MUSCLE ACTIVATION DURING A DECLINE PUSH UP ON AN UNSTABLE SURFACE

A THESIS

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Kelsey Todd

Research Advisor, Dr. Edwin Zuchelkowski

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CALIFORNIA, PA

THESIS APPROVAL

Graduate Athletic Training Education

We hereby approve the Thesis of

Kelsey Todd
Candidate for the degree of Master of Science

Date	Faculty
5/23/11	Edwin Zuchelkowski, PhD (Chair)
5/23/11	Shelly DiCesaro PhD, ATC, CSCS
5/23/11	Rebecca Hess, PhD

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INTRODUCTION

A common and very basic exercise is the standard push up. The push up is an exercise that helps strengthen the upper body and the core. It is also used to test the strength and endurance of the arms, shoulders and chest.[1] The push up is traditionally performed with both the hands and the feet placed on the floor. The body is kept in a straight line from the head to the heels and is lowered to the ground where the chest just barely touches and then is returned to the starting position. Gravity is responsible for the movement seen during the first phase. The muscles forcefully contract to return the body from the ground to the top position.[2] The primary muscles involved in this exercise are the pectoralis major, pectoralis minor, serratus anterior, triceps and the wrist extensors. However, stabilizer muscles such as the rectus abdominus, internal and external obliques, and the hip flexors are also important muscles as they keep the body in a straight alignment.

When performing a push up, one might have to practice the proper form until he/she is competent with the

exercise. To make the exercise easier, a variation of the standard push up can be performed by placing the knees on the ground and producing a straight line from the knees to the head.[2] This variation reduces the amount of resistance placed on the body, making the exercise less difficult. On the contrary, the level of difficulty can be increased by performing the push up using one hand or on a piece of equipment.

These multiple variations may act to increase or decrease the relative contribution of a given muscle. Previous studies have shown that by varying the hand placement from the standard positioning to a narrow position where the hands form a diamond shape, muscle activation of the triceps brachii and pectoralis major was increased.[3] Other variants of the push up have been tested and the results showed that the more dynamic the push up, the greater the muscle activation.[4]

Over the years, performing exercises while on an unstable surface has grown in popularity. Stability balls have been found in physical therapy clinics, gyms, strength and conditioning programs and even in the home. The thought behind the use of a stability ball is that its inherent instability places a higher demand on the proprioceptors which sense where different parts of the

body are located with respect to one another. More importantly for the present study, instability is thought to place a higher demand on postural muscles, therefore causing the stabilizing muscles to activate at a higher rate.[5]

In order to help achieve a greater outcome during a workout, people have been adding an instability factor to common exercises. One such exercise is the push up. This exercise can be performed by placing the hands on the ball with the feet on the ground or vice versa. Limited research has been conducted on this instability factor to determine if it indeed creates an environment where muscles are more active than normal. Marshall and Murphy[6] concluded that an increase in muscle activation is dependent on the particular exercise. Other authors' results showed that by replacing a stable surface with an unstable surface, muscle activation was unchanged for a majority of the muscles tested.[5,7,8]

Studies completed by Lehman[5,8,9] have extensively looked at the relationship between the use of a physioball and mean muscle activation. His first study looked at the muscle activity of the trunk muscles during upper extremity strength exercises performed on and off a physioball.[9] He later went on to experiment with the effects of a

physioball on the shoulder and scapulothoracic musculature during multiple push up variations.[5,8] All of his results concluded that there was not a significant change in muscle activity between the stable and unstable (physioball) surfaces.

The purpose of this study was to further investigate whether performing a push up off a physioball will increase the level of muscle activation of four particular muscles. This study also looked at the difference in muscle activation between a standard push up and a decline push up. The results of this study could be beneficial to the active population as well as physical therapists and athletic trainers in knowing if there is a significant difference in muscle activation levels between a standard push up, a decline push up and a decline push up performed on an unstable surface. With this knowledge, people can determine if it is actually beneficial to perform these different push up variations in regards to muscle activation level rather than the level of difficulty.

METHODS

The primary purpose of this study was to examine the difference in muscle activation when an unstable surface is used during a decline push up when compared to a stable surface. EMG activity was measured to evaluate muscle activation of several muscle groups. This section includes the Research Design, Subjects, Instruments, Procedures, Hypotheses and Data Analysis.

Research Design

This research was a within-subjects, repeated measures design. The independent variable was stability condition with three levels; ground, bench and physioball. The dependent variable was muscle activation in each of the four muscles (pectoralis major, external oblique, serratus anterior, and lower trapezius) as measured by peak activity of surface EMG.

Subjects

The subjects used for this study were 20 volunteer (10 male and 10 female) undergraduate and graduate students from California University of Pennsylvania. All subjects were at least 18 years of age and were screened for a history of shoulder, elbow and/or wrist injury within the previous six months. The subjects were active individuals who all knew the basic technique of a push up. An active individual is defined as someone who engages in 30 minutes of moderate exercise five days a week or 20 minutes of vigorous exercise three days a week.[10] The basic technique of a push week or vigor up is defined as hands and feet placed on the ground with back and knees straight. The feet are in dorsiflexion while the toes are in extension. The subjects were required to establish the plank position before being able to participate in the study.

Subjects also understood and agreed that it was required to perform this study shirtless due to electrode placement and interference with the leads. Females were required to wear a sports bra and shorts, while the males wore only shorts. The push ups were also performed in bare feet.

All subjects in the study signed an Informed Consent Form (Appendix C1) and filled out a demographic information sheet (Appendix C2) prior to participation in the study. Each participant's identity remained confidential and was not included in the study. The study was approved by the Institutional Review Board (Appendix C3) at California University of Pennsylvania prior to subject recruitment and/or testing.

Preliminary Research

Pilot testing was performed to assess the experimental design of the study. An individual, who was not a subject in the study, was used to perform this test. This test was used to review the protocol and to make sure the instruments were working properly. The researcher also checked for the subject's ability to understand the directions, the amount of time used to complete each task, and the accuracy of the protocol. During this time, the subject was taught the correct method of performing the decline push up, including proper hand and feet placement on the ground and ball/bench respectively. The researcher and the assistant also determined the proper placement of electrodes per muscle.

Instruments

The researcher used a demographic sheet (Appendix C2) to screen potential subjects. The demographic sheet determined the gender, age, level of physical activity, history performing a push up and a physioball and if the subject had an upper extremity injury within the previous six months. This study used a bench, physioball, a three and one half inch wooden block, a metronome to keep the proper pace, and Biopac MP150. The bench and the physioball sat approximately 45cm off the ground. The height of the physioball was checked prior to each testing session.

In collecting the EMG data, the researcher used four channels from a Biopac MP150 electromyography machine. The four channels were connected to electrodes located on the pectoralis major, external oblique, serratus anterior and lower trapezius. The Biopac MP150 amplifer with wired telemetry unit was connected to a laptop running Biopac Acknowledge 4.0 software to collect and analyze the data. The peak muscle activation as well as the mean activation scores were collected. The raw EMG signal was band pass

filtered at 10 and 1000 Hertz (Hz).[5,8] The researcher utilized a sampling rate of 2000 Hz.

Procedures

The Institutional Review Board at California University of Pennsylvania approved all testing protocols prior to experimentation (Appendix C3). Each potential subject filled out a demographic information sheet and signed an informed consent form. Once this was completed there was a brief explanation reviewing the testing protocol.

Prior to the initial set of tests, individuals were instructed to properly perform the push up as directed by the researcher. Once the proper form was established, the subject then performed a standard push up with the hands and feet on the ground and then the decline push up with his/her toes on the bench and again on the physioball.

The testing protocol consisted of measuring each subject's maximum voluntary isometric contraction of the pectoralis major, external oblique, serratus anterior and lower trapezius. These four particular muscles were chosen due to their location and function. The pectoralis major is the agonist muscle of the shoulder joint during the

concentric phase of the push up. The serratus anterior is an anterior shoulder girdle muscle and is the agonist muscle of the shoulder girdle during the concentric phase as well.[2] The external oblique is a stabilizer muscle of the lumbo-pelvic-hip complex,[11] while the lower trapezius is a posterior shoulder girdle muscle that is a stabilizer muscle during the eccentric phase of the push up.[2] The pectoralis major electrode was placed four finger widths below the clavicle and medial to the anterior axillary border. The external oblique electrode was placed 15cm lateral to the umbilicus along the direction of muscle fibers.[5] For the serratus anterior, the electrode was placed on the mid-axillary line of the muscle belly located over the fifth rib. The lower trapezius electrode was placed 1.5 cm lateral to the T6 spinous process with the electrodes at an inferior angle along the muscle fibers.[8]

For the testing protocol, the subjects were randomly assigned as to which push up condition (ground, bench, physioball) was performed first. The sites of the electrode placement were then prepared by cleaning the area with alcohol pads to remove any dead skin and/or oil.

The EMG machine was turned on and connected to the laptop to begin the testing. The subject positioned his/her hands so that the third phalanx was lined up with

the acromioclavicular joint on bilateral sides.[5,8] The feet were placed on the ball/bench so that the foot was dorsiflexed and the toes were extended. The only part in contact with the ball/bench was the toes. An assistant helped place the subject's feet on the ball/bench to limit any potential injury. The subject was instructed to lower the body until his/her nose touched a three and one half inch block. He/she was instructed to eccentrically lower the body for three seconds, hold the bottom position for three seconds, concentrically raise the body for three seconds, and then hold for a final three seconds at the top position while listening to the beat of the metronome and being prompted by the researcher. This three second count was adapted from Sandhu et al.[7] The subjects performed one set of three push ups per test. There was a minimum of a three-minute rest between tests. The testing protocol was performed one time per subject. The data was then collected from the Biopac Acknowledge software and recorded on a data collection sheet (Appendix C4) per subject.

Hypotheses

The following hypotheses were based on previous research and the researcher's intuition based on a review of the literature.

1. There will be a difference in muscle peak activation between the bench and physioball push ups compared to the ground push up.
2. There will not be a difference in muscle peak activation during the push up off the bench (stable condition) compared to the push up off the physioball (unstable condition).

Data Analysis

The research hypotheses were analyzed using a repeated measures MANOVA. All data was analyzed by Statistical Package for Social Sciences (SPSS) version 18.0 for Windows at an alpha level of ≤ 0.05. All EMG scores were reported as a percentage of maximal voluntary contraction.

RESULTS

The purpose of this study was to investigate the difference in muscle activation during a decline push up performed on an unstable surface (physioball) compared to a stable surface (bench). The following section contains data collected throughout the study and is divided into three subsections: Demographic Information, Hypotheses Testing, and Additional Findings.

Demographic Information

There were 20 physically active individuals that participated in this study. The age range was 19-25 years and the mean age was 20.95 years (Figure 1). Ten (50%) of the subjects were males and the remaining ten (50%) were females. Fifty percent of the subjects reported engaging in physical activity at least 3-4 times a week. The remaining fifty percent reported participating in physical activity 5-7 times a week. Eight (40%) of the subjects participated in an organized sport. When asked how often the subjects perform push ups, three (15%) responded daily,

eight (40%) weekly, four (20%) monthly and five (25%) responded occasionally throughout the year.

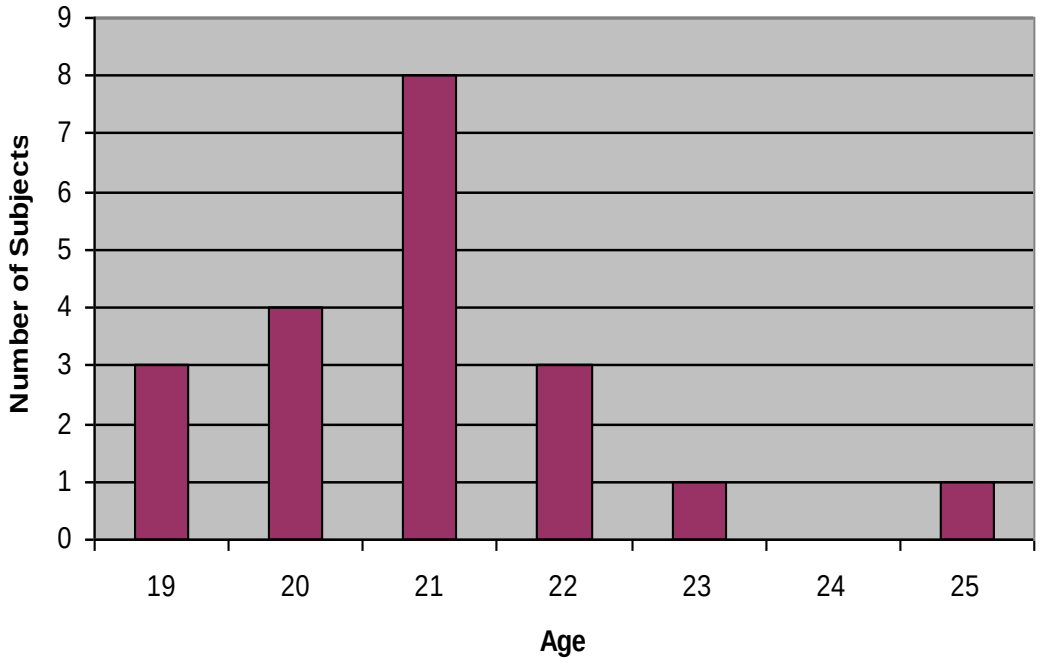

Figure 1. Distribution of Subjects' Age

Hypothesis Testing

The following hypotheses were tested during this study. Both hypotheses were tested with a level of significance set at $\alpha \leq 0.05$. A repeated measures ANOVA was calculated to find the effect of a decline push up on muscle activation when compared to a standard push up and

the effect of an unstable surface on muscle activation during a decline push up.

Hypothesis 1: There will be a difference in muscle peak activation between the bench and physioball push ups compared to the ground push up.

Hypothesis 2: There will not be a difference in muscle peak activation during the push up off the bench (stable condition) compared to the push up off the physioball (unstable condition).

Conclusion: A repeated measures MANOVA was calculated examining the effect of peak muscle activity of the pectoralis major, external oblique, serratus anterior and lower trapezius during push ups performed on the ground, off a bench and off a ball (Table 1). No significant effect was found between the push ups and peak activation levels (F (2,38) = .809, P > 0.05) (Table 2). The hypotheses were rejected.

Table 1. Descriptive Statistics for Maximal Peak Muscle Activation (%MVIC)

	Push Up Condition		
Muscle	**Ground Mean (SD)**	**Bench Mean (SD)**	**Ball Mean (SD)**
Pectoralis Major	190 (152.4)	221 (250.6)	202 (163.4)
External Oblique	280 (275.3)	302 (316.6)	288 (251.7)
Serratus Anterior	112 (58.7)	133 (80.6)	132 (81.6)
Lower Trapezius	99 (41.0)	84 (37.0)	89 (31.0)

Table 2. Effect of Peak Muscle Activation During Push Ups

Effect	**df**	**F**	**Sig.**
Condition	2	0.809	0.453
Muscle	3	5.312	0.003
Condition * Muscle	6	0.434	0.855

Additional Findings

Due to the circumstances of finding higher standard deviations, additional tests were ran to determine if there were any possible outliers in the data. The researcher took the mean of the scores and added two times the standard deviation to the mean. This resulted in eliminating six of the twenty subjects. A repeated

measures MANOVA was calculated with the new data. There was not a significant effect found when the outliers were eliminated (F (2,26) = .762, P > 0.05). The hypotheses were still rejected.

Additional peak activation scores among the four muscles were significant (P = 0.003). A repeated measures MANOVA was calculated comparing the peak activation level between the four muscles: pectoralis major, external oblique, serratus anterior and lower trapezius. A significant effect was found (F (3,57) = 5.312, P = 0.003). A follow up post-hoc paired t-test showed that scores were significant between external oblique and serratus anterior, serratus anterior and lower trapezius, pectoralis major and lower trapezius, and external oblique and lower trapezius (Table 3).

Table 3. Significant Differences Between Muscle Pairs

Muscle Pairs	**Sig.**
Pectoralis Major/External Oblique	0.300
Pectoralis Major/Serratus Anterior	0.097
Pectoralis Major/Lower Trapezius	0.010
External Oblique/Serratus Anterior	0.016
External Oblique/Lower Trapezius	0.003
Serratus Anterior/Lower Trapezius	0.049

In addition to the hypothesis testing, the researcher ran a between-subjects test along with the repeated measures MANOVA. Here gender was added as the between-subjects factor. There was no significant difference ($F(1,18) = .497$, $P > 0.05$) between the males and females when compared to the different push up conditions (ground, bench and ball) as well as the muscles tested.

Another repeated measures MANOVA was run, this time looking at the overall mean activation scores of the muscles over the course of the three push ups (Table 4). The results showed that there was not a significant effect found

(F (2,38) = 1.910, $P > .162$) in the overall mean activation scores during the three different push up conditions (ground, bench, and ball). However, the results showed a significant effect (F (3,57) = 3.976, $P = 0.012$) between the four individual muscles: pectoralis major, external oblique, serratus anterior, and lower trapezius. A follow up post-hoc paired t-test showed that scores were significant between the pectoralis major and lower trapezius, external oblique and serratus anterior and the external oblique and lower trapezius.

Table 4. Descriptive Statistics for Mean Muscle Activation (%MVIC)

	Push Up Variation		
Muscle	**Ground**	**Bench**	**Ball**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**
Pectoralis Major	101 (78.7)	145 (191.0)	112 (100.8)
External Oblique	175 (201.6)	192 (239.7)	165 (174.9)
Serratus Anterior	68 (46.3)	89 (78.7)	80 (58.0)
Lower Trapezius	63 (30.8)	52 (31.9)	50 (29.4)

DISCUSSION

The purpose of this study was to investigate the difference in muscle activation during a decline push performed on an unstable surface (physioball) compared to a stable surface (bench). The following section is divided into three subsections: Discussion of Results, Conclusions, and Recommendations.

Discussion of Results

Upon completion of this study, it was found that there was not a significant difference in the muscle activation patterns found when a push up was performed on the ground, off of a bench or physioball. The main findings showed that the type of surface, either stable or unstable, did not affect the amount of peak muscle activation in the pectoralis major, external oblique, serratus anterior and lower trapezius.

These findings were consistent with findings of previous studies performed by Lehman et al.[5,8] Lehman performed two different studies in which he examined muscle

activation during several variations of a push up. In both studies the push up was performed with the feet on a bench and with the feet on a ball as well as other variations. In the first study, Lehman et al[5] looked at the mean muscle activation of the triceps brachii, pectoralis major, rectus abdominis and external oblique in healthy male volunteers. Their results concluded that there was not a significant difference in any of the previously listed muscles when the push up was performed with the feet on a bench compared to when the feet were on a ball.

Lehman's second study was very similar to the first study. Here he looked at the difference in mean muscle activation between the upper trapezius, lower trapezius, serratus anterior, and biceps brachii. Once again, his results were consistent with the first study in which there was not a significant difference between the muscle activation of all the muscles when the push up was performed with the feet on the bench compared to the feet on a ball.[8] Even though Lehman et al[5,8] examined the mean muscle activation of the muscles involved, his results were consistent with the results we found with the peak muscle activation as well as the mean activation.

For this study, we used four muscles previously tested by Lehman. The pectoralis major and external oblique were

used for Lehman's first study and the serratus anterior and lower trapezius were used from his second study. Our results supported Lehman's findings that there is no significant difference within these four particular muscles when an unstable surface is used in conjunction with a decline push up.

Some researchers have also compared the use of a physioball and a stable surface. Sandhu et al[7] studied the effects of stable and unstable surfaces placed under the hands during variations of the push up and push up plus exercises. His results were in agreement with this study in that there was not a significant increase in the activity of the serratus anterior and upper trapezius. However, he did find a significant increase in the pectoralis major and triceps brachii but only during the eccentric phase of the elbow push ups. Lehman et al[9] looked at the effects of an unstable surface in trunk muscle activity while performing six upper extremity strength exercises. These results were in agreement with his other studies and our study in the conclusion that there was not a significant difference in muscle activity.

Along with investigating the difference between performing a push up off a bench and off a ball (a stable compared to an unstable surface), we looked at the muscle

activation between a push up performed with the hands and feet on the ground (standard) with the previously mentioned push up variations. There has been limited research done that has compared the difference between a standard push up and a decline push up. Interestingly, one would believe that if the feet were placed above the level of the head and hands that there would be more weight placed on the upper extremity and that the level of muscle activation would increase due to that level of weight increase. Due to this belief, we hypothesized that there would be a higher level of muscle activation during a decline push up compared to a standard push up. However, the results showed that there was not a significant difference between the standard push up and the decline push up.

The results showed that the push up performed on the ground did indeed have the lowest peak and mean muscle activation levels within the pectoralis major, external oblique and the serratus anterior when compared to the other two push up variants. However, the numbers were not large enough to be considered significant. When looking at the statistics, one can notice that there is a large variation in muscle activity due to individual differences between the subjects.

From observations made, a possibility as to why there was a large variation in muscle activity could be due to the actual form of the push up being performed according to the particular subjects. Even though the alignment of the hands with the acromioclavicular joint was regulated with each subject, the actual push up form was different. Several of the subjects' elbows were not held close to the body, therefore recruiting other muscles to activate to help perform the push up. With a number of subjects, there seemed to be abnormal tracking of the scapulae. The scapulae did not fluently move throughout the entire motion of the push ups. This abnormal tracking could have been caused by the scapulae not being moved fully into the abducted position, which indicates a weakness in the serratus anterior.[12] Another observation made was that many of the subjects began to fatigue during the protocol and began to arch/sag the lower back. This was seen particularly during the push up off the bench and off the physioball. This arching of the back signifies a weakness in the core strength.[2]

Several studies have used the push up exercise in their testing procedures, either comparing a stable versus unstable condition or the difference in hand placement.[1,5,7-9,13,14] However, many of these studies used only male

subjects. Due to this gender bias, I was interested in looking at both genders. The results showed that there was no difference between the genders in regards to muscle activation levels.

When reflecting on the testing procedure, it was noted that there might have been a reason why other researchers did not include females in their tests. The electrode placement proved difficult due to the muscles being tested. As it was unethical to test the females completely topless, they were required to wear a sports bra. The serratus anterior electrode was placed directly underneath the sports bra. When placing the electrodes, it was difficult to be precise due to the presence of the sports bra and the close proximity of the breasts. The pectoralis major and lower trapezius sites also provided some difficulty with the electrodes. Depending on the cut of the sports bra, the straps were found to rub against the electrodes and the leads. This could have caused interference with the leads during the EMG readings.

I was also interested to see if the stereotypical notion that males are better than females when performing push ups (hence the term for the knee bent push up as girl push ups) was valid. After observing all twenty subjects, there did not appear to be a difference in either gender's

ability to perform the push ups. Several members of both genders showed difficulty with the push up protocol. However, one should remember that during this testing protocol, the EMG looked at the muscle activation not the actual strength of the individual muscles.

Another observation noted was the level of difficulty between the three push up variations. The ground push up appeared to be the least difficult, followed by the push up off the bench, then the push up off the physioball. A possible reasoning behind the difference in difficulty is seen with the biomechanics of the push up. The push up exercise can be considered a second-class lever. This is where the resistance (gravity) is located between the axis (feet) and the effort (hands pushing up).[2] When the feet are placed above the level of the head, then a greater resistance is added to the body. This will cause the exercise to become more difficult in nature. Even though there was not a significant difference in muscle activation between the three push up variations, the level of difficulty should be taken into consideration when deciding to perform these exercises.

When looking at the results, it is interesting to see that the level of muscle activation per muscle per variation was not affected between the three push up

variations. For example, the external oblique showed the highest level of activation followed by the pectoralis major, serratus anterior and lastly the lower trapezius. This concludes that if one wants to activate the external oblique, it does not matter which push up variation is performed because they all will activate this particular muscle. In contrast, if one wants to activate the lower trapezius or even the serratus anterior, it is recommended not to perform these particular types of push ups.

When further investigating the results, one can see that there is no pattern found proving that one type of push up variation is superior to another in terms of activating the individual four muscles. On the contrary, if the lower trapezius was eliminated and only the pectoralis major, external oblique and serratus anterior muscles were observed then there appears to be a trend throughout the push up variations. The push up on the ground presented the lowest peak muscle activation levels, followed by the push up off the ball, then the push up off the bench.

Conclusions

This study resulted in no difference found in peak muscle activation of the pectoralis major, external oblique, serratus anterior and lower trapezius when performing a push up on the ground, with feet on a bench or with the feet on a physioball. Further, no difference in the mean muscle activation between the previously mentioned muscles and push up variations was reported. Additionally, gender does not appear to have an effect on muscle activation during the different push up variations. Trends were found showing that during these three particular push up variations, the external oblique produced the highest activation levels followed by the pectoralis major, serratus anterior and lastly the lower trapezius.

Recommendations

To further advance the study just completed, I would have the subjects perform the protocol several times. This would provide the researcher with more data. Also, during this time, the correct push up form would be strictly enforced and be made uniform throughout the subjects. If one subject showed a hint of muscle weakness then he or she

would be disqualified from the study. In addition, the length of time each push up took would be decreased to help minimize the possible chance of fatigue. This way the variability between push up forms would be decreased, providing more valid results. I would also recruit more subjects, both males and females.

This study required the subjects to have previous experience using a physioball. It would be interesting to recruit subjects who had never used a physioball and have them perform the push up protocol. Afterwards, they could be taught the proper form in regards to bracing the core musculature, practice the proper form and then repeat the testing protocol. This could help determine if there would be a learning effect present that could affect the level of muscle activation of the core muscles.

Due to the lack of research comparing the standard (ground) push up to the decline push up, further research should be done in this area. I would suggest adding a force platform in addition to the use of the EMG. This way the researcher could determine if there is a greater force placed on the upper extremity during the decline push up. While using the force platform, the researcher could examine if there is a greater force placed upon on one hand compared to the other while the subject is performing the

push up off the physioball (unstable surface). To go into further detail, the researcher could observe the activation of the muscles bilaterally and see if there is a greater level of muscle activation if/when the weight is shifted from side to side due to the instability factor.

The results from this study should be taken into consideration when selecting exercises for a rehabilitation or workout program. The use of an unstable surface (physioball) shows no effect on the levels of peak or mean muscle activation levels. However, the level of difficulty of the push up exercise is seen to increase when this unstable surface is incorporated. Therefore, the use of an unstable surface is beneficial at least for proprioception exercises to increase the ability to balance. Athletic trainers and physical therapists should also note that this study only looked at four particular muscles; pectoralis major, external oblique, serratus anterior and lower trapezius. It is possible that the use of an unstable surface does affect muscle activation levels of muscles not previously mentioned or tested in other studies.

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APPENDICES

APPENDIX A

Review of Literature

REVIEW OF LITERATURE

A common exercise performed by many people is the push-up. There are many variations in which this simple exercise can be performed depending on the desired outcomes. These can range from varying hand placements to adding a piece of equipment under the feet and/or hands. However, do these different push-up variations actually change the amount of muscle activation to justify performing the different push up variants? The purpose of this literature review will be to examine the anatomy of the shoulder, muscle activation and how to measure activity, the differences of various hand placements and their respective effects on the musculature when performing a decline push up, and the use of stable and unstable surfaces.

Shoulder Anatomy

The shoulder is known for being one of the most complex joints in the human body. It is very mobile but due to the shoulder's increased level of mobility there is a decrease in the level of stability. The bony make up of

the shoulder is responsible for these two critical levels of mobility and stability.

The shoulder is made up of two separate anatomical structures which are the shoulder girdle and the actual shoulder joint. The shoulder girdle consists of the scapula and clavicle, whereas the true shoulder joint is the articulation between the scapula and the head of the humerus.[1] The head of the humerus fits into the glenoid fossa of the scapula, hence the name the glenohumeral joint.

The glenohumeral joint is one of several joints associated with the shoulder. In addition, there is the acromioclavicular joint made up of the acromion process and the lateral end of the clavicle. A third joint would be the sternoclavicular joint. This is an articulation between the clavicular notch of the sternum and the medial end of the clavicle. The sternoclavicular joint is the only direct attachment between the upper extremity and the trunk. The last joint relating to the shoulder is the scapulothoracic joint. This is an articulation between the scapula and the thorax. However, this last joint is considered a false joint because there is no bone to bone contact.[1]

Nevertheless, the scapulothoracic joint plays an important role along with the glenohumeral joint to provide the large amount of mobility seen within the shoulder. There are two main muscle groups that are responsible for all the mobility; the scapulohumeral and scapulothoracic. The scapulohumeral muscles include the coracobrachialis, deltoid, teres major, supraspinatus, infraspinatus, subscapularis and the teres minor. These muscles all originate on the scapula and attach on the humerus.[2,3] This group of muscles help dynamically stabilize the glenohumeral joint by assisting in minimizing the translation of the humeral head against the glenoid fossa. The movements caused by this muscle group include flexion, extension, internal rotation, external rotation, abduction, adduction and circumduction.[2]

The scapulothoracic muscle group is responsible for providing stability to the glenoid fossa while the humerus is in motion. The muscles included in this group are the trapezius (upper, middle and lower), rhomboids (major and minor), pectoralis minor and the serratus anterior. Once again these muscles are named due to their origin on the thorax and their insertion on the scapula. The movements associated with these muscles are elevation, upward rotation, downward rotation, and adduction of the

scapula.[1,2] All of the previously mentioned muscles are very important in the mobility and stability of the shoulder. However, even if one muscle is not firing correctly, the whole series of motion of the shoulder can be affected.

Muscle Function

Each muscle in the body is made up of muscle cells that are often called muscle fibers. A muscle fiber is collectively made up of thousands of myofibrils. The myofibrils contain the actual structures that contract the muscle cell, which are known as the myofilaments, actin and myosin. The actin and myosin are arranged parallel to the muscle fiber. The myofilaments overlap one another which, due to their respective sizes, gives the muscle fiber the striated appearance.

When a muscle fiber contracts, the myofilaments pull towards what is called the Z-line of the myofibril. A Z-line is where the actin filaments attach to the sarcomere. The actin filaments slide over the myosin filaments therefore causing the contraction. Due to the minute size of the myofilaments, hundreds of thousands of these Z-lines are found in one muscle fiber.[4]

Each muscle fiber is innervated by motor neurons that carry a signal from the spinal cord to the muscle. The motor neuron and all of its muscle fibers are collectively known as a motor unit. Each muscle has a different number of motor units, depending on the precision of the muscle's movement. For example, muscles of the fingers will have a larger number of motor units than the muscles of the quadriceps.[1]

The motor neuron is also responsible for sending an electrical current to the muscle fiber in order for contractions to occur. The motor neuron innervates the muscle fibers by a chemical transmission. A chemical called acetylcholine is released, which causes excitation of the sarcolemma. Once this chemical is released, an action potential is generated and a contraction occurs within the fiber.[4] The action potential is also very important because this is how muscle activation is measured.

Measuring Muscle Activation

There are two methods by which muscle activation can be measured. The first method is called muscle mechanomyography or MMG. This method is a non-invasive

technique that records and quantifies contracting muscle fibers. MMG can be used to assess a variety of areas such as muscle pain, muscle fatigue, firing patterns, delayed-onset muscle soreness and neuromuscular disease.[5]

A second method of measuring muscle activation is called electromyography or EMG. This technique is typically used to assess the initiation of muscle activation and the level of fatigue occurring within a muscle. EMGs are also used as a way to differentiate various forms of muscle contractions; isometric, eccentric and concentric.[5]

These two methods can be used together in detecting muscle activation. MMG is used to measure the mechanical aspect of muscle contractions whereas EMG is used to measure the electrical component. However, the use of EMG is more common within the clinical setting because it has been around longer and more clinicians are familiar with using this method.

Electromyography

The main concept of the EMG is to measure the electrical impulses given off by muscles when they are contracting or at rest. EMGs record the action potentials as they are generated by chemical releases in the muscle

fibers.[6] One great contribution that EMGs have given is that they are able to record the impulses of both deep and superficial muscles.

Surface electromyography (SEMG) is most commonly used in biomechanical studies because it has a non-invasive nature. It uses surface electrodes to detect the myoelectric signal given off from the muscles. However, the drawback of this type of SEMG is that it can only be used for superficial muscles.[7]

EMGs play a large role in the world of biomechanics. They can be used to measure and analyze the coordination and function in almost any type of physical performance. EMGs function varies from studying different types of muscle contraction, evaluating functional muscle activity, to fatigue studies and the influence of equipment on muscle activity.

The most important aspect of electromyography is that it reports if a muscle is active or not. From there, one can tell if a certain muscle is firing more or less than other muscles, how active that muscle is and if that muscle fatigues at one point in time.[7]

Techniques of the Push Up

The push up is an exercise that has a variety of uses. Due to its easy execution, no equipment requirement, and adaptability, the push up has become a very popular exercise.[8] It can be used as part of a strengthening program, a tool to measure strength and endurance of the upper extremity or even as part of a rehabilitation protocol.[8-11]

The push up is considered a closed-kinetic chain exercise where the hands are fixated on an object and the body weight is placed directly on the hands. As a result, the pectoralis major and triceps brachii are the primary action muscles. Therefore, when performing a push up, one can increase the level of strength of these two muscles. As an assessment tool, the push up has been incorporated in multiple fitness tests such as the Army Physical Fitness Test and the FITNESSGRAM.[9,10,11] In the clinical setting, the push up is seen as an example of a closed kinetic chain exercise and a plyometric exercise when rehabilitating the shoulder.[2] Some observations even show that when performing a push up, pain is relieved in patients with chronic back pain.[12] Whether the push up is used as a strengthening or

an assessment tool, it is important to learn the different forms in which a push up can be performed.

Researchers have looked at multiple variants of the push up and recorded the results of the various positions. The standard push up is described to be when the hand placement is normalized to the distance between a person's acromion process or the middle phalanx is aligned with the acromion process.[13] The hands are placed flat on the ground while the toes are also on the ground. The arms are to be perpendicular to the floor.

As for the action of the exercise itself, the body is kept in a straight line and the arms are flexed at the elbow joints and eccentrically lowered to the floor until the chest nearly touches the floor. The body is then returned to the starting position by pushing the hands forcefully against the ground. The force of motion during the eccentric phase is gravity where the muscles are the force during the concentric phase.[6]

When looking at the anatomical analysis of a push up, the exercise is broken down into two phases, the eccentric or dip phase and the concentric or up phase. During the dip phase the main actions are horizontal abduction (shoulder), adduction (shoulder girdle), flexion (elbows) and reduction of hyperextension (wrists). For the up phase

the actions are the opposite; horizontal adduction (shoulder), abduction (shoulder girdle), extension (elbows), and hyperextension (wrists). The primary muscles that are active during these movements are the pectoralis major, anterior deltoid, pectoralis minor, serratus anterior, triceps and extensor carpi radialis and ulnaris. Also, when performing a push up one must maintain a straight line from the head to the heels. In order for this to happen, the cervical extensors, rectus abdominus, obliques and hip flexors must be statically contracted throughout both phases.[6]

A common push up variant is the bent knee push up. Instead of having the hands and toes on the ground, the knees are bent and resting on the floor. This variant is usually performed when a person is not able to perform a full body push up due to a lack of upper body strength. The bent knee push up is commonly seen in fitness tests such as the Presidents' Challenge and FITNESSGRAM.[10] A second push up variant also seen in these fitness tests is the ninety degree push up. This is where the hands and toes are on the ground and the subject lowers his or her body until the elbows are bent to a ninety degree angle and then returns to the starting position.[10]

Other push up variants have been studied in accordance with muscle activation patterns. Cogley et al[9] examined the difference in muscle activation of the triceps brachii and pectoralis major while the hands were placed in three different positions: shoulder width base, wide base and narrow base. For the shoulder width hand position, the subjects' middle finger was aligned with the edge of the deltoid via plumb line. The wide base position was measured by twenty centimeters laterally from their shoulder width position. Lastly, the narrow based position was characterized by placing the hands together, making a diamond shape between the first and second digits. The results of this study showed a significant difference in muscle activation of the triceps brachii and pectoralis major during the narrow base hand position compared to the shoulder width and wide base positions.

Gouvali and Boudolos[8] performed a study that was similar to Cogley et al[9]. They looked at six different push up variants: normal position, wide position (150 % of shoulder width), narrow position (50% of shoulder width), anterior position, posterior position and bent knee. For the anterior position, the subjects' hands were placed 30% of their arm length anteriorly compared to the normal positioning. The same was done for the posterior position,

the hands were placed 30% posteriorly so that the hands were located under the subjects' rib cage. The muscles studied were once again the triceps brachii and pectoralis major. The results showed that the bent knee push up was the least demanding of overall muscle activation and that only during the posterior position, the pectoralis major was activated to a greater extent compared to the other positions.

When looking at the push up variants, there is one called the push up plus. This is when the standard push up is performed then followed by scapular protraction then retraction returning the body to the starting position. This variant is used when wanting to activate the scapular stabilizers.[13] Tucker et al[13] performed a study looking at the different hand placements on the muscle activation of the serratus anterior, middle trapezius, and lower trapezius during the push up plus exercise. The hand placements were normal (48 cm apart), wide (70.5 cm apart) and narrow (25.5 cm apart). The results concluded that the muscle activation of serratus anterior was significantly greater in the wide hand placement, the lower trapezius muscle activity was greater in the narrow hand placement and there was no difference regarding hand placement for the middle trapezius.

Other variations seen are the: 1) single arm push up; 2) uneven hand placement, where one hand is placed three inches in front and the other hand is three inches behind the normal position; 3) push up with a clap, the subject forcefully contracts during the concentric phase, allowing the body to elevate off the ground and then the subject claps before catching the body on the hands once again; 4) one hand on a ball and the other hand on the ground; 5) depth push up, where the subject's hands are placed on an object that elevates the hands allowing the body to perform a deeper push up, and 6) the decline push up, where the feet are placed on an object so that the feet are elevated above the subject's head, producing a declined angle.[12]

A final push up variant is that of incorporating an unstable surface. One of the most common is adding a stability ball to the standard push up. One can either place the feet on the ball or the hands on the ball. Other unstable surfaces can include foam pads, BOSU balls, Dyna discs, wobble boards and mini trampolines.

Stability Balls

The stability ball was developed in 1963 by Aquilino Cosani. They were first used during rehabilitation of children suffering from neurological impairments. The rehabilitation techniques were then passed on to physical therapists dealing with children with cerebral palsy and eventually to treat patients with back pain.[14] Now the use of stability balls can be seen in physical therapy and strength and conditioning.

The use of an unstable surface is thought to put a higher demand on the neuromuscular system, therefore causing the small stabilizing muscles to activate at a greater rate.[15] Other assumptions are that an unstable surface increases the demands of the propriceptors during balancing, which in turn leads to a reduction in injuries.[14,16] Cassady et al[17] found the use of a stability ball can increase oxygen consumption during exercise. However, another study by Stanton, Reaburn, and Humphries[18] shows there is no improvement in VO_2 max or running economy when subjects were to perform a six week exercise program involving exercises on a stability ball.

The use of a stability ball can be seen as a variant for many exercises. The most popular exercises are ones

that relate to the core musculature. Escamilla et al[19] performed a study that investigated the level of muscle activation during swiss ball exercises compared to traditional core exercises. Subjects were to perform eight swiss ball exercises and two traditional abdominal exercises. EMG data was collected and used to compare the level of muscle activation of five abdominal and back muscles. Results concluded that the use of a swiss ball increases the muscle activation in some exercises but not all compared to the traditional exercises.

Similarly, Marshall and Murphy[20] conducted a study looking at three different exercises, both with a stable and unstable surface (a stability ball). The three exercises that were performed were a double leg hold, push up and wall squat. For the double leg hold, the subjects were to lower their legs from 90 degrees of hip flexion to just parallel with their trunk, and hold that position for three seconds. The subjects performed this exercise lying supine on a bench and then repeated on a ball. The subjects performed standard push ups with their hands placed on a stable surface and then on a ball. For the squat, the subjects performed a squat with their backs against a wall and then repeated the test with a ball between them and the wall. The results of this study showed

that there was no difference in the two squat exercises. During the push up, greater muscle activation was seen in the transverse abdominis/internal oblique, rectus abdominis, and in the triceps brachii. As for the double leg hold, only the rectus abdominis showed a significant difference in muscle activity.

Several authors took the growing popularity of the stability ball and combined it with the already popular push up exercise. Here they tested the common belief that adding an unstable component to an exercise will increase the muscle activation of the muscles involved.

Push ups on a Stability Ball

The push up is known to be a very adaptable exercise. By adding a common piece of equipment, the push up can be altered slightly producing different results compared to the standard push up. Several studies have been conducted to measure this muscle activation during push ups on and off a stability ball. Sandu, Mahajan and Shenoy[21] had subjects perform four push up variations on a stable surface and a stability ball. For each exercise, the hands were placed on the ball while the feet or knees were on the ground. During these exercises, the pectoralis major,

upper trapezius, serratus anterior, and tricpes brachii were connected to an EMG machine. The results concluded that only the pectoralis major showed a significant difference in muscle activation.

Lehman, Gilas and Patel[16] conducted a study looking at an unstable surface and its effect on scapulothoracic stabilizing muscles. Subjects performed three different variants of the push up once again replacing a stable surface (bench) with an unstable surface (ball). The three exercises were: push up with hands on bench/ball with feet on ground, push up with feet on bench/ball with hands on ground, and push up plus with hands on bench/ball. The muscles involved in the study were the upper trapezius, lower trapezius, biceps brachii and serratus anterior. Results showed no significant difference in muscle activity for all four muscles.

Lehman et al[15] also performed a very similar study where they observed the triceps brachii, pectoralis major, rectus abdominis and external oblique during the three push up variations mentioned in the previous study. The triceps brachii and the rectus abdominis showed a significant difference when the stability ball was added to the hands replacing the bench. The pectoralis major and external

oblique were not influenced by the replacement of the ball compared to the bench.

As these studies have shown, muscle activity can be affected by varying the hand placement during the push up exercise. However, the literature found does not specifically support that the use of an unstable surface will increase muscle activity.

Summary

The literature depicts that the shoulder complex is made up of a multitude of muscles that have a large amount of responsibility regarding movement and stability. In order for the muscles to function the way that they do, signals from the central nervous system must be sent out to initiate the contractile tissues within the muscle fibers. In order for one to determine if the muscles are firing, electromyography machines are used to measure the signal given off from the muscles. The push up is a common exercise in which to activate and strengthen the muscles of the upper body. There are many ways to execute this popular exercise. One way is to perform the push up off a stability ball. When an unstable factor is added to an exercise, the assumption is that it puts a greater demand

on the neuromuscular system, in turn creating greater muscle activation. More evidence is needed to determine if these claims are in fact true when instability is added to a basic exercise.

APPENDIX B

The Problem

THE PROBLEM

Statement of the Problem

The push up is a common and widely used exercise to strengthen the upper body. It can also be used to measure strength and muscle endurance of the arms and shoulders. The push up traditionally is performed with the feet and hands on the floor but it can also be performed on an unstable surface. The common belief is that this will help increase the level of muscle activation levels during the exercise.

The purpose of this study is to test the claims that the use of an unstable surface helps activate more motor units while performing traditional exercises. This study will investigate if these claims are in fact true while performing the push up combined with an unstable surface. It would be beneficial for the physically active and injured population to know if the use of an unstable surface via a physioball actually increases the effectiveness of general exercises.

Definition of Terms

The following terms were operationally defined for this study:

1) Physioball – Large inflatable ball made out of plastic that come in varying sizes. Also known as exercise balls, stability balls, Swiss balls, or fit balls.
2) EMG – Electromyography. A technique used to measure and record the electrical activity of muscles.
3) Muscle Activation - The level of recruitment of muscle as sent via the afferent nerve pathway from the brain measured by EMG.

Basic Assumptions

The following were basic assumptions of this study:

1) The equipment will work correctly and will be properly calibrated.
2) The subjects will perform to the best of their ability during the experiment.
3) The subjects will answer truthfully on the pre-participation questionnaire.

Limitations of the Study

The following were possible limitations of the study:

1) The equipment may not have been sensitive enough to accurately detect the muscle activation levels.

2) The participants were limited to college students at California University of Pennsylvania.
3) Subjects had varying experience with proper push up form.

Delimitations of the Study

The following were the delimitations of the study:

1) Experience performing push ups.
2) Physically active individuals enrolled at California University of Pennsylvania.
3) Experience using a physioball.
4) The bench and physioball stood at the same height. The physioball was measured before each testing session.

Significance of the Study

The push up is a popular exercise to strengthen the upper body as well as test muscle endurance of the shoulder girdle. The stability ball is used to add instability to a basic exercise in hopes of recruiting more muscle units and increasing muscle firing. This study will investigate if there is a difference in muscle activation levels when a push up is performed at a declined angle (with feet on a bench) compared to a standard push up. It will also

investigate if the use of a physioball ball during a decline push up will indeed increase the level of muscle activation than the decline push up alone. If it finds that the presence of an unstable surface is beneficial in activating the muscles then one can transform traditional exercises easily by adding an unstable factor.

APPENDIX C

Additional Methods

APPENDIX C1

Informed Consent Form

California University of Pennsylvania

Informed Consent Form

1. Kelsey Todd, who is a Graduate Athletic Training Student at California University of Pennsylvania, has requested my participation in a research study at California University of Pennsylvania. The title of the research is "Muscle Activation During a Decline Push Up on an Unstable Surface".

2. I have been informed that the purpose of this study is to test the claims that the use of an unstable surface helps activate more motor units while performing traditional exercises. I understand that I must be 18 years of age or older to participate. If I am under 18 years of age, I will be eliminated from the study. I understand that I have been asked to participate along with 19 other individuals because I do not have a history of shoulder, elbow and/or wrist injury within the previous six months. I also have previous experience performing push ups. I also understand and agree that it is required that I perform these tests without a shirt or in a sports bra, if I am a female, due to electrode placement and interference with the leads.

3. I have been invited to participate in this research project. My participation is voluntary and I can choose to discontinue my participation at any time without penalty or loss of benefits. My participation will involve an informational meeting and a maximum voluntary contraction testing session followed by the testing protocol. For the testing protocol, I will be required to perform a set of three decline push ups off a bench, a second set of three decline push ups off a stability ball and a third set of standard push ups on the ground. There will be a minimum of three minutes between each set of push ups.

4. I understand there are foreseeable risks or discomforts to me if I agree to participate in the study. With participation in a research program such as this there is always the potential for unforeseeable risks as well. The possible risk and/or discomforts could include having my feet fall from the ball or bench due to instability or general weakness. To minimize these risks, I will be instructed to stop if I feel I can no longer perform the push ups. Also, the research assistant will assist me by placing my feet on the ball and/or bench. I also understand that it is required to perform this study without a shirt, due to electrode placement and the interference of the leads with clothing.

5. I understand that, in case of injury, I can expect to receive treatment or care in Hamer Hall's Athletic Training Facility. This treatment will be provided by the researcher, Kelsey Todd, under the supervision of the CalU athletic training faculty, all of which can administer emergency care. Additional services needed for prolonged care will be referred to the attending staff at the Downey Garofola Health Services located on campus.

6. There are no feasible alternative procedures available for this study.

7. I understand that the possible benefit of my participation in the research is to help determine the effects of an unstable surface on muscle activation during a decline push up. This study can help athletic trainers and other clinicians decide whether or not it is beneficial to use an instability factor during exercise.

8. I understand that the results of the research study may be published but my name or identity will not be revealed. Only aggregate data will be reported. In order to maintain confidentially of my records, Kelsey Todd will maintain all documents in a secure location on campus and password protect all electronic files so that only the student researcher and research advisor can access the data. Each subject will be given a specific subject number to represent his or her name so as to protect the anonymity of each subject.

9. I have been informed that I will not be compensated for my participation.

10. I have been informed that any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by:

Kelsey Todd, ATC
Student/Primary Researcher
Tod8725@calu.edu
(330) 692-2854

Edwin Zuchelkowski, PhD
RESEARCH ADVISOR
Zuchelkowski@calu.edu
(724) 938-4202

11. I understand that written responses may be used in quotations for publication but my identity will remain anonymous.

12. I have read the above information and am electing to participate in this study. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request.

13. This study has been approved by the California University of Pennsylvania Institutional Review Board.

14. The IRB approval dates for this project are from: 03/14/11 to 03/13/12.

Subject's signature:_____
Date:_____

Witness signature:_____
Date:_____

APPENDIX C2

Demographic Information Sheet

Demographic Information

Subjects Number _____

Gender:

____ Male ____ Female

Age: _____

Do you currently take part in physical activity? If so, how often?

Are you part of an organized sport?

Have you ever performed a push up?

If you answered yes to the previous question, how often do you perform push ups?

_____ Daily

_____ Several times a week

_____ Several times a month

_____ Occasionally throughout the year

Have you ever performed an exercise on a stability ball?

Have you had an injury to the upper extremity (shoulder, elbow or wrist) that has prevented you to from working out within the previous six months? If yes, please explain.

Appendix C3

Institutional Review Board –

California University of Pennsylvania

California University of Pennsylvania

Proposal Number

Date Received

PROTOCOL for Research Involving Human Subjects

Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects

(Reference IRB Policies and Procedures for clarification)

Project Title *Muscle Activation During a Decline Push Up on an Unstable Surface*

Researcher/Project Director *Kelsey Todd*

Phone # *330-692-2854* ***E-mail Address*** *tod8725@calu.edu*

Faculty Sponsor (if required) *Dr. Edwin Zuchelkowski - zuchelkowski@calu.edu*

Department *Health Science*

Project Dates *1/15/2011* ***to*** *1/15/2012*

Sponsoring Agent (if applicable) _____

Project to be Conducted at *California University of Pennsylvania*

Project Purpose: ☒ ***Thesis*** ☐ ***Research*** ☐ ***Class Project*** ☐ ***Other***

Keep a copy of this form for your records.

Approved, September 12, 2005 / (updated 02-09-09)

Please attach a typed, detailed summary of your project AND complete items 2 through 6.

1. *Provide an overview of your project-proposal describing what you plan to do and how you will go about doing it. Include any hypothesis(ses)or research questions that might be involved and explain how the information you gather will be analyzed. For a complete list of what should be included in your summary, please refer to Appendix B of the IRB Policies and Procedures Manual.*

The purpose of this study is to test the claims that the use of an unstable surface helps activate more motor units while performing traditional exercises. This study will investigate if these claims are in fact true while performing the push up combined with an unstable surface. It would be beneficial for the physically active and injured population to know if the use of an unstable surface such as a stability ball actually increases the effectiveness of general exercises.

Hypotheses

The following hypotheses were based on previous research and the researcher's intuition based on a review of the literature.

1. There will be a difference in muscle peak activation in both the stable and unstable decline push up compared to a standard push up.

2. There will not be a difference in muscle peak activation during the decline push up under the unstable condition compared to the stable condition.

Procedure

Each potential subject will fill out a demographic information sheet and sign an informed consent form. Once this is completed there will be an explanatory session reviewing the testing protocol. The Institutional Review Board at California University of Pennsylvania will approve all testing protocol prior to experimentation. Subjects must also understand and agree that it is required to perform this study shirtless due to electrode placement and interference with the leads. Females are required to wear a sports bra. Subjects will also perform all exercises in bare feet. Volunteers will be disqualified is there is a history of shoulder, elbow and/or wrist injury within the previous six months, or any other condition that may affect the subject's ability to perform a push up. The subjects will be active individuals and must know the basic technique of a push up.

Each subject will go through testing to measure his/her maximum voluntary contraction of the pectoralis major, lower trapezius, serratus anterior and external oblique. The pectoralis major electrode will be placed four finger widths below the clavicle and medial to the anterior axillary border. The lower trapezius electrode will be placed 1.5cm lateral to the T6 spinous process. For the serratus anterior, the electrode will be placed on the mid-axillary line of the muscle belly located over the fifth rib. The external oblique electrode will be placed 15cm lateral to the umbilicus along the direction of muscle fibers.

The subjects will be instructed to properly perform the push up as directed by the researcher. Once the proper form has been established, the subject will then perform the push upon the ground, then with his/her feet on the bench and again on the physioball.

For the testing protocol, the subjects will be randomly assigned to three groups, one group performing push ups off the ball first, the second group performing push ups off the bench first and the third group performing the standard push up first. The subjects will then perform the other two types of push ups accordingly. The sites of the electrode placement will be prepared by shaving (when necessary) and cleaning with alcohol. The muscles tested will be pectoralis major, lower trapezius, external oblique, and serratus anterior.

The EMG machine will be turned on and connected to the laptop to begin the testing. The raw EMG signal was band pass filtered at 10 and 1000 Hertz (Hz).1,2 The subject will position his/her hands so that the third phalanx is lined up with the acromioclavicular joint on bilateral sides. The feet will be placed on the ball/bench so that the foot is dorsiflexed and the toes are extended. An assistant will help place the

subject's feet on the ball/bench to limit the risk of potential injury. The subject will be instructed to lower down until his/her nose touches a three and one half inch block. He/she will be instructed to eccentrically lower the body for three seconds, hold the bottom position for three seconds, concentrically raise the body for three seconds, then hold for a finally three seconds at the top position. The subject will perform one set of three push ups per test. The subject will perform three tests during one session, push ups off the ball, push ups off the bench and push ups on the ground. There will be a minimum of a three-minute rest between tests. The testing protocol will be repeated three times. The scores will then be averaged. The data will be collected on a data collection sheet per subject.

Data Analysis

All data will be analyzed by Statistical Package for Social Sciences (SPSS) version 18.0 for Windows at an alpha level of ≤ 0.05. The research hypotheses will be analyzed using a repeated measures analysis of variance.

2. *Section 46.11 of the Federal Regulations state that research proposals involving human subjects must satisfy certain requirements before the IRB can grant approval. You should describe in detail how the following requirements will be satisfied. Be sure to address each area separately.*

   a. *How will you insure that any risks to subjects are minimized? If there are potential risks, describe what will be done to minimize these risks. If there are risks, describe why the risks to participants are reasonable in relation to the anticipated benefits.*

      There will be minimal risks which will be monitored by taking every precaution necessary. This study will use healthy, physically active volunteers to help decrease the likelihood of sustaining an injury. Volunteers will be disqualified from the study if they have a history of shoulder, elbow and/or wrist injury within the previous six months. Volunteers will also be disqualified if they have no prior experience performing a push up. During the testing protocol, there will be an assistant to help placed the subjects' feet on the bench and ball. This will help prevent rolling off the ball and sustaining an injury. The assistant will remain beside the subject throughout the entire testing session to help stabilize the subject on the ball. If at any time the subject feels unable to finish the exercise, he/she will be permitted to stop. In any event of an injury, a Certified Athletic Trainer will be present to evaluate and treat the subject. The risk to the participants is reasonable with respect to the benefits because the risk is very low. Also, this study can change the way people view and understand the use of an unstable surface during a push up.

   b. *How will you insure that the selection of subjects is equitable? Take into account your purpose(s). Be sure you address research problems involving vulnerable populations such as children, prisoners, pregnant women, mentally disabled persons, and economically or educationally disadvantaged persons. If this is an in-class project describe how you will minimize the possibility that students will feel coerced.*

      The subjects will be volunteers from the student population of California University of Pennsylvania. The study will be announced in undergraduate athletic training classes, to the varsity athetic teams via the strength and conditioning coaches and flyers will be posted around campus including the Herron fitness center and the athletic training room. The potential subject will in no way be coerced to participate in this study. I will not have any research problems pertaining to vulnerable populations because my subjects will be college aged students that will not include prisoners, pregnant, mentally disabled, educationally or economically disadvantaged people.

   c. *How will you obtain informed consent from each participant or the subject's legally authorized representative and ensure that all consent forms are appropriately documented? Be sure to attach a copy of your consent form to the project summary.*

The informed consent form will be distributed prior to participation during an explanatory session. This paper will inform the volunteer about the procedure and purpose of the study and their role within the study. All information will be kept confidential.

d. *Show that the research plan makes provisions to monitor the data collected to insure the safety of all subjects. This includes the privacy of subjects' responses and provisions for maintaining the security and confidentiality of the data.*

The researcher and the research advisor will be the only people to have access to the data collected. Each subject will be assigned a number to keep the subjects' results anonymous. Also, the subjects' names will never appear on the data collection sheets or any other information that links the results to that particular subject. The data will be stored in a secure location that will be locked down when not in use by the researcher.

3. *Check the appropriate box(es) that describe the subjects you plan to use.*

☒ *Adult volunteers*	☐ *Mentally Disabled People*
☒ *CAL University Students*	☐ *Economically Disadvantaged People*
☐ *Other Students*	☐ *Educationally Disadvantaged People*
☐ *Prisoners*	☐ *Fetuses or fetal material*
☐ *Pregnant Women*	☐ *Children Under 18*
☐ *Physically Handicapped People*	☐ *Neonates*

4. *Is remuneration involved in your project?* ☐ *Yes or* ☒ *No. If yes, Explain here.*

5. *Is this project part of a grant?* ☐ *Yes or* ☒ *No If yes, provide the following information:*

   Title of the Grant Proposal _____

   Name of the Funding Agency _____

   Dates of the Project Period _____

6. *Does your project involve the debriefing of those who participated?* ☐ *Yes or* ☒ *No*

   If Yes, explain the debriefing process here.

7. *If your project involves a questionnaire interview, ensure that it meets the requirements of Appendix___in the Policies and Procedures Manual.*

California University of Pennsylvania Institutional Review Board
Survey/Interview/Questionnaire Consent Checklist (v021209)

This form MUST accompany all IRB review requests

Does your research involve ONLY a survey, interview or questionnaire?
☐ **YES**—Complete this form
☒ **NO**—You MUST complete the "Informed Consent Checklist"—skip the remainder of this form

Does your survey/interview/questionnaire cover letter or explanatory statement include:

☐ (1) Statement about the general nature of the survey and how the data will be used?

☐ (2) Statement as to who the primary researcher is, including name, phone, and email address?

☐ (3) FOR ALL STUDENTS: Is the faculty advisor's name and contact information provided?

☐ (4) Statement that participation is voluntary?

☐ (5) Statement that participation may be discontinued at any time without penalty and all data discarded?

☐ (6) Statement that the results are confidential?

☐ (7) Statement that results are anonymous?

☐ (8) Statement as to level of risk anticipated or that minimal risk is anticipated? (NOTE: If more than minimal risk is anticipated, a full consent form is required—and the Informed Consent Checklist must be completed)

☐ (9) Statement that returning the survey is an indication of consent to use the data?

☐ (10) Who to contact regarding the project and how to contact this person?

☐ (11) Statement as to where the results will be housed and how maintained? (unless otherwise approved by the IRB, must be a secure location on University premises)

☐ (12) Is there text equivalent to: "Approved by the California University of Pennsylvania Institutional Review Board. This approval is effective nn/nn/nn and expires mm/mm/mm"? (the actual dates will be specified in the approval notice from the IRB)?

☐ (13) FOR ELECTRONIC/WEBSITE SURVEYS: Does the text of the cover letter or explanatory statement appear before any data is requested from the participant?

☐ (14) FOR ELECTONIC/WEBSITE SURVEYS: Can the participant discontinue participation at any point in the process and all data is immediately discarded?

California University of Pennsylvania Institutional Review Board
Informed Consent Checklist (v021209)

This form MUST accompany all IRB review requests

Does your research involve ONLY a survey, interview, or questionnaire?
☐ **YES**—DO NOT complete this form. You MUST complete the "Survey/Interview/Questionnaire Consent Checklist" instead.
☒ **NO**—Complete the remainder of this form.

1. **Introduction** (check each)
   ☒ (1.1) Is there a statement that the study involves research?
   ☒ (1.2) Is there an explanation of the purpose of the research?

2. **Is the participant.** (check each)
   ☒ (2.1) Given an invitation to participate?
   ☒ (2.2) Told why he/she was selected.
   ☒ (2.3) Told the expected duration of the participation.
   ☒ (2.4) Informed that participation is voluntary?
   ☒ (2.5) Informed that all records are confidential?
   ☒ (2.6) Told that he/she may withdraw from the research at any time without penalty or loss of benefits?
   ☒ (2.7) 18 years of age or older? (if not, see Section #9, Special Considerations below)

3. **Procedures** (check each).
   ☒ (3.1) Are the procedures identified and explained?
   ☒ (3.2) Are the procedures that are being investigated clearly identified?
   ☒ (3.3) Are treatment conditions identified?

4. **Risks and discomforts**. (check each)
   ☒ (4.1) Are foreseeable risks or discomforts identified?
   ☒ (4.2) Is the likelihood of any risks or discomforts identified?
   ☒ (4.3) Is there a description of the steps that will be taken to minimize any risks or discomforts?
   ☒ (4.4) Is there an acknowledgement of potentially unforeseeable risks?
   ☒ (4.5) Is the participant informed about what treatment or follow up courses of action are available should there be some physical, emotional, or psychological harm?
   ☒ (4.6) Is there a description of the benefits, if any, to the participant or to others that may be reasonably expected from the research and an estimate of the likelihood of these benefits?
   ☒ (4.7) Is there a disclosure of any appropriate alternative procedures or courses of treatment that might be advantageous to the participant?

5. **Records and documentation**. (check each)
   ☒ (5.1) Is there a statement describing how records will be kept confidential?
   ☒ (5.2) Is there a statement as to where the records will be kept and that this is a secure location?
   ☒ (5.3) Is there a statement as to who will have access to the records?

6. For research involving more than minimal risk (check each),

☒ (6.1) Is there an explanation and description of any compensation and other medical or counseling treatments that are available if the participants are injured through participation?

☒ (6.2) Is there a statement where further information can be obtained regarding the treatments?

☒ (6.3) Is there information regarding who to contact in the event of research-related injury?

7. Contacts.(check each)

☒ (7.1) Is the participant given a list of contacts for answers to questions about the research and the participant's rights?

☒ (7.2) Is the principal researcher identified with name and phone number and email address?

☒ (7.3) FOR ALL STUDENTS: Is the faculty advisor's name and contact information provided?

8. General Considerations (check each)

☒ (8.1) Is there a statement indicating that the participant is making a decision whether or not to participate, and that his/her signature indicates that he/she has decided to participate having read and discussed the information in the informed consent?

☒ (8.2) Are all technical terms fully explained to the participant?

☒ (8.3) Is the informed consent written at a level that the participant can understand?

☒ (8.4) Is there text equivalent to: "Approved by the California University of Pennsylvania Institutional Review Board. This approval is effective nn/nn/nn and expires mm/mm/mm"? (the actual dates will be specified in the approval notice from the IRB)

9. Specific Considerations (check as appropriate)

☐ (9.1) If the participant is or may become pregnant is there a statement that the particular treatment or procedure may involve risks, foreseeable or currently unforeseeable, to the participant or to the embryo or fetus?

☐ (9.2) Is there a statement specifying the circumstances in which the participation may be terminated by the investigator without the participant's consent?

☐ (9.3) Are any costs to the participant clearly spelled out?

☐ (9.4) If the participant desires to withdraw from the research, are procedures for orderly termination spelled out?

☐ (9.5) Is there a statement that the Principal Investigator will inform the participant or any significant new findings developed during the research that may affect them and influence their willingness to continue participation?

☐ (9.6) Is the participant is less than 18 years of age? If so, a parent or guardian must sign the consent form and assent must be obtained from the child

- ☐ Is the consent form written in such a manner that it is clear that the parent/guardian is giving permission for their child to participate?
- ☐ Is a child assent form being used?
- ☐ Does the assent form (if used) clearly indicate that the child can freely refuse to participate or discontinue participation at any time without penalty or coercion?

☒ (9.7) Are all consent and assent forms written at a level that the intended participant can understand? (generally, 8th grade level for adults, age-appropriate for children)

California University of Pennsylvania Institutional Review Board
Review Request Checklist (v021209)

This form MUST accompany all IRB review requests.
Unless otherwise specified, ALL items must be present in your review request.

Have you:

☒ (1.0) FOR ALL STUDIES: Completed ALL items on the Review Request Form?
Pay particular attention to:

- ☒ (1.1) Names and email addresses of all investigators
  - ☒ (1.1.1) FOR ALL STUDENTS: use only your CalU email address)
  - ☒ (1.1.2) FOR ALL STUDENTS: Name and email address of your faculty research advisor
- ☒ (1.2) Project dates (must be in the future—no studies will be approved which have already begun or scheduled to begin before final IRB approval—NO EXCEPTIONS)
- ☒ (1.3) Answered completely and in detail, the questions in items 2a through 2d?
  - ☒2a: NOTE: No studies can have zero risk, the lowest risk is "minimal risk". If more than minimal risk is involved you MUST:
    - ☒ i. Delineate all anticipated risks in detail;
    - ☒ ii. Explain in detail how these risks will be minimized;
    - ☒ iii. Detail the procedures for dealing with adverse outcomes due to these risks.
    - ☒ iv. Cite peer reviewed references in support of your explanation.
  - ☒ 2b. Complete all items.
  - ☒ 2c. Describe informed consent procedures in detail.
  - ☒ 2d. NOTE: to maintain security and confidentiality of data, all study records must be housed in a secure (locked) location ON UNIVERSITY PREMISES. The actual location (department, office, etc.) must be specified in your explanation and be listed on any consent forms or cover letters.
- ☒ (1.4) Checked all appropriate boxes in Section 3? If participants under the age of 18 years are to be included (regardless of what the study involves) you MUST:
  - ☐ (1.4.1) Obtain informed consent from the parent or guardian—consent forms must be written so that it is clear that the parent/guardian is giving permission for their child to participate.
  - ☐ (1.4.2) Document how you will obtain assent from the child—This must be done in an age-appropriate manner. Regardless of whether the parent/guardian has given permission, a child is completely free to refuse to participate, so the investigator must document how the child indicated agreement to participate ("assent").
- ☒ (1.5) Included all grant information in section 5?
- ☒ (1.6) Included ALL signatures?

☐ (2.0) FOR STUDIES INVOLVING MORE THAN JUST SURVEYS, INTERVIEWS, OR QUESTIONNAIRES:

- ☒ (2.1) Attached a copy of all consent form(s)?
- ☐ (2.2) FOR STUDIES INVOLVING INDIVIDUALS LESS THAN 18 YEARS OF AGE: attached a copy of all assent forms (if such a form is used)?
- ☒ (2.3) Completed and attached a copy of the Consent Form Checklist? (as appropriate—see that checklist for instructions)

☐ (3.0) FOR STUDIES INVOLVING ONLY SURVEYS, INTERVIEWS, OR QUESTIONNAIRES:

- ☐ (3.1) Attached a copy of the cover letter/information sheet?
- ☐ (3.2) Completed and attached a copy of the Survey/Interview/Questionnaire Consent Checklist? (see that checklist for instructions)
- ☐ (3.3) Attached a copy of the actual survey, interview, or questionnaire questions in their final form?

☐ (4.0) FOR ALL STUDENTS: Has your faculty research advisor:

- ☒ (4.1) Thoroughly reviewed and approved your study?
- ☒ (4.2) Thoroughly reviewed and approved your IRB paperwork? including:
  - ☒ (4.2.1) Review request form,
  - ☒ (4.2.2) All consent forms, (if used)
  - ☐ (4.2.3) All assent forms (if used)
  - ☐ (4.2.4) All Survey/Interview/Questionnaire cover letters (if used)
  - ☒ (4.2.5) All checklists
- ☒ (4.3) IMPORTANT NOTE: Your advisor's signature on the review request form indicates that they have thoroughly reviewed your proposal and verified that it meets all IRB and University requirements.

☒ (5.0) Have you retained a copy of all submitted documentation for your records?

Project Director's Certification
Program Involving HUMAN SUBJECTS

The proposed investigation involves the use of human subjects and I am submitting the complete application form and project description to the Institutional Review Board for Research Involving Human Subjects.

I understand that Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects. If the Board grants approval of this application, I agree to:

1. Abide by any conditions or changes in the project required by the Board.
2. Report to the Board any change in the research plan that affects the method of using human subjects before such change is instituted.
3. Report to the Board any problems that arise in connection with the use of human subjects.
4. Seek advice of the Board whenever I believe such advice is necessary or would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board in its effort to provide a continuing review after investigations have been initiated.

I have reviewed the Federal and State regulations concerning the use of human subjects in research and training programs and the guidelines. I agree to abide by the regulations and guidelines aforementioned and will adhere to policies and procedures described in my application. I understand that changes to the research must be approved by the IRB before they are implemented.

Professional Research

Project Director's Signature

Department Chairperson's Signature

Student or Class Research

Student Researcher's Signature

Supervising Faculty Member's Signature if required

Department Chairperson's Signature

ACTION OF REVIEW BOARD (IRB use only)

The Institutional Review Board for Research Involving Human Subjects has reviewed this application to ascertain whether or not the proposed project:

1. provides adequate safeguards of the rights and welfare of human subjects involved in the investigations;
2. uses appropriate methods to obtain informed, written consent;
3. indicates that the potential benefits of the investigation substantially outweigh the risk involved.
4. provides adequate debriefing of human participants.
5. provides adequate follow-up services to participants who may have incurred physical, mental, or emotional harm.

☐ Approved[_____] ☐ Disapproved

Chairperson, Institutional Review Board

Date

Approved, September 12, 2005 / (updated 02-09-09)

Ms. Todd

Please consider this email as official notification that your proposal titled "Muscle Activation During a Decline Push Up on an Unstable Surface" (Proposal #10-028) has been approved by the California University of Pennsylvania Institutional Review Board as amended.
The effective date of the approval is 03-14-2011 and the expiration date is 03-13-2012. These dates must appear on the consent form.

Please note that Federal Policy requires that you notify the IRB promptly regarding any of the following:

(1) Any additions or changes in procedures you might wish for your study (additions or changes must be approved by the IRB before they are implemented)

(2) Any events that affect the safety or well-being of subjects

(3) Any modifications of your study or other responses that are necessitated by any events reported in (2).

(4) To continue your research beyond the approval expiration date of 03-13-2012 you must file additional information to be considered for continuing review. Please contact instreviewboard@calu.edu

Please notify the Board when data collection is complete.

Regards,
Robert Skwarecki, Ph.D., CCC-SLP
Chair, Institutional Review Board

Appendix C4

Sample Individual Data Collection Sheet

Sample Individual Data Collection Sheet

Subject # _____
Gender _____

MVC

Pec major	_____	_____	_____
Ex Oblique	_____	_____	_____
Serratus Ant	_____	_____	_____
Low Trap	_____	_____	_____

		Max	Mean
Push Up – Standard	PM	_____	_____
	EO	_____	_____
	SA	_____	_____
	LT	_____	_____
Push Up – Bench	PM	_____	_____
	EO	_____	_____
	SA	_____	_____
	LT	_____	_____
Push Up – Ball	PM	_____	_____
	EO	_____	_____
	SA	_____	_____
	LT	_____	_____

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ABSTRACT

Title: MUSCLE ACTIVATION DURING A DECLINE PUSH UPON AN UNSTABLE SURFACE

Researcher: Kelsey Todd

Advisor: Dr. Edwin Zuchelkowski

Date: May 2011

Research Type: Master's Thesis

Purpose: To investigate the peak muscle activation levels of the pectoralis major, external oblique, serratus anterior, and lower trapezius during a standard push up, a decline push up on a stable surface and a decline push up on an unstable surface.

Problem: The push up is a common and widely used exercise to strengthen the upper body. It can also be used to measure the strength and muscle endurance of the arms and shoulders. The push up is traditionally performed with the hands and feet on the floor but it can also be performed on an unstable surface. The common belief is that this will help increase the level of muscle activation levels during the exercise.

Method: This study looked at twenty physically active individuals recruited from the general population. Testing took one day to complete for each subject. During the testing session, surface electromyography was taken of the pectoralis major, external oblique, serratus anterior and lower trapezius. The subjects were randomly assigned to perform three sets of three push ups. One set was performed on the ground, another set was performed with the feet placed on a bench and the third set was performed with the feet placed on a physioball. There was a minimum of a three minute break between sets. Peak muscle

activation measurements were collected and analyzed.

Findings: The data was analyzed by using a repeated measures MANOVA. There was no significant difference found with the peak muscle activity between the three push up variations. There was also no significant difference found between mean muscle activity and gender. There were trends found showing that the external oblique's activation levels were the highest followed by the pectoralis major, serratus anterior and lower trapezius.

Conclusion: When trying to establish a higher level of muscle activation of the pectoralis major, external oblique, serratus anterior or lower trapezius, there is no difference in performing a push up off the ground, with the feet on a bench or with the feet on a physioball.