bench press compared to the decline and incline bench press, however findings regarding the pars clavicularis differs between studies.


Introduction

A commonly used training concept within resistance training among bodybuilders is to strive after muscle isolation for optimal muscle hypertrophy. A wide range of exercises are often used to work the same muscles in different angles to stress different parts of a muscle or a muscle group. Add to this the recommended repetition range of 6-12 for hypertrophy training according to Coburn & Malek (2004), and the result is a very time consuming workout. M.pectoralis major is divided into three segments, clavicularis, pars sternocostalis and pars abdominals, and different angles of bench press are often used for targeting each segment (Heinz & Dauber 2011).

Flat bench press seems to be the most used exercise in resistance training for m.pectoralis major followed by other complimentary exercises used to further isolate different segments of the m.pectoralis major. However, research into optimal training for hypertrophy of the three segments of the pectoralis major muscle is limited and a more effective training concept might be possible. The aim of this study was to investigate muscle activity in m.pectoralis major's three segments with different variations of bench press.

1. Background

1.1 Skeletal muscle

A muscle contraction is an advanced physiological process that is important to understand to be able to measure the muscle activity during training; therefore this process will be described below.

1.1.2 Sarcomeres

The muscle consists of muscle fibers grouped together, and each muscle fiber consists of myofibrils. The smallest unit in the myofibrils is called sarcomere. Sarcomeres are built up by proteins actin and myosin. Rows of actinfilament are attached to z-lines and between each row is myosin. On the surface of the actinfilament we find binding sites for myosin, however while the muscle is relaxed, these binding sites are covered by the protein tropomyosin. Myosin has myosin heads that will bind to the actinfilament when ATP binds to myosin and splits into ADP and phosphate which releases energy; however tropomyosin prevents them from doing so (Sand, Sjaastad & Haug 2004; Greig & Jones 2010).
1.1.3 Motor unit

The motor unit consists of an anterior motor neuron and muscle fibers. These motor units perform specific muscle tasks depending on how many units that are working. Each muscle fiber is connected to a motor neuron and receives information from this neuron; however each motor neuron innervates several muscle fibers. The amount of fibers innervated by each motor neuron differs and some neurons can have up to thousand fibers connected (Sand et al., 2004).

The muscle fibers in the motor units differ from each other. There are two main fiber types slow (type 1) and fast (type 2) and the relative proportion between these types differs in the different muscles. Muscles which works under longer periods, such as posture muscles consists of more type 1 fibers and muscles used for faster movements such as the arms consists of more type 2 fibers. The type 2 fibers can be divided into two groups weather they are able to produce high power during shorter periods (type 2x) or produce high power during longer periods (type 2a) (Sand et al., 2004; Greig & Jones 2013).

1.2 Action potential

The central nerve system (CNS) sends out an electrical nerves impulse in order to create a muscle contraction. This electrical nerve cell impulse is called action potential. These action potentials travel fast along the axon to target cell. This signal reaches the synapse; a connection between two cells that allows the electrical signal to travel across cell membrane between two cells. The synapse between the nerve cell and the skeletal muscle is an example of this connection. The action potential travels to the t-tubuli which is in contact with the sarcoplasmic reticulum. The action potential that reaches the t-tubuli depolarizes the membrane which opens up Ca$^{2+}$- channels from the sarkoplasmic reticulum which release Ca$^{2+}$ into the sarcoplasma (Sand et al., 2004; Greig & Jones 2013).

1.3 Muscle contraction

When Ca$^{2+}$ is released into the muscle, it binds to troponin which rearranges tropomyosin and exposes binding sites for myosin heads. The myosin head is now able to bind on the actin and creates a cross bridge. Myosin drags the actinfilament and the overlapping of myosin and actin increases. Myosin releases from actin and binds on a new binding site and further drags the actinfilament. This causes sarcomeres to shorten and the muscle contracts (Sand et al., 2004; Greig & Jones 2013)
A muscle is connected to the bone by tendon. The muscle is attached to each side of a joint, which is called origin and insertion. When a muscle contracts, for example m.biceps brachii which is attached on both side of the elbow joint, the muscle shortens and the origin and insertion moves closer to each other, which causes the arm to move (Sand et al., 2004). Muscle contraction allows us to move and plays a crucial part in all sports whether the task is to run a mile or lift heavy objects.

The contraction force depends on the amount of motor units recruited. A small amount of motor unit recruitments results in a weak muscle contraction; however the motor unit recruitment is increased with time during stimulation (Sand et al., 2004).

The actions potential only contracts the muscle for a short amount of time. It is the continued action potential that comes close to each other that allows a longer muscle contraction. This type of contraction is called a tetanic contraction and will keep contracting as long as the stimulation is there. The skeletal muscle uses tetanic contraction for both short (for example while jumping) and long (during resistance training) (Sand et al., 2004; Greig & Jones 2013).

1.4 Resistance training

Resistance training is a well-established method for increasing strength. This increased muscle strength occurs with increased muscular cross sectional area (muscle hypertrophy) via resistance training (Myer 2006; Schoenfeld et al., 2014) Studies have shown several potential benefits from resistance training besides muscle strength, for example increased cardiorespiratory fitness, increased resistance to injury and enhanced mental health and well-being (Myer 2006). The most common resistance training is dynamic constant external resistance training (DCER). This form of training consists of lifting and lowering an external weight, for example a barbell or dumbbell (McArdl, Katch, & Katch 2015).

The barbell bench press is a commonly used DCER exercise in the gym and can for example be used for training power, strength and hypertrophy which makes this exercise a valid choice in many sports. The barbell bench press is often used for training the m.pectoralis major and it is believed that the angle of the bench while performing this exercise targets different segments of this muscle, however more studies into these different segments is needed.

1.4.2 Muscle hypertrophy and atrophy

In specific adaptation training, for example hypertrophy, the muscle fibers does not increase in amount, they rather transform. Hypertrophy training increases the proteins actin and
myosin synthesis which leads to a larger amount of myofilament, increased diameter and larger contraction force (Sand et al., 2004; Greig & Jones 2013).

Muscle breakdown or muscle atrophy is the opposite of muscle hypertrophy. When a muscle is not regular loaded for example when a person is bed rested for a longer period of time, the muscle start to lose maximal muscle contraction and the diameter decreases (Sand et al., 2004; Schoenfeld et al., 2014).

1.4.3 **Muscle fatigue**

Muscle fatigue could occur during muscle activity that is performed on a high intensity or under a long period. Muscle fatigue can occur from many different factors, both physiological and psychological. This results in lower maximal contraction force in muscle. Physiological factors might be due to lower releasing of calcium ion a possible explanation to muscle fatigue. The psychological factors can differ between different athletes (Sand et al., 2004; Greig & Jones 2013).

1.5 **Previous research in bench press**

The primary active muscle while performing bench press is m.pectoralis major. M.pectoralis major is divided into three segments, pars clavicularis (upper segment with origin on clavicular), pars sternocostalis (middle segment with origin on sternum and costae) and pars abdominals (lower segment with origin on rectus sheath) (Feneis & Dauber, 2011). The bench press exercises with numerous variations and its effect on muscle activity in m.pectoralis major are examined in many previous studies.

In a study by Welsch, Bird & Mayhew (2005) the differences in electromyography activity in m.pectoralis major during 3 repetitions of barbell bench press, dumbbell bench press and dumbbell fly were investigated. They found the peak activity levels for bench press to be higher than in dumbbell fly and dumbbell bench press. The mean activity did not show any significant difference in m.pectoralis major. They also found that barbell bench press had the greatest relative time of muscle activity compared to dumbbell bench press and dumbbell flies.

In another study done by Glass & Armstrong (1997), the muscle activity in the upper and lower part of m.pectoralis major were measured during two bench press variations, decline bench press (-15 ° from horizontal) and incline bench press (+30° from horizontal). The test subjects performed 6 repetitions on a load of 70 % of 1RM. They found that there were no
significant differences in the upper part of m.pectoralis major while performing these two exercises. In decline bench press, the lower part of m.pectoralis showed a significant higher activity than in incline bench press.

Barnett, Kippers & Turner (1995) investigated the muscle activity in five shoulder muscles while performing different variations of the bench press. The variations tested were decline bench press (18° from horizontal), flat bench press (horizontal body), incline bench press (40° from horizontal) and vertical press (press with a vertical upper body). The test subjects performed these variations at a load of 80 % of their 1RM with a 2 second long eccentric phase. They found a significantly higher muscle activity in pars sternocostalis while performing the flat bench press compared to both the decline and incline bench press. A significantly higher muscle activity was found in pars clavicularis while performing the incline bench press in comparison to the decline bench press.

Keogh, Wilson and Weatherby (1999) studied seven different resistant training techniques in bench press. The different techniques included isokinetic (six repetitions with a velocity of 0.2 ms⁻¹), eccentric training (load at 110 % of 1RM), functional isometrics (6RM load however the MVIC test was performed with an 160° elbow angle compared to the other exercises with an elbow angle of 110°), super slow motion (load at 55 % of 1RM with an 5 seconds eccentric and 5 seconds concentric phase), rest paus (6RM load with a rest pause without any load at the top of the exercise), breakdowns (at 95, 90, 85, 82.5 and 80 % of 1RM with an decreased load for each repetition) and maximal power training (Load at 30 % of 1RM with six explosive repetitions). They compared these seven techniques with heavy weight training (HWT), which uses loads at six repetition maximum (6RM). The authors mention that “Heavy weight training (HWT) with loads of approximately 6 repetition maximum (RM) has been shown to lead to significant increases in most aspects of muscular function…” (Keogh et al, s. 247). They found that super slow motion and maximal power training showed significantly lower muscle activity than the HWT.

In a recent study by Lauver, Cayot & Scheuermann (2015) the influence of bench angle on upper extremity muscles during bench press was investigated. They measured various time points in the barbell bench press in different angles (-15°, 0°, 30° and 45° from horizontal). The test subjects performed six repetitions on each bench press variation with the same absolute load of 65 % of 1RM. The pace in which the exercises were performed was 2 seconds eccentric and two seconds concentric phase. They found a greater muscle activity in
pars clavicularis, m.triceps brachii and m.anterior deltoid during the incline concentric phase compared to the decline and horizontal bench press. They also found a higher activity in pars abdominals during the horizontal and decline bench press compared to the incline bench press.

1.6 Electromyography

A commonly used method to analyze muscle activity is electromyography (EMG). Electrical signals (action potentials) in muscle during a muscle contraction are registered with EMG by placing small electrodes on the muscle along the muscle fibers. Two measurement electrodes are placed on the muscle of interest and a reference electrode is placed on an area nearby Konrad (2006). Disposable gelled electrodes were used for this study.

When obtaining EMG-measurements, it is important to take the placement of the electrodes under consideration to make sure that the intended muscle is measured and that factors that could interfere with the measurement is limited. Optimal placement is on a line between two anatomical landmarks, which contributes to a more reliable measurement together with making sure the electrodes is placed in the same way on all of the test subjects and that it is placed in the same way every time you test the same test subject (Day 2003).

De Luca (2002) discusses placement of the electrodes. The electrodes should not be placed near or on the tendon of the muscles due to thinner and fewer numbers of fibers. This will reduce the signal from EMG. Electrodes also should not be placed on the outside edges of the muscle. By placing electrodes near the edges, you increase the chance of crosstalk from neighboring muscles. It is also important to place electrodes along the direction of the fibers so that the pair of electrodes used measure as much of the same fibers as possible. The reference electrode should be placed as far away from the measurement electrodes as possible, and on a neutral tissue such as a bone.

De Luca (2002) discusses concerns when using EMG. Noise is a common issue that could affect the EMG measurement. De Luca defines noise as electrical signals that are not part of the wanted EMG. Day (2003) talks about two different types of noise, ambient- and transducer noise. Ambient noise is created by electromagnetic devices like computers or power lines. Transducer noise is created at the electrode-skin connection, this noise can occur from chemical reactions in the region were the electrodes and the conductive gel is in contact. Day (2003) also talks about crosstalk as a factor. It is important to understand that when using
EMG, crosstalk from other muscles may occur. Crosstalk occurs especially when measuring small muscles with neighboring muscles. According to Konrad (2006), crosstalk is especially common in the upper trunk muscles.

1.6.2 **Maximal voluntary isometric contraction**

EMG measures muscle activity, however many different factors affect the EMG measurements (body fat and level of training for example) which yields individual data. A common way to compare EMG data from different individuals is to compare measurement data to a maximal voluntary isometric contraction (MVIC). An isometric contraction occurs when the muscle activates and yields force without muscle shortening; this contraction occurs when the object a person is trying to lift does not move (Sand et al., 2004). Halaki and Ginn (2012) discuss the lack of standard tests for the MVIC. A test which produces maximal activity consistently in all individuals on every attempt does not exist, however a high repeatability is shown for the MVICs for the same individual when performed on the same day.

Previous studies findings considering the viability, limitations and error sources during EMG testing helps us to conduct a test procedure which portrays the muscle activity with as much reliability as possible. This study will add a greater understanding of the m.pectoralis major muscle and its three segments (pars clavicularis, pars sternocostalis and pars abdominals) and how they are affected by different bench press variations. Previous studies has investigated some of the commonly used bench angles for the bench press exercises used for training the different segments; however other commonly used bench angles is yet to be investigated. Furthermore, previous studies does not investigate the difference in muscle activity in all three segments between all three bench press variations (incline, flat and decline) which this study adds.

**1.7 Aim**

The aim of this study was to examine muscular activity in three segments of m.pectoralis majors (pars clavicularis, pars sternocostalis and pars abdominals) in three different angles in barbell bench press to acquire a greater understanding of the different functions of the m.pectoralis major and how these three segments might be trained.
1.7.2 Research questions

1. Are there any differences in muscle activity in the upper part of m.pectoralis major (pars clavicularis) between any of the bench press exercises (decline, flat and incline bench press)?

2. Are there any differences in muscle activity in the middle part of m.pectoralis major (pars sternocostalis) between any of the bench press exercises (decline, flat and incline bench press)?

3. Are there any differences in muscle activity in the lower part of m.pectoralis major (pars abdominals) between any of the bench press exercises (decline, flat and incline bench press)?

2. Method

2.1 Subjects

The subject group consisted of thirteen healthy males (age 23± 3.8 year and BMI 24.3±1.8 kg/m²). Sixteen test subjects signed up for the study; however three dropouts occurred before the study began. The inclusion criteria in this study were that the subject is familiar with the exercises (bench press, incline bench press and decline bench press). Exclusion criterions for the study was that the test subject did not have any injuries in structures involved while performing the exercises involved in the study or suffer from any form of cardiovascular diseases. This study was performed on male subjects due to the method used for collecting test data in m.pectoralis major. Recruitment of subjects was done at Halmstad University and local gym facilities in Halmstad.

2.2 Muscle activity data collection

The data were collected using electromyography and the average root-mean-square (RMS) was collected in raw free mode. The ME6000-unit (Kuopio, Finland) was used together with the Megawin software (700046 Version 3.0, Mega Electronics LTD Kuopio, Finland) 1000Hz to collect the data. Electrodes were connected to the ME6000-unit and placed on three areas on the m.pectorals major. The average EMG activity (in µV) was analyzed together with the max EMG activity (in µV). The average EMG activity (in µV) was the main focus since the specific focus was hypertrophy training. The electrodes were placed in pairs against each other on the lower, inner and upper part of the m.pectoralis major (see appendix 2).
2.3 Test procedures

2.3.2 Test day 1: Six repetition maximum test

A week before the main test, a test was performed to establish each subject’s six repetition maximum (6RM) for each of the three exercises. The 6RM load was used for a lower injury risk (compared to 1RM) for the test subjects and to simulate hypertrophy training. This test was performed in the Halmstad University laboratory. The 6RM test was performed with a 2-2 rate (2 seconds eccentric face and 2 seconds concentric face without any rest in the top or bottom) and a metronome was used to make sure that the test subjects followed this rate. This velocity was used to make sure the test subjects performed the exercises in the same way every repetition, and on both test days as the velocity affects the amount of repetition performed and a lower velocity might result in a lower EMG measurement (Sakamato and Sinclair 2006, Keogh, Wilson and Weatherby 1999). A lower velocity is also common while training for hypertrophy.

Each subject started at a low weight (50% of their estimated 1RM) for warmup and to prevent injuries and allow the test subjects to get comfortable with the repetition pace. The weight was slowly increased (5-10 kg depending on the test subjects own estimated ability) to reach each test subjects individual 6RM in the three exercises. Between each attempt, the test subjects rested for four minutes. The 6RM for the exercises was established one at the time in the following order: Decline, flat and incline bench press.

2.3.3 Test day 2: Muscle activity in m.pectoralis major

Before the electrodes were applied, the skin was shaved and cleaned with alcohol. This was done to eliminate dead skin and hair as they might affect the measurement. A total of 9 electrodes (6 measurement electrodes and 3 reference electrodes) were then applied in the fiber direction on the three segments of m.pectoralis major (see appendix 2). The electrode placement on pars clavicularis and pars abdominals was done similar to Glass & Armstrong (1997) and the same anatomical landmarks was used however the electrodes on pars abdominals was placed closer to the insertion of the segment due to small chest area of some test subjects to avoid to place electrodes directly on the nipple which could result in an uncomfortable experience for the test subject. The electrodes on pars sternocostalis was placed on a line between the insertion of the muscle and the middle of sternum. A short warm-up of 5 min was performed on a Monark Ergomedic stationary bike with 50 W resistance followed by 3 set of 10 reps with a lighter load on the barbell bench press.
2.3.3 **Maximal voluntary isometric contraction test**

To obtain the maximal voluntary isometric contraction (MVIC) value for *m*.pectoralis major, the test subjects performed a MVIC while lying on a flat bench with a barbell held above the chest in 90° elbow flexion. The barbell was fixed and could not be moved upwards. On the test leader's signal, the test subject pressed the barbell up as hard as they could. This contraction was held for 3-5 seconds followed by one minute rest. This procedure was repeated 2 additional times. The barbell used for the MVIC-test was an international Eleiko 20 kg's barbell. This test was performed in the Halmstad University laboratory (Hislop & Montgomery 2007).

2.3.4 **Measurement activity in *m*.pectoralis major**

During the main test, the subjects performed three different exercises: flat bench press, incline bench press (+45° from horizontal) and decline bench press (-30° from horizontal). The subjects performed a total of 3 lifts which consisted of one attempts per exercise (decline, flat and incline bench press). On each attempt the test subjects performed six repetitions. Coburn and Malek (2004) discussed the optimal repetition range for hypertrophy and six repetitions were their lowest recommendation. This repetition range was used to avoid that muscle fatigue occurs that might affect the EMG measurement but also for time efficiency due to the amount of subjects and attempts of each subject (Konrad 2006).

A metronome was used to assure that the test subjects lifted in the same way and that every repetition looked the same. Each repetition consisted of 2 seconds concentric phase and 2 seconds of eccentric phase.

2.4 **Ethical and social considerations**

This study has the safety and well-being of the test subjects as the highest priority. Information for the test subjects were given both verbally and written in an information letter regarding the study design, aim, method test preparations and the risks and benefits of participating in the study, as well as how to reach the test leader if any further questions should arise. The test subjects were also informed that they could under any circumstances drop out of the stud at any time without stating any reason or explain themselves.

The informed consent forms were signed by the test subject before participating in any part of the study to ensure that the test subjects read and understood the study and their own rights.
The information letter and the informed consent form given to the subjects can be found in the appendices.

Before the test began, the supervisors took note of personal information to eliminate that the same subject was tested more than once or that their information is lost. This information is not included in the study or shared among others than the supervisors. This information included name, age, height and weight. To prevent the personal information of the test subjects and the data from the measurements to reach a third hand party, this information was stored on an USB device and away from the data collection sheets.

This study can be useful in a larger perspective. Coaches, trainers, athletes and even recreational active people could use the results from this study and apply these on their training programs. A greater understanding of the bench press exercise and its effect on the different segments of the m.pectoralis major could help individuals to target more specific areas of the chest to improve towards their individual goal. Time efficiency is a common goal for many athletes and recreational active people when designing their training schedule due to today’s busy lifestyles. By studying the m.pectoralis major and the activity in the three segments during different bench press variations, more efficient training schedules could be composed.

2.5 Statistical analyses

The program SPSS was used for the statistical calculations and Microsoft Office Excel was used for figures and tables presenting the result.

A Shapiro-Wilk test for non-normality was done in SPSS to analyze the distribution of the data Shapiro and Wilk (1965). Royson (1991, s.117) states that Shapiro and Wilk’s (1965) W-test of departure from normality is a powerful test. The three segments in percent of MVIC in the three bench press variations were tested for normality and the result showed that almost all of the data was normally distributed (activity in pars sternocostalis were the only non-distributed of the nine tested) and thus parametric statistics were used for all the data, also for the data that was not normally distributed. The parametric test used was a paired t-test to compare statistical significance. The statistical significance level will be set at α=0.05 for this study.
3. Results

3.1 Exercise load

The load used for the three exercises (flat, incline and decline bench press) is shown in Figure 1. The mean load used for the decline bench press was 78 ± 17 kg. The mean load used for the flat bench press was 76 ± 15 kg. The mean load used for the incline bench press was 59 ± 12 kg.

![Six repetition maximum graph]

*Figure 1.* Mean load (kg) used for the six repetition maximum with standard deviation error bars

3.2 Muscle activity in different parts of m.pectoralis major

The muscle activity in each of the three segments while performing the three exercises (flat, incline and decline bench press) is shown in Figure 2.
The muscle activity in pars clavicularis while performing the three exercises is shown in table 1. While performing the flat bench press, the mean activation in pars clavicularis was 61.1 ± 14.4 % of MVIC. While performing the decline bench press and the incline bench press, the muscle activity in pars clavicularis displayed a strong trend of a lower muscle activity (decline: p= 0.055 and incline: p=0.052) in comparison to the flat bench press. The muscle activity in pars clavicularis did not show any significant difference (p= 0.997) while performing the incline bench press in comparison to the decline bench press.

The muscle activity in pars sternocostalis while performing the three exercises is shown in table 1. While performing the flat bench press, the mean activation is pars sternocostalis was 60.2 ± 17.4 % of MVIC. The muscle activity in pars sternocostalis while performing the incline bench press was significantly lower (p<0.001) in comparison to the flat bench press. A weak trend (p=0.168) of lower muscle activity could also be seen while performing the decline bench press compared to the flat bench press. The muscle activity in pars sternocostalis while performing the decline bench press was significantly higher (p<0.001) in comparison to the incline bench press.
The muscle activity in pars abdominals while performing the three exercises is shown in table 1. While performing the flat bench press, the mean activation is pars was 62.9 ± 13.9 % of MVIC. The muscle activity in pars abdominals while performing the decline bench press was significantly higher (p=0.013) in comparison to the flat bench press. The muscle activity in pars abdominals while performing the incline bench press were significantly lower than both the flat and decline bench press (flat: p<0.001 and decline: p<0.001).

Table 1. Mean muscle activity in percent of MVIC with standard deviation (SD) in the three bench press variations.

<table>
<thead>
<tr>
<th>Muscle segment</th>
<th>Decline bench press</th>
<th>Flat bench press</th>
<th>Incline bench press</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pars clavicularis</td>
<td>53.2 ± 11</td>
<td>61.1 ± 14.4</td>
<td>53.3 ± 14.8</td>
</tr>
<tr>
<td>Pars sternocostalis</td>
<td>56.7 ± 15.4Δ</td>
<td>60.2 ± 17.4</td>
<td>34.2 ± 13.9*</td>
</tr>
<tr>
<td>Pars abdominals</td>
<td>68.8 ± 14.5#</td>
<td>62.9 ± 13.9#</td>
<td>21.2 ± 8.3#</td>
</tr>
</tbody>
</table>

The abbreviation MVIC refers to maximal voluntary isometric contraction. * indicates significant difference in muscle activity compared to the flat bench press. Δ indicates significant difference compared to incline bench press. # indicates significant difference in muscle activity between all bench press variations.

4. Discussion

To summarize the findings of this study, the research questions will try to be answered below:

1. Are there any differences in muscle activity in the upper part of m.pectoralis major (pars clavicularis) between any of the bench press exercises (decline, flat and incline bench press)? The highest muscle activity in pars clavicularis was seen while performing the flat bench press, as compared to incline or decline bench press.

2. Are there any differences in muscle activity in the middle part of m.pectoralis major (pars sternocostalis) between any of the bench press exercises (decline, flat and incline bench press)? Flat or decline bench press induced highest muscle activity in pars sternocostalis, with no difference between flat or decline bench press.
3. Are there any differences in muscle activity in the lower part of m.pectoralis major (pars abdominals) between any of the bench press exercises (decline, flat and incline bench press)? The highest muscle activity in pars abdominals is acquired with the decline bench press.

4.1 Result discussion

4.1.2 Muscle activity in Pars clavicularis

The muscle activity in pars clavicularis while performing the incline bench press did not show any significant difference in comparison to the decline bench press. This corresponds with the findings Glass & Armstrong (1997) did were no significant difference in pars clavicularis when performing the decline bench press in comparison to the incline bench press could be seen. However Barnett, Kippers & Turner (1995) found a significantly higher muscle activity in pars clavicularis while performing the incline bench press in comparison to the decline bench press which does not correspond with the findings in this study. The angle of the bench used for their study was slightly lower (40° from horizontal) than in this study. The pace of their lift (2 seconds eccentric phase and no restrictions on the concentric phase) also differed from this study were the eccentric and concentric phase lasted 2 seconds each. This could possibly have lead to the different results.

Lauver, Cayot & Scheuermann (2015) found a greater muscle activity in pars calvicularis in the concentric phase of the incline bench press compared to the decline and flat bench press. This does not correspond with the findings in this study were a strong trend of a higher muscle activity in pars clavicularis could be seen while performing the flat bench press in comparison to the incline bench press however; this study did not separately measure the concentric and eccentric part of the lift which was done in the study by Lauver, Cayot & Scheuermann (2015).

Lauver, Cayot & Scheuermann (2015) also found greater muscle activity in pars clavicularis when performing the eccentric phase of the flat bench press in comparison to the incline bench press. This corresponds with the findings in this study were a trend of higher muscle activity could be seen while performing the flat bench press in comparison to the incline bench press.

This study focused on the full lift of the three bench press variations, however due to different muscle activity seen in the eccentric and concentric phase in the study by Lauver, Cayot &
Scheuermann (2015) it could have been interesting to investigate the eccentric and concentric phase separately instead of the complete lift for a better understanding of the muscle activity.

Lauver, Cayot & Scheuremann (2015) also investigated other muscles involved in the bench press (m.anterior deltoid and m.triceps brachii) and found a higher muscle activity in these two muscles during the eccentric phase of the incline bench press in comparison to the flat and decline bench press. These two muscles could also have been measured in this study for a greater understanding of the muscle activity.

4.1.3 Muscle activity in Pars sternocostalis
A weak trend of lower muscle activity in pars sternocostalis could be seen while performing the decline bench press in comparison to the flat bench press. The muscle activity was significantly lower while performing the incline bench press in comparison to the flat and decline bench press. These findings somewhat corresponds with previous findings done by Barnett, Kippers & Turner (1995) were a significantly higher muscle activity could be seen in pars sternocostalis while performing the flat bench press compared to both the decline and incline bench press.

4.1.4 Muscle activity in Pars abdominals
Glass & Armstrong (1997) found a significantly higher muscle activity in pars abdominals when performing the decline bench press in comparison to the incline bench press. Lauver, Cayot & Scheuremann (2015) also found a lower muscle activity while performing the incline bench press in comparison to the decline and flat bench press. The findings of these previous studies corresponds with the findings in this study were the muscle activity in pars abdominals were significantly higher while performing the decline and flat bench press in comparison to the incline bench press. The muscle activity were also significantly higher when performing the decline bench press in comparison to the flat bench press. This suggests that the decline bench press is the preferred exercise to isolate the pars abdominals.

4.2 Method discussion
The test group was homogeneous (healthy young males) and therefore the findings in this study is only applicable on healthy young males. Future studies could investigate the activity in m.pectoralis major’s segments in other groups or between groups for a larger applicability among the population.
To avoid crosstalk, the correct size of the area where electrodes are placed should be chosen. The distance between the electrodes should also be appropriate length to avoid crosstalk, this however decreases the measurement distance of EMG (Day, 2003). During the measurements of the muscle activity in m.pectoralis major, some interference in form of cross-talk could be seen. This could lead to wrong interpretation of the data. Crosstalk is common when measuring the upper trunk muscles due to the fact that the heart's electrical signals could interfere with the measurement and create crosstalk, however the right side of chest was measured to decrease this as much as possible. The electrode placements (see appendix 2) could possibly be done in another way to allow more space between the different segments and avoid crosstalk even more, however the difference in chest size of the test subjects did affect the electrode placement.

The moderate grip used for this study was chosen on the recommendations done by Lehman (2005) were the grip width and its effect on myoelectric activity was examined. It was found that a moderate grip width result in the sticking region to occur at a greater distance from the shoulder axis and last for a smaller time of the ascent phase. The sticking region is the parts of the eccentric phase were failure is most likely to occur. However Lehman (2005) investigated the flat bench press and different relations between sticking region and grip width might be seen in the incline or decline bench press. This could future studies also take under consideration.

During the test, a pace of 2-0-2 seconds was used for both the 6RM test and the main test. This pace was unfamiliar to some of the subjects and could have affected the performance of the lifts; however this pace was used to strive after a similar activity that is commonly used for bodybuilders while trying to achieve muscle isolation. The data from this study was also used for another study were the velocity of the bench press was examined and the 2-0-2 pace was used for time efficiency. Keogh, Wilson and Weatherby (1999) studied seven different resistant training techniques and found that heavy weight training (which uses loads at six repetition maximum) showed significantly higher muscle activity than both super slow motion (load at 55 % of 1RM with an 5 seconds eccentric and 5 seconds concentric phase) and maximal power training (load at 30 % of 1RM with six explosive repetitions). A higher load at with a normal speed could therefore increase the muscle activity in the muscle. Sakamato and Sinclair (2006) also investigated the movement velocity and the effect it has on the relationship between training load and number of repetitions done while performing bench press. Their results showed that a faster velocity resulted in more repetitions performed while
using the same load. To acquire highest muscle activity possible for the three segments in m.pectoralis major, a faster velocity could be used. A higher load for the test subjects 6RM could then possibly be seen. If a faster velocity were used, the test subjects could possibly perform better if they did not need to concentrate on the metronome and stop themselves from going faster than allowed. By reducing this psychological factor, the muscle fatigue could possibly be decreased to get a more reliable EMG measurement.

The load used for each test subject was chosen to imitate the test subject’s workout load. The same load in all the three exercises was another possible option for this study; however the exercises are often performed with different loads due to strength differences in the different angles.

Glass & Armstrong (1997) investigated the incline bench press (+30 ° from horizontal) and decline bench press (-15 ° from horizontal) and this study investigated incline bench press (+45 ° from horizontal) and decline bench press (-15 ° from horizontal). The angle of the bench in this study while performing the decline bench press was not as great as first planned. Due to unavailable equipment, a bench was used without the optimal support for declined exercises. A larger difference between the flat and the decline bench press could be used for greater understanding of the difference between these exercises and future studies could further investigate this. The incline bench press could also be investigated in angles between (+30 ° and +45 ° from horizontal).

The three exercises were tested on the same day. This meant that the two exercises performed last of the three might have been affected of muscle fatigue or that the test subject might have been mentally tired and performed poorly. Muscle fatigue increases the EMG due to recruitment of new motor units or an increased frequency in the already active motor units during submaximal contractions (Viitasalo & Komi 1977). The test subjects needed experience of the exercises so that the inexperience did not affect the measurement due to muscle fatigue or different movement pattern.

For a more fair comparison between the three exercises, two additional test days might have been useful so that the exercises could have been performed on individual days. Another option for a more fair comparison between the three variations is to randomize the test order for each test subject. An additional study was performed on the same test subjects where one of the exercises from this study was included and two additional exercises were added. This
prevented a randomized order due to the additional exercises that would have affected the result differently on each test subject.

5. Conclusion

In conclusion, the decline bench press should be used for athletes with the goal to isolate pars abdominals. Muscle activity in pars sternocostalis did not show any significant difference between flat and decline bench press and could be isolated with either of these two exercises. The incline bench press however showed significantly lower muscle activity compared to flat and decline bench press. The muscle activity in pars clavicularis showed a strong trend of higher activity while performing the flat bench press compared to the decline and incline bench press, however findings regarding the pars clavicularis differs between studies depending on the focus of the study. Future studies could investigate this further taking time points, grip width, bench angle, exercise load and pace under considerations.
6. References


Appendix 1.

Information om testutförandet

Kontaktuppgifter:
Testledare: Adam Sahlén
Telefon: 070-5206547
Mail: adam-sahlen@hotmail.com

Syfte:
Syftet med studien är att undersöka muskelaktiveringen i m.pectoralis major (stora bröstmuskeln) för att se om olika övningar som är vanligt förekommande på gymmet kan användas för att stimulera specifika delar av denna muskel.

Utförande:

Allmän information om studien:
- Testpersonerna kan när som helst välja att hoppa av studien utan att behöva uppgö ett skäl till detta
- Som testperson ska du vara fri från skador som kan påverka din prestation vid de tre övningarna
- Som testperson får du inte tidigare haft problem med hjärt- och kärlsjukdomar
- Namn, kroppsvikt, längd och vikt använd vid alla tre övningar kommer att antecknas av testledaren men kommer inte att ingå i studien och kommer enbart läsas av testledaren. Ett medelvärde på de 15 testpersonernas BMI kommer att finnas med i studien
• Skaderisken under de både testtillfällena är inte högre än om dessa övningar skulle utförts på egen hand under träning
• Elektroderna innebär ingen smärta under eller efter testet, men kan ge en lätt irritation någon timme efter

Testtillfällen:


Testtillfälle 1: 6RM

Under det första testtillfället kommer ett 6RM (det vill säga den maximala vikten vid 6 repetitioner) för varje person tas ut vid varje övning (Bänkpress, Bänkpress i +45° vinkel och Bänkpress i -30° vinkel). Testpersonerna kommer starta på en lättare vikt, utföra sina 6 repetitioner för att sedan vila 5 minuter. Detta för att testpersonerna ska bli varma samt att testledarna ska kunna standardisera lyften. Testet upprepas tills en 6RM nåttas för varje övning.

Testtillfälle 2: EMG

1. MVIC (Maximal volontär isometrisk kontraktion)

Eftersom mätvärdena som fås vid EMG-mätningen är individuella och inte går att jämföras mellan testpersonerna så tas ett MVIC-värde ut för att kunna analysera de mätvärden som fås. Detta görs 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. En 10 minuter lång uppvärmning på låg intensitet på en stationär motionscykel kommer att utföras innan MVIC testet.
2. EMG-mätning

Huvudtestet involverar totalt 3 lyft per testperson (Bänkpress, Bänkpress i +45° vinkel och Bänkpress i -30° vinkel). En kortare uppvärmning involverade samma övningar kommer att ges innan testet startar. Mellan varje övning kommer testpersonerna att få vila 5 minuter.
Samtycke

- Jag har läst informationen om testutförandet och har förståelse för vilka tester som kommer utföras under de båda testtillfällena
- Jag har förstått syftet med studien
- Jag har förståelse för vilka risker som studien medför
- Jag deltar frivilligt i studien och jag har förstått att jag när som helst kan hoppa av studien utan att behöva förklara varför

________________________________________
Ort/datum

__________________________ ___________________________
Namnteckning Namnförtydligande
Appendix 2.

Chart showing the electrode placement

The chart above shows the placement of the electrodes for the measuring of the three segments. The white colored markers represent the measurement electrodes and the black markers show the placement of the reference electrode.
My name is Adam Sahlén, I have studied the Bachelor's programme in Exercise Biomedicine 180 credits. I am also a certified Flowin Instructor and Eleiko Strength Coach step 1.