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LIST OF ABBREVIATIONS

EMG	Electromyography
ST	Suspension Training
TRX®	Total-body Resistance Exercise – Suspension trainer®
RA	Rectus Abdominis
SPU	Suspension Push-Up
PU	Traditional Push-up
C	Traditional Supine Crunch
mV	milliVolts
MVC	Maximum Voluntary Contraction
%MVC	Percentage of Maximum Voluntary Contraction
BMI	Body Mass Index
PM	Pectoralis Major
AD	Anterior Deltoid
TB	Triceps Brachii
BOSU	Both Sides Utilized – balance/stability training device

INTRODUCTION

Suspension training (ST), a recent fitness trend, has emerged as a way to perform bodyweight resistance exercises in an unstable environment. This type of device employs the use of two independent, freely moving handles suspended by two straps with a fixed anchor position above the exerciser (e.g., pull-up bar, smith machine). ST claims to provide a greater disruption, or increased muscular demand in stability while performing typical bodyweight exercises (e.g., pushups, pull-ups), thereby causing an increase in muscular activation. Thus, increasing motor unit recruitment.

The traditional push-up (PU) is one of the most well-known exercises to target the musculature of the upper body (e.g., pectoralis major, triceps brachii, and anterior deltoid). Typically performed on a flat, stable surface, a push-up can also provide an isometric challenge to abdominal wall musculature. However, research indicates that with the introduction of an instability device, the primary movers and abdominals can be activated to a greater extent than the traditional push-up. The majority of previous studies on instability training have focused on equipment such as the Swiss Ball or BOSU, but minimal research to date has examined the effects of suspension training.

Purpose of Study

An abundance of research has been performed to date examining different modalities of stability training (e.g., Swiss balls, BOSUs, wobble boards). However, only several research publications have examined the effects of ST on muscular activation. Therefore, the purpose of this study was two-fold: 1. To compare the electromyographic (EMG) response of the rectus abdominis (RA) during three exercises (i.e., traditional push-up, suspension push-up, and traditional supine crunch); 2. To determine the extent of EMG activity of the pectoralis major (PM), anterior deltoid (AD), and triceps brachii (TB) while performing push-ups with and without a suspension device.

Hypothesis

It was hypothesized that the suspension device would elicit a greater electromyographic activation of the rectus abdominis when compared to the traditional push-up (PU) and supine crunch (C). It was also hypothesized that the suspension push-up (SPU) would elicit a greater activation of the primary musculature (i.e., PM, AD, and TB) as compared to the PU.

CHAPTER 1

REVIEW OF LITERATURE

Stability and balance training has become an important aspect in training, due to its cross-transfer of application into functional movements. These types of training methods are being utilized in professional sports, rehabilitation clinics, and elderly populations to mimic activities of daily living (ADL's), thereby increasing injury prevention. Therefore, commercial fitness companies have flooded the market with products that are designed to decrease stabilization while performing exercises. The intent of these products is to provide multiple planes of movement throughout the exercise, as compared to fixed range-of-motion machines; thereby causing internal stabilization musculature to activate to a greater extent.

In an attempt to determine the effectiveness of suspension devices, Beach et al., (2008) completed an investigation to measure the EMG activity of the rectus abdominis and latissimus dorsi during standard push-ups and suspension push-ups. Eleven recreationally trained males performed 8-10 repetitions of both suspended and traditional push-ups with a two minute rest in between. Results of the study demonstrated that push-ups performed on a suspension device elicited significantly greater muscle activation in the abdominals (RA) and latissimus dorsi (LD) as compared to their traditional counterpart.

Another attempt to determine the effectiveness of instability devices was performed by Goodman et al., (2008). EMG activity values of the primary movers, along with secondary and stabilization musculature was measured. Goodman et al., sought to explore the differences in EMG activation when comparing the stable bench press versus Swiss ball bench press. Maximum bench press strength (1RM) was also measured to determine if traditional exercises performed on instability devices would further decrease force production. For this, thirteen subjects, both male (n=10) and female (n=3), participated in this study. The study consisted of participants performing a 1RM bench press test on a stable bench and swiss ball. A week after these initial values were recorded, subjects were asked to repeat the two 1RM tests for test-retest reliability. Results of the study indicate that there was no significant difference in 1RM bench press strength between the stable and unstable bench press. There were no significant differences in EMG activation of the selected musculature examined between the two surfaces. Therefore, researchers concluded that instability devices did not decrease force produce or EMG activation. However, the instability devices did not elicit greater activation during the exercise and question as to whether there is any benefit to be gained by performing traditional movements on these types of devices (e.g., Swiss ball).

With the ever increasing list of instability devices, Sternlicht and Rugg (2003) attempted to measure EMG activation of the upper and lower rectus abdominis (URA and LRA), external oblique (EO), rectus femoris (RF) with four commercial abdominal devices. EMG values for each device were compared to a traditional crunch. Thirty-three men (n=20) and women (n=13) participated in this investigation. Each subject performed 1 set of 8-10 repetitions of the supine crunch while using each device. Results showed minimal recruitment of the rectus femoris with each of the exercises performed, confirming that the devices and supine crunch are meant to encourage core activation, while prohibiting synergists to initiate and complete the movements. In terms of the

URA and LRA, three of the devices elicited significantly less activity than the crunch. Although, the 'Perfect Abs' device, performed with a high resistance band, produced activation of the URA that was significantly greater than the crunch. After measuring EO levels, there was only one device that produced significantly lower activation than the crunch (i.e., AB-DOer) and two that were significantly greater (i.e., Perfect Abs and Torso Track).

Schoffstall et al., (2010) investigated one traditional isometric core movement with and without abdominal devices while using the supine crunch as a criterion. Twenty-one individuals agreed to perform the V-up exercise using several variations (i.e., prone and supine) and modalities (i.e., stability ball, slide board, TRX, and foot wheel). Surface EMG was used to determine the extent of activation levels of five muscles: upper rectus abdominis (URA), lower rectus abdominis (LRA), external oblique (EO), internal oblique (IO), and rectus femoris (RF). EMG was recorded and analyzed using only one repetition of a 5-second isometric hold of each exercise. Root mean square peak activity was used to access any significant differences between the exercises performed. Results of this investigation determined that there was no difference in muscular activity between the EO, URA, or LRA between any of the exercises performed. However, in terms of the RF, the crunch produced significantly less activation than any of the V-up exercises. Measurements of the IO revealed that the slide board V-up was significantly lower than the supine V-up. Researchers also noted that the crunch was the only exercise to limit hip flexor movement (i.e., RF activity), but produced the most focused intensity in the core region (e.g., RA, EO, IO) when compared to the other exercises.

A similar investigation to Schoffstall et al., was performed by Sternlicht et al. (2005), in which several commercial abdominal devices were studied to determine their effectiveness on the core. Six portable training devices were used for this study (i.e., Ab-One, Ab Scissor, Ab Swing, 6SecondAbs, Perfect Abs Roller, and the Torso Track device) and were compared to a criterion (i.e., supine crunch). Forty-six subjects (20 men and 26 women) performed one set of 8-10 repetitions while EMG was recorded for the EO, URA, and LRA. Results for the URA indicated that the crunch produced significantly greater activation when compared to the Ab Scissor, 6SecondAbs, Torso Track, and Ab Swing. On the other hand, the URA was consistent with EMG activity for the Perfect Abs Roller, but significantly less than the Ab-One. The LRA showed similar results to the URA. However, the only device to be significantly less in activation level for the EO was determined to be the Perfect Abs Roller.

Duncan (2009) studied fourteen male (n=7) and female (n=7) subjects in order to compare muscle activity of the URA and LRA while performing exercises on an instability device (i.e., swiss ball). Four common abdominal exercises were used during this study: curl-up, swiss ball curl-up, swiss ball rollout, and the swiss ball jackknife. Duncan determined that URA activity was significantly greater that LRA activity during the swiss ball curl-up, curl-up and swiss ball rollout. He also concluded that LRA activity was significantly greater than URA during the jackknife only. Furthermore, there were significant differences between the exercises themselves and muscular activation. The highest activation resulted from the swiss ball jackknife and rollout (no significant difference), followed by the swiss ball curl-up (significantly different), and the curl-up elicited the least amount of URA and LRA activation (significantly different).

Therefore, performing common abdominal exercises may produce increased amounts of rectus abdominis activation than stable surface movements.

Another study that examines the use of the swiss ball was performed by Marshall and Murphy (2006). They examined the differences of superficial muscles (pectoralis major, rectus abdominis, triceps brachii, anterior deltoid, biceps brachii, and transverse abdominis/internal oblique) during a dumbbell bench press with and without a swiss ball. Ratings of Perceived Exertion (Borg Scale) were also recorded during each phase of the exercises (eccentric vs. concentric). Fourteen subjects (9 men and 5 women) participated in this investigation. Marshall and Murphy found that the swiss ball bench press produced greater activation of the anterior deltoid and rectus abdominis when compared to the stable counterpart. However, the prime movers (pectoralis major, triceps brachii) showed no difference in activation levels between the exercises performed. RPE's on the swiss ball were found to be significantly greater on both phases (eccentric and concentric) when compared to the stable bench press.

Marshall and Murphy (2006) also examined three common exercises (squat, push-up, and double leg lowering) performed on and off a swiss ball in order to determine if a difference in primary or trunk muscle activation exists. While, the squat did not use the swiss ball as the primary base of support (i.e., ball positioned against the lumbo-sacral area against a wall), the remaining exercises did. Therefore, the results of this study showed no significant difference in EMG activity in any of the muscles examined during the squat movement (i.e., RA, EO, TA-IO, VF, and BF). However, during the push-up movement, where the swiss ball was the main base of support, the TB, RA, and TA-IO showed increased activation during an isometric hold at the top position. Although, at the bottom position of the push-up (i.e., phase between concentric and eccentric motion), there was no difference in muscle activity, except for the TB. The double-leg lift demonstrated that only the RA muscle was enhanced by the swiss ball. These results led authors to believe that these increases in muscular activation were simply caused by the diminishing base of support caused by the unstable surface.

An examination of the superficial stabilization muscles (i.e., upper trapezius, lower trapezius, serratus anterior, and biceps brachii) used during a push-up on and off a swiss ball was done by Lehman et al. (2008). Studies that typically use unstable surfaces exam the effects on the core and primary movers, however, Lehman et al., decided to determine the effects on the synergists associated with the push-up. Ten male participants underwent several forms of push-ups on and off a swiss ball while EMG was recorded. Researchers found no significant difference between muscle activity in any of the paired (e.g., hands on floor vs. hands on swiss ball, feet on bench vs. feet on swiss ball) exercises performed. However, there were significant differences between exercises that switched hand and foot position. This conclusion may possibly be due to the increased loads placed upon the body when the feet are elevated.

In addition to examining push-ups, Lehman et al., (2005) sought to examine the differences in trunk muscular activation during plank exercises performed on and off a swiss ball. Researchers were attempting to determine whether the addition of an unstable surface would elicit a greater activation of core musculature (rectus abdominis, erector spinae, external and internal obliques). For this study, only male college students (n = 11) were used. All subjects completed two repetitions of five different plank variations (side plank, prone bridge, prone bridge on swiss ball, supine bridge, and supine bridge with swiss ball). Researchers determined that with the addition of a swiss ball only the external oblique and rectus abdominis were activated to a greater extent. The instability device had no affect on internal oblique or erector spinae.

Lehman et al., (2006) performed a follow-up investigation in order to see if a swiss ball could provide consistent trunk activation during upper-body strength exercises (i.e., crunches, dumbbell chest press, shoulder press, seated lateral raise, and seated double-arm overhead dumbbell triceps extension). Their results indicated no significant difference between the RA, EO, IO, or ES when the exercises were performed on and off a swiss ball. Therefore, researchers concluded that upper-body movements can be performed on instability devices, but no further core activation may result. Further research from this study may be warranted to determine how primary movers (e.g., pectoralis major, anterior deltoid, triceps brachii, etc.) are affected during upper-body movements performed on a swiss ball.

Youdas et al., (2010) attempted to measure the difference in EMG activation between a traditional push-up and a Perfect Pushup™, a device designed to increase activation of the primary and secondary movers used during a push-up. For this, 20 subjects were recruited to participant in this study. Subjects were asked to perform three consecutive push-ups in several hand positions (i.e., wide-base, shoulder-width, and narrow base) during a traditional push-up and push-ups performed on the device. Peak EMG values were used to determine muscular activation levels in the pectoralis major, triceps brachii, posterior deltoid, and serratus anterior. Results of this study indicated that the Perfect Pushup™ does not produce significantly greater activation of the examined musculature. However, Youdas et al., found that the narrow base hand position activated the triceps brachii and posterior deltoid to a significantly greater extent than the wide base and shoulder-width base in the push-up performed with and without the device.

Wahl and Behm (2008) used EMG to study four different types of instability devices (Dyna Disc, BOSU ball, wobble board, and a swiss ball) and the effects on the lower abdominals, erector spinae, soleus, bicep femoris, and rectus femoris. The purpose of this investigation was to determine if instability devices could elicit greater muscular activation in highly-trained individuals. Sixteen participants performed several different lower-body static and dynamic exercises (e.g., standing, squatting posture, static lunges, 1-leg hip extensions, calf raises, etc.). A fatigue test was also used to determine if an individual would possibly tire faster while performing a wall sit while standing on a BOSU ball (flat side up) versus a stable platform. Results of this study indicated that certain instability devices (dyna disc and BOSU ball) had no significant difference in EMG activity in any musculature examined during the static and dynamic movements. However, there was a significant difference for all muscles while standing on the swiss ball and wobble board, except for the rectus femoris on the wobble board. The fatigue test concluded that only the soleus was activated to a greater extent while standing on the floor than the BOSU ball, all other muscles had no significant difference. Researchers speculate that highly-trained individuals may demonstrate lower EMG activation with instability devices due to an increased exposure to free weights, which may moderately enhance stability. Therefore, highly-trained individuals may require a greater degree of instability to elicit increased EMG values.

In order to determine the effectiveness of stability training on another specific population, Schilling et al., (2009) studied the effects of unstable surface training on older adults. Their purpose was to measure the pre- and post-balance confidence of older adults after a 5-week balance training program. To accomplish this, nineteen older men and women, between the ages of 60-68, were split into two groups: training group (5 women and 5 men) and a control group (4 women and 5 men). All subjects who participated in this investigation were physically active, but not on a structured exercise program. Prior to beginning the study, all participants completed the Activity-specific Balance Confidence (ABC) questionnaire, which assesses an individuals' confidence performing activities which require balance. During the 5 week study period, the control group was asked to continue their normal routines, while the training group underwent three training sessions per week for five consecutive weeks. Each training group session consisted of 15-30 minutes of balance exercises performed on air-filled rubber discs. After the five weeks, mean ABC questionnaire scores in the training group increased, while mean control group scores decreased. Researchers speculate that the increase in ABC scores may be linked to the increase in frequency of balance specific training, and therefore more research is warranted to determine long-term effects.

Since core strength is a key determinant in sports performance and lower back injury prevention, Shinkle (2012) sought to determine if a field test could be created to assess core musculature dynamic strength and its ability to transfer forces during performance. Twenty-five subjects were recruited from a collegiate football team in order to perform several versions of medicine ball throws, a 1RM squat, 1RM bench press, countermovement vertical jump, 40 yard dash, push press, and proagility test. Several types of the medicine ball toss were created for this exam (e.g., static forward throw, static reverse throw, dynamic reverse throw, static lateral throws) in order to test upper extremity power generation with and without the core. This would be accomplished by measuring medicine ball throwing distances between static and dynamic movements. These tests would help determine if dynamic core movements could enhance power during throwing movements. Results indicated that there was a significant difference when static throws were compared to dynamic throws, with exclusion of the forward throw. Investigators theorized that the anterior musculature (i.e., rectus abdominis) provides minimal assistance to forward dynamic movement; therefore, the main function is to stabilize and protect the spine from unexpected external forces. Researchers also hypothesized that the external obliques contribute more to athletic performance, due to its ability to resist excessive rotation of the body and through this stabilization allow for a better transfer of forces to the extremities.

Comfort et al., (2011) also sought to examine the differences in RA and EO activation during isometric abdominal exercises versus dynamic strengthening exercises. Ten moderately-trained men performed 1 set of 3 repetitions of the following exercises while RA and EO EMG were recorded: prone bridge (PB), superman on swiss ball (SM), military press (MP), back squat (BS), and front squat (FS). For all strengthening exercises (FS, BS, MP), a standard weight of 40 kg was used to keep all repetitions between subjects comparable. For the abdominal exercises (PB and SM), no external resistance was added. Results indicated that the PB activated the RA to a significantly greater extent when compared to all other exercises performed. The EO had the greatest activation during the front squat and superman exercises. However, activation of the RA during strengthening exercises is load dependent; therefore, if greater external loads were used during this investigation, values for the RA may have differed.

Ekstrom et al., (2007) attempted to determine the extent of EMG activation during nine different exercises using the core, thigh and hip muscles. Researchers wanted to distinguish between exercises (i.e., side bridge, unilateral-bridge, lateral step-up, quadruped arm/lower leg lift, active hip abduction, Dynamic edge device, lunge, bridge, prone-bridge) that were appropriate for strengthening vs. endurance training. Thirty subjects (19 males and 11 females) completed 3 repetitions of 5-second isometric holds of each exercise, along with a continuous recording during a Dynamic Edge exercise. EMG was used to differentiate muscular activity levels. Eight different muscle groups were examined: EO, RA, longissimus, multifidus, gluteus maximus, gluteus medius, vastus medialis, and hamstrings group. After completion of the study, results showed that the prone-bridge and side-bridge provided the greatest activation of the RA as compared to the remaining exercises. Therefore, bridge and plank like movements may be more beneficial for core training as compared to other traditional movements.

A study performed by Sarti (1996) was designed to compare the average surface EMG of the upper rectus abdominis (URA) and lower rectus abdominis (LRA) during common abdominal exercises. Thirty-three healthy individuals volunteered to perform ten repetitions of both a standard curl-up (CU) and posterior pelvic tilt (PT). From the selected participants, they were divided into those who engaged in high levels of physical activity and those who did not. Groups were then divided further into two subcategories: correct and incorrect performers of the exercises. Results showed that there was a significant difference during each of the two exercises between the two sections of muscle groups, URA and LRA. The CU placed a greater emphasis on the URA. However, the PT had a greater impact on the LRA than the URA, but only in those who were highly trained and performed the exercise correctly. These findings suggest that further research is warranted in EMG activity of multiple exercises were the participants are separated by the ability to properly perform the movements versus those who cannot.

Drysdale et al., (2004) compared the electromyography of the rectus abdominis and external oblique during the posterior tilt and an abdominal-hollowing exercise. Twenty-six healthy college female athletes participated in this investigation to determine whether either of these exercises were an efficient exercise to be performed during rehabilitation for lower back pain. Surface EMG recordings were taken during three repetitions of a 5-second isometric hold for each exercise. Results indicated that the hollowing exercise produced significantly less activation than the pelvic tilt exercise. This was hypothesized by researchers because traditional hollowing movements are designed to activate deep core musculature to draw in the abdomen while minimizing superficial musculature (EO and RA) activation. Drysdale et al., concluded that the pelvic tilt exercise may not be an initial choice for those wanting to recover from low-back pain, due to the spinal flexion and load placement involved.

Barnett et al., (1995) attempted to measure the EMG extent of five superficial muscles during different inclinations of a bench press along with varying hand positions. Six male weight lifters performed one repetition each of a decline, flat, incline, and vertical press with two types of hand positions (i.e., narrow and wide grip). Surface EMG was used to determine the extent of activation for the anterior deltoid, long head of the triceps, latissimus dorsi, sternocostal head of the pectoralis major, and clavicular head of the pectoralis major. Results indicate that hand position and varying inclination had an effect on the superficial musculature. The sternocostal portion of the PM had the greatest amount of activation during the horizontal press with a wide hand grip; and lowest activation during the vertical military press with a narrow grip. The clavicular head of the PM obtained the greatest activation during the incline press with a narrow grip; the lowest activation occurred in the vertical press with a wide grip. However, the highest muscular activity for the anterior deltoid occurred in a vertical press with a wide grip; and lowest in a wide-grip decline press. Tricep activation was greatest during a narrow-grip horizontal press and least with an incline wide-grip press. However, the latissimus dorsi provided very minimal activation during any of the exercises performed, and therefore, was concluded to not be an effective synergist during pressing movements.

Another studying investigating hand position and upper-body movements was done by Cogley et al. (2005). Researchers examined the differences in three hand positions while performing the standard pushup using forty subjects (11 men and 29 females). Surface EMG was used to determine the extent of pectoralis major and triceps brachii activation during the PU with a wide-base, standard-base, and narrow-base hand position. Results showed that the triceps brachii and pectoralis major had the greatest activation levels during the narrow-base and least amount during the wide-base.

However, increased PM activity in NB push-ups contradicts previous studies which state that a WB position elicits greater activation due to a greater isolation, by minimizing tricep and anterior deltoid activity. Researchers concluded that the greater PM activity was possibly due an increased range of motion during the NB push-up.

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CHAPTER 2

ELECTROMYOGRAPHIC ACTIVITY OF RECTUS ABDOMINIS DURING A SUSPENSION PUSH-UP COMPARED TO TRADITIONAL EXERCISES

ABSTRACT

Purpose: The purpose of this study was to compare the electromyographic (EMG) activity of the rectus abdominis (RA) across three different exercises [i.e., suspension pushup (SPU), standard pushup (PU) and abdominal supine crunch (C)]. **Methods:** Fifteen apparently healthy men (n = 12, age = 25.75 ± 3.91 yrs) and women (n = 3, age = 22.33 ± 1.15) volunteered to participate in this study. The subjects performed four repetitions of SPU, PU, and C. The order of the exercises was randomized. Mean peak EMG activity of the RA was recorded across the 4 repetitions of each exercise. Raw (mV) and normalized (%MVC) values were analyzed. **Results:** The results of this study showed that SPU and C elicited a significantly greater ($P<0.05$) activation of the RA reported as raw (2.2063 ± 1.00198 mV and 1.9796 ± 1.36190 mV, respectively) and normalized values (68.0 ± 16.5% and 52 ± 28.7%, respectively) compared to PU (i.e., 0.8448 ± 0.76548 mV and 21 ± 16.6%). **Conclusions:** The SPU and C were not significantly different ($P>0.05$). This investigation indicated that SPU and C provided similar activation levels of the RA that were significantly greater than PU.

INTRODUCTION

Previous trends in strength and conditioning have primarily focused on exercises designed for sport-specificity (kicking, jumping, throwing, and pushing) and not specific core training (9). However, the recent sport scientific literature indicates that strengthening the core musculature leads to a greater transfer of power to the limbs during functional movements, which appears to improve sports performance (1,13,16,19). During athletic performance, it takes the entire body working as one functional reactive unit to provide speed, velocity, agility, and strength (19). In addition, the increase in core strength may also prevent injuries, improve coordination, and help to ensure proper spine protection and function (4,12,18,20,23). Therefore, from a functional and health point of view, further investigation on exercises designed to target the core musculature is warranted.

The traditional push-up (PU) is one of the most well-known exercises to target the musculature of the upper body (e.g., pectoralis major, triceps brachii, and anterior deltoid). Often, it is used as a test to measure upper body muscular endurance (11). Interestingly, several studies have shown that the traditional push-up also provides an isometric challenge to abdominal wall musculature (2,12), which becomes activated to a greater extent with the introduction of a suspension device (8). However, most investigations have focused on established modalities designed to challenge core stability, such as the Swiss Ball or BOSU. There is very little research to date that investigates the effects of a push-up using a suspension device (SPU) on electromyographic (EMG) activity of core musculature.

Of the limited data in this area, Beach et al. (2) compared EMG activity of the rectus abdominis (RA) between PU and SPU. The results indicated that the RA was elicited to a significantly greater extent during the SPU compared to PU. However, additional research is needed to determine if SPU activates the RA to the level of traditional abdominal exercises. The purpose of this study was to compare the EMG response of the RA during three exercises: SPU, PU, and traditional supine crunch (C). For comparative purposes, C was used in this investigation as it is the current standard to which most exercises are compared when investigating RA activity (12,18,22). It was hypothesized that the SPU would elicit a greater activation of the RA compared to PU and C.

METHODS

Subjects

Fifteen apparently healthy men (n = 12) and women (n = 3) volunteered to participate in this study. Descriptive statistics are shown in Table 1. All subjects were asked to complete a health history questionnaire and informed consent. Those who were free from musculoskeletal dysfunctions, cardiovascular, and metabolic diseases were allowed to participate. The study was approved by the Institutional Review Board at Auburn University at Montgomery.

Procedures

Surface Electromyography

Electromyographic activity was recorded using a MP150 BioNomadix Wireless Physiology Monitoring system (*Biopac System, Inc., Goleta, CA*). Two Ag-AgCl surface electrodes (*Biopac EL504, Biopac Inc. Goleta, CA*) were placed 2 cm to the right of the umbilicus and 3 cm apart (vertically) directly over the muscle fibers. A ground surface electrode was placed directly over the right anterior superior iliac spine. Prior to all electrode placements the skin sites were properly prepared by shaving (if needed), exfoliating, and cleansing with alcohol wipes to reduce any impedance. The EMG signals were sampled at a rate of 1.000 kHz using Acqknowledge 4.2 software (*Biopac*. Inc., *Goleta, CA*). The EMG values were stored in a Dell PC for analysis.

Exercise Trials

The subjects were instructed on proper exercise technique of the SPU, PU, and C. If the exercises were not completed with proper technique, the data were not used in the collection process. Before the exercise trials, a maximum voluntary contraction (MVC) of the RA was determined to allow normalizations of the EMG data (%MVC). To obtain these values, the subjects assumed a supine position on a padded mat with the knees flexed to 90° with the arms crossed over the chest. Then, the subjects attempted to perform a sit-up while the investigator provided a matched resistance to prevent motion. After the MVC data was recorded, the subjects performed the exercises.

Suspension Push-Up (SPU): A suspension device (TRX® Suspension Trainer®, Fitness Anywhere, LLC) was attached overhead to a standard smith machine. The handles of the suspension device were placed at the height of the fitness step (in which the subjects' feet were placed during the exercise) to ensure that the hands and feet were at the same level while performing the push-ups. The subjects then assumed a standard push-up position with their hands placed in the handles of the suspension device (starting position) that were slightly wider than shoulder-width apart. While maintaining a neutral spine position with the feet together, the subjects were instructed to perform a push-up.

In order for successful trial to be recorded, the subjects' chest reached the level of the hands at the transitional portion of each repetition (i.e., between the concentric and eccentric phases).

Standard Push-Up (PU): All traditional push-ups were performed on a flat, stable surface with hands placed slightly wider than shoulder-width apart and fingers pointed forward. During the standard push-up, the subject was instructed to lower the upper body until the chest reached 2 inches from the floor. If the correct depth was not reached, the repetition was repeated.

Lying Supine Crunch (C): To perform the crunch, the subjects were instructed to lay supine with knees flexed to 90°, feet flat on the floor, and arms crossed over the chest. The subjects then flexed the spine to lift the head and shoulders until the inferior angle of the scapula did not touch the mat. Then, the subjects returned to the starting position.

Statistical Analysis

The data was analyzed using SPSS/PASW Statistics version 18.0 (Somers, NY). Repeated measures analysis of variance (ANOVA) was used to determine if there were differences in raw (mV) and normalized (%MVC) RA EMG values across the three exercises. Bonferroni follow-up tests were used to further examine the differences. A priori statistical significance was set to a value of $P<0.05$.

RESULTS

All of the subjects successfully completed each exercise trial. The RA activity during the SPU, PU, and C exercises were 2.21 ± 1.00 mV, 0.84 ± 0.77 mV, and 1.98 ± 1.36 mV, respectively (Figure 1). When normalized for MVC, RA activity during SPU, PU, and C were 68.0 ± 16.5%, 21 ± 16.6%, and 52 ± 28.7%, respectively (Figure 2). The raw and

%MVC values were lower during PU compared to SPU and C (P<0.05). The differences between SPU and C in raw and normalized RA values were not significant (P>0.05).

DISCUSSION

The purpose of this study was to determine if the SPU elicited greater activation of the RA when compared to the PU and C. Our findings were consistent with a previous study by Beach et al. (2) in that the RA was activated to a significantly greater extent during the SPU when compared to PU. However, the most important finding of the current investigation extends previous reports by demonstrating a similar RA level of activation during SPU compared to a traditional abdominal exercise, the C.

Exercise devices designed to challenge stability are relatively recent trends to increase core strength along with improving coordination, balance, and sports performance (21). These devices are typically used while performing abdominal-specific exercises, though conflicting evidence exists as to whether these unstable pieces of equipment have a significant effect on core stability. Several studies report an increased challenge to abdominal wall activation with the instability training devices (3,6,22). For example, Duncan (6) demonstrated that RA activity was greater when the C was performed on a Swiss Ball than on the floor. However, several other studies demonstrated opposite findings (18,21), with some authors suggesting stability devices could actually assist the subject with performing the abdominal-specific movement (24).

Additional studies have shown that when closed kinetic chain lower body movements (e.g., squat and deadlift) are performed on unstable devices, RA activation decreases compared to the traditional approach (10,17,25). This is primarily because of a decreased force production and lower load displacement when the exercises were performed in the unstable environment. However, the suspension device increased RA activity of the push-up in the current study. Similar to our findings, Marshall and Murphy (15) demonstrated an increase in RA activation while push-ups were performed with the hands placed on a Swiss ball. Furthermore, Freeman et al. (8) demonstrated a 2.5-fold increase in RA activation when push-ups were performed with the each hand placed on a basketball. Therefore, it seems reasonable to consider that when body-weight resisted movements of the upper extremities, such as the PU, are performed on unstable devices there is a greater muscular force production that leads to an increased RA activity.

Previous studies have also indicated that the plank or prone-bridge elicited higher values of RA activation when compared to traditional abdominal movements, such as the C (5,7). For example, Lehman et al. (14) demonstrated an increased RA activation when the prone-bridge was performed with the elbows placed on a Swiss ball. Therefore, because of the plank-like position and unstable nature of the upper body in the present study (i.e., hands in the suspension trainer), the SPU significantly increased RA activation.

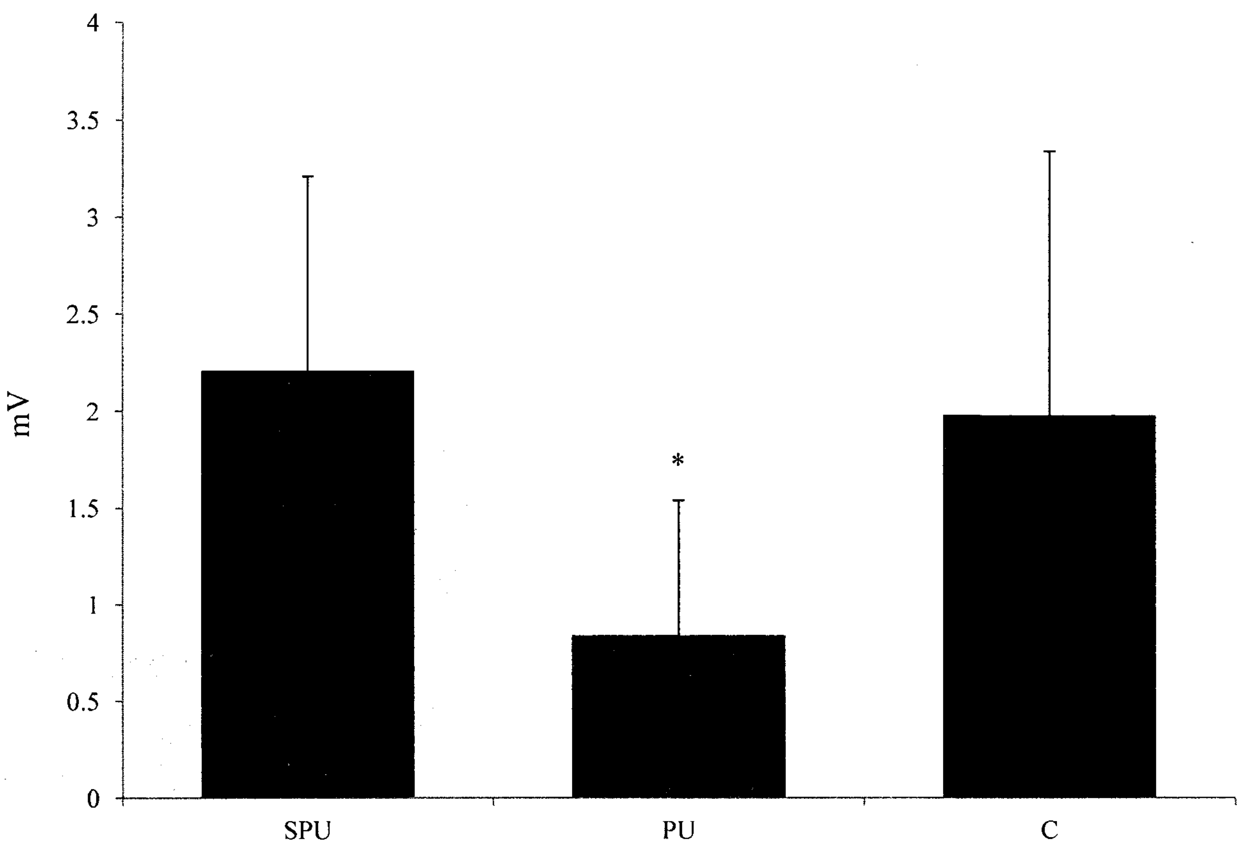
CONCLUSIONS

This study showed that the SPU provides a level of RA activation that is higher than the PU while comparable to the C. Thus, it is appropriate to conclude that the SPU can be used as a substitute for the C and vice versa. Individuals who are interested in developing a stronger core may benefit from new and unusual exercises, such as the SPU, (2,22) while also lowering their risk of injuries to the spine.

Table 1. Descriptive characteristics of the subjects (*P<0.05)

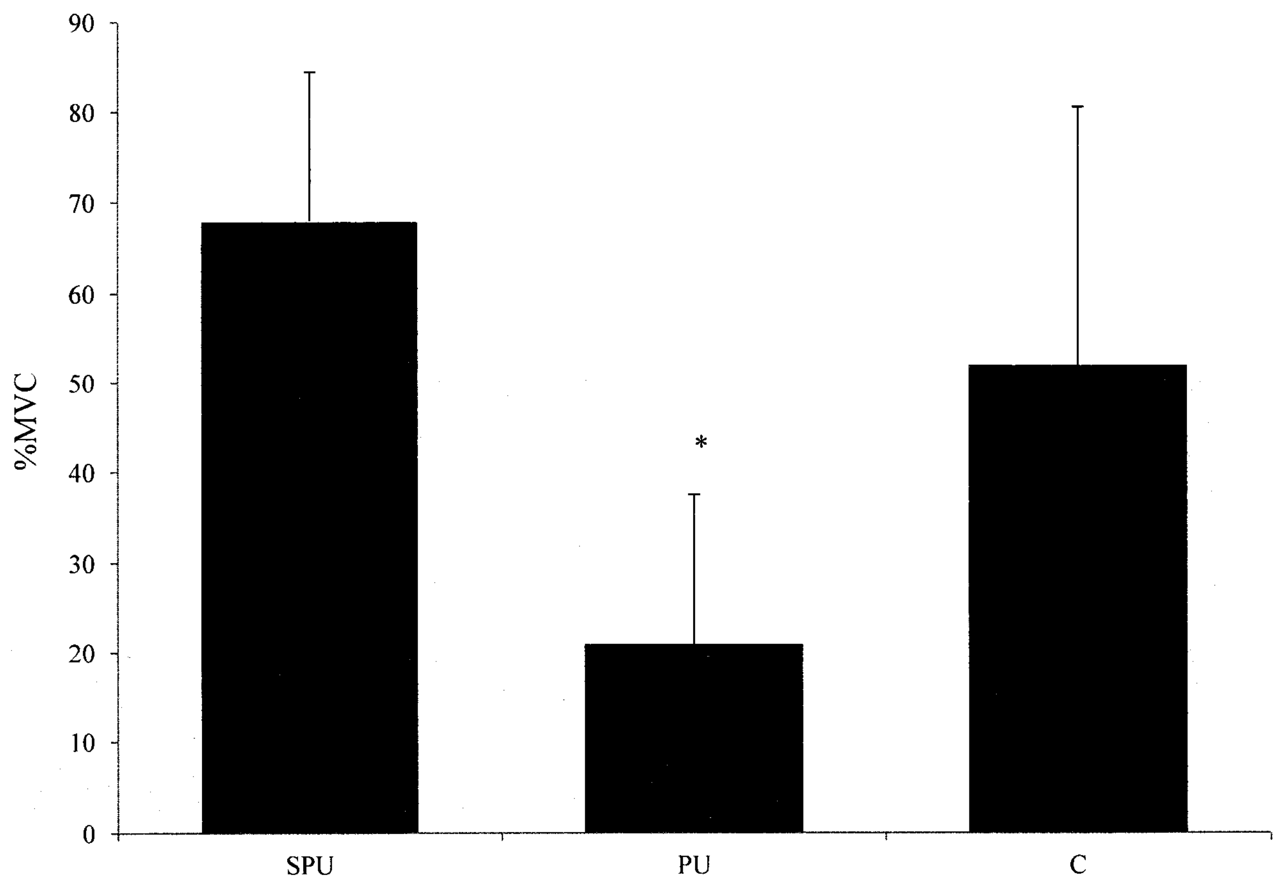
Conditions	Males	Females	All
Age (yrs)	25.75 ± 3.91	22.33 ± 1.15	25.27 ± 3.86
Height (cm)	179.08 ± 7.74	172.67 ± 6.43	177.8 ± 7.75
Weight (kg)	81.17 ± 7.28	66.33 ± 8.33*	78.2 ± 9.45
BMI	25.35 ± 2.33	22.23 ± 2.38*	24.73 ± 2.59

Figure 1. Comparison of Electromyographic activity (mV) of the rectus abdominis across three exercise trials: Suspended Push-Up (SPU); Traditional Push-Up (PU); and the Crunch (C).



*PU was significantly lower than SPU and C ($P<0.05$).

Figure 2. Comparison of Electromyographic activity (%MVC) of the rectus abdominis across three exercise trials: Suspended Push-Up (SPU); Traditional Push-Up (PU); and the Crunch (C).



*PU was significantly lower than SPU and C (P<0.05).

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CHAPTER 3

ELECTROMYOGRAPHIC COMPARISON OF SELECTED SHOULDER GIRDLE MUSCULATURE DURING TRADITIONAL AND SUSPENSION PUSH-UPS

ABSTRACT

There is very limited published scientific information concerning suspension training (ST). **Purpose:** The purpose of this investigation was to compare the electromyographic (EMG) activity of the pectoralis major (PM), anterior deltoid (AD), and triceps brachii (TB) between a suspension push-up (SPU) and traditional push-up (PU). **Methods:** Twenty-one apparently healthy men ($n = 15$, age $= 25.93 \pm 3.67$ years) and women ($n = 6$, age $= 23.5 \pm 1.97$ years) volunteered to participate in this study. All subjects performed four repetitions of SPU and PU where the order of the exercises was randomized. The mean peak EMG of PM, AD, and TB were compared across the two exercises. **Results:** SPU elicited the following EMG values: PM (3.08 ± 1.13 mV), AD (5.08 ± 1.55), and TB (5.11 ± 1.97). The EMG activities during the PU were as follows: PM (2.66 ± 1.05 mV), AD (4.01 ± 1.27 mV), and TB (3.91 ± 1.36 mV). The mean peak EMG values were significantly higher for all 3 muscles during SPU compared to PU ($p < 0.05$). **Conclusions:** This study suggests that SPU elicited a greater activation of PM, AD, and TB when compared to PU. Therefore, SPU may be considered an advanced variation of a traditional push-up when a greater challenge is warranted.

INTRODUCTION

The push-up (PU) is a popular exercise that is performed with the purpose of increasing strength and hypertrophy of upper extremity musculature (14,29,32,33). It is also considered the standard measurement of upper-body muscular endurance (1). Though the PU serves as an exercise to primarily target the pectoralis major (PM); it also activates the anterior deltoid (AD) and triceps brachii (TB) (33,37).

This exercise is traditionally performed on a flat, stable surface with hand placement at slightly wider than shoulder width. However, common variations exist involving changes in hand position from standard (e.g., wide or narrow) and modifying body posture by elevating the feet. A change in surface stability has recently been shown to also add variation and increased intensity of the PU. Most research in this area that has suggested that performing PU with instability devices such as Swiss balls, inflated discs, BOSUs and wobble boards may increase the activity of shoulder girdle and upper arm muscular compared to the traditional approach (11,12,18,23,37).

Suspension training (ST) is one of the newest forms of stability training that utilizes hanging ropes and straps that are anchored to a fixed point from above (e.g., ceiling or pull-up bar) allowing the user to work against their own body weight from a suspended position. Hypothetically, the greater disruption in stabilization from ST elicits increased motor unit recruitment, essentially causing the muscle to "work harder" to perform a particular movement (6,25). Unfortunately, limited published scientific research exists regarding the effectiveness of this newer form of exercise. Two recent studies demonstrated that PU performed on a suspension device elicited a greater activation of the rectus abdominis (31) and latissimus dorsi (6) compared to traditional stable PU. However, neither study examined the activity of the prime movers of the glenohumeral (e.g., PM and AD) and humeroulnar (e.g., TB) joints. Therefore, the purpose of this investigation was to determine the extent of electromyographic (EMG) activity of the PM, AD, and TB while performing push-ups with (SPU) and without (PU) a suspension device. As mentioned above, previous research has shown a greater EMG output of the selected muscles when performing the PU on common instability devices such as the Swiss ball (11,12,18,23,25,37). Therefore, it was hypothesized in the current study that SPU would elicit a greater activation of the studied musculature compared to PU.

METHODS

Experimental Approach to the Problem

There is increasing public interest on ST, yet limited scientific published data. Research is needed to determine the effectiveness of this newer form of exercise. This investigation was performed to compare the EMG activity of PM, AD, and TM between SPU and PU. A group of subjects performed SPU and PU in randomized order. The EMG activity of the selected musculature was compared between the two trials. All measurements were taken on the same day. The complete details of the study are described in the following sections.

Participants

Subjects were recruited through flyers and word of mouth at Auburn University at Montgomery. Subjects (n = 21) consisted of 15 men and 6 women who volunteered to participate in this study. Descriptive statistics for the participants are shown in Table 1. Participants were informed of all risks and discomforts that could occur and were asked to complete a health history questionnaire and informed consent. Only those who were classified as low risk, according to the American College of Sports Medicine guidelines were used in this study. Individuals with any previous chest, shoulder, or arm injuries were excluded from this investigation. All subjects were currently physically active with at least six months of resistance training experience. This study was approved by the Institutional Review Board.

Electromyography

All EMG values were collected using a Biopac MP150 BioNomadix Wireless Physiology Monitoring system at a sampling rate of 1.000 kHz, and analyzed using Acqknowledge 4.2 software (BIOPAC System, Inc., Goleta, CA). Disposable Ag-AgCl surface electrodes (Biopac EL504) were used for this study. Before placing the surface electrodes, all skin sites were prepared with shaving, abasing, and alcohol cleansing in order to reduce impedance. All electrodes were placed on the right side of the subjects. Researchers assumed that bilateral symmetry was occurring throughout each exercise performed; therefore, electrodes were not placed on both sides of the subject. Pectoralis major electrodes were positioned halfway between the sternal notch and anterior axillary line, approximately 2 cm apart in-line with muscle fibers. Anterior deltoid electrodes were placed two finger-breadths below the acromio-clavicular joint and angled towards the deltoid tuberosity. The electrodes for the triceps brachii were positioned mid-way between the acromion and olecranon processes on the posterior portion of the upper arm on the long head of the tricep, approximately 2 cm apart following the muscle fibers. A ground electrode was placed directly over the right anterior-superior iliac spine. This method of electrode placement is similar to that of Cram and Kasman (13).

Exercise Trials

After all electrodes were placed, subjects drew numbers in order to randomize the exercises performed. All subjects were instructed on proper technique of the traditional and suspended push-up by a Certified Strength and Conditioning Specialist. If subjects were unable to complete the push-ups with proper technique, they were not used in the data collection process. The techniques for the exercises are as follows:

Suspension push-up (Figure 1): Prior to performing the SPU, the suspension device was securely attached overhead to the top portion of a Smith Machine. In order to mimic the traditional PU, the handles of the suspension device were set to match the level of the feet when placed on a fitness step. The TRX® Suspension Trainer® was used for this investigation. Participants assumed a standard push-up position with hands placed in the handles of the suspension device (starting position). The hands were placed slightly wider than shoulder-width apart. Next, while maintaining a neutral spine and feet together position, subjects began the eccentric portion (descent) of the push-up. Suspension push-ups were only recorded when the correct depth was reached (chest reached the level of the hands) for each repetition. Push-ups were performed at a rate of 1 push-up every three seconds. Timing was measured by a metronome.

Standard push-up (Figure 2): Standard push-ups were performed on a flat, stable surface, hands placed slightly wider than shoulder-width apart, and fingers pointed forward. Subjects were instructed to maintain a neutral spine and feet together position throughout the entire movement. Once again, in order for the repetition to be recorded the correct depth needed to be met. Participants were instructed to lower the body until the chest was within 2 inches from the floor. All repetitions were repeated if the correct depth was not acquired. The same repetition timing was applied for all push-ups (1 push-up every 3 seconds).

Statistical Analysis

Data was analyzed using SPSS/PASW Statistics version 18.0 (Somers, NY). Means and standard deviations were calculated for the studied variables (PM, AD, TB). Paired samples T-tests were used to determine if the mean peak EMG values for the PM, AD, and TB were significantly different between the PU and SPU. A priori statistical significance was set to a value of $p < 0.05$.

RESULTS

All of the subjects completed each exercise trial successfully and were included in the data collection process. The PM activity during the SPU and PU was 3.08 ± 1.13 mV and 2.66 ± 1.05 mV, respectively (Figure 3). Activity for the AD during the SPU and PU was 5.08 ± 1.55 mV and 4.01 ± 1.27 mV, respectively (Figure 4). While, the TB activity for the SPU was 5.11 ± 1.97 mV and the PU was 3.91 ± 1.36 mV (Figure 5). The EMG values for each muscle were all significantly higher during the SPU compared to the PU ($p < 0.05$).

DISCUSSION

The purpose of this study was to compared the EMG activity of the PM, AD, and TB between the SPU and PU. The major finding of this study was that the SPU resulted in significantly greater EMG activity of the selected muscles compared to PU. These results indicate that ST may be a method to increase the intensity of the standard PU when targeting the PM, AD, and TB.

The three muscles were chosen in this study because of their particular roles on glenohumeral and humeroulnar joint movement during the push-up. The PM is a uni-articulate muscle responsible for horizontal and diagonal adduction, along with internal rotation of the humerus. Various fibers of the PM (i.e., clavicular head) are also responsible for humeral flexion, while the sternocostal portion provides humeral extension (16). While the entire deltoid provides, multiple roles during the PU, the AD was chosen primarily for it's' role of humeral flexion, which is distinct to the anterior fibers (16). The AD also provides horizontal and diagonal adduction, along with internal rotation of the humerus (16). In addition, the TB is the primary concentric elbow extender during PU (16).

An abundance of research has examined the EMG activity of selected musculature while performing exercise on various instability devices (6,17,24,25,26). For example, the Swiss Ball has been shown to be an effective device for eliciting an increased level of muscular activity when used with exercises designed to target the PM, AD, and TB (22,25,26). Our findings are consistent with previous research about the global topic of instability exercise; i.e., increased muscular activation during body weight exercise when stability is challenged (4,17,22,24,25,31). However, the current study is one of the first to suggest ST may be a superior method for increasing EMG activity of PM, AD, and TB. Several theories are available to help explain our findings, which are detailed within the following two paragraphs.

During a typical PU, each dynamically active joint has only one degree of freedom in which to function (i.e., a vertical, up-and-down movement). However, the ST decreases the base of support for the upper body, as it is suspended above the floor. This unstable kinetic chain results in additional degrees of freedom as the limbs work to prevent unnecessary horizontal and diagonal movements. This creates a "multiple-role" within the active musculature as they not only serve as PU agonists, but also joint stabilizers (21,26,28). The hands being placed in the handles of the suspension trainer provides additional degrees of freedom compared to the standard [fixed] floor placement. With additional ranges of freedom, a greater number of motor units are recruited to execute a particular exercise resulting in an increased EMG output (6,7,24,25,34,35). This characteristic is similar when performing dumbbell versus barbell chest presses, as the former has been shown to provide an increased level of instability (7,30). Furthermore, Saeterbakken et al. (30) showed that with a shift from a one degree to a multiple degree of freedom bench press exercise (i.e., comparing barbells to dumbbells), EMG activation levels remained consistent in the primary musculature. However, the average load of the barbell bench press was 17% greater compared to the dumbbell bench press (30). In the current study, the participants performed both exercises while using the same load (i.e., their personal body weight) even though the degrees of freedom were greater with SPU. Therefore, EMG output was higher.

In addition, previous research has shown that varying the position of the hands while performing a PU can lead to an increased EMG output of targeted musculature (11,37). Cogley et al. (11) showed that when hands are placed narrower compared to wider than shoulder width, EMG output of the PM and TB is higher primarily due to a greater range of motion with the former. With the SPU, the hands are wider at the start and move to a more narrow position at the end of a concentric action. In contrast, the hands remained slightly wider than shoulder width throughout the PU movement.

Therefore, the SPU resulted in a greater range of humeral motion compared to the PU, resulting in a greater EMG output of the selected glenohumeral musculature (i.e., PM and AD). Furthermore, narrow hand placement with PU has been shown to increase humeroulnar torque by 71% compared to a wider base (15). Since the base of support is narrowed at the end of a concentric action with SPU, a greater EMG output of TB is also elicited, which is consistent with previous studies (11,15).

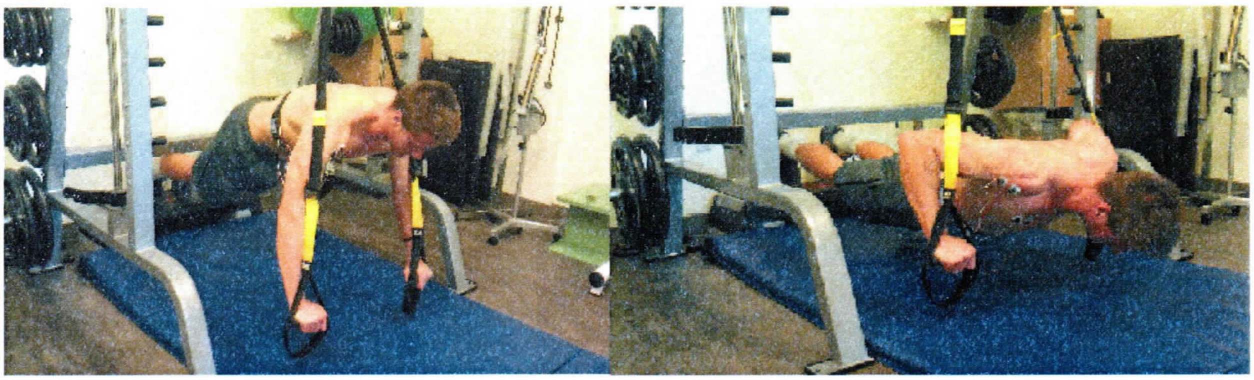
This study is not without possible limitations. First, the sample size had a diverse background with ST, with some subjects more familiar with this form of exercise compared to others. The EMG output of the selected muscular may decrease as familiarity with ST increases. A study performed by Wahl and Behm (35) demonstrated that with highly resistance-trained individuals, that not all instability devices were able to elicit significantly greater muscular activations during training. It may be warranted that future studies examine if EMG activation is different between individuals of various ST background levels. Second, only one device was used in this investigation (i.e., suspension device). A cross-comparison of multiple instability devices (e.g., swiss ball, wobble boards, etc.) may provide further insight into the overall effectiveness of ST. Last, the group of subjects was not analyzed across a chronic training period. Longitudinal investigation is certainly needed before determining the effectiveness of ST on muscular hypertrophy and strength. However, the novel findings of the current study provide an important first step for future studies on ST.

In conclusion, it is important that with any new training device that proper research be completed in order to determine the level of safety and effectiveness. Based on EMG values alone, our study indicates that the SPU exercise elicits greater muscular activation of PM, AD, and TB compared to the traditional PU. The traditional PU, when performed on a stable surface can provide a sufficient stimulus to increase upper body muscular strength and endurance (1). However, when an increased challenge is warranted, a suspension training device may be incorporated to increase muscular activation and possibly enhance neuromuscular adaptations with the push-up. Therefore, practitioners should consider using a ST for advancing the traditional push-up movement.

Table 1. Descriptive characteristics of the subjects

	Men (n = 15)	Women (n = 6)	All (n = 21)
Age (yr)	25.93 ± 3.67	23.50 ± 1.97	25.24 ± 3.42
Height (cm)	180.78 ± 8.54	174.05 ± 4.96	179.01 ± 8.21
Weight (kg)	83.65 ± 7.72	68.04 ± 6.56	79.54 ± 10.12

Picture 1. Starting and ending position of the suspension push-up (SPU)



Picture 2. Starting and ending position of the traditional push-up (PU)

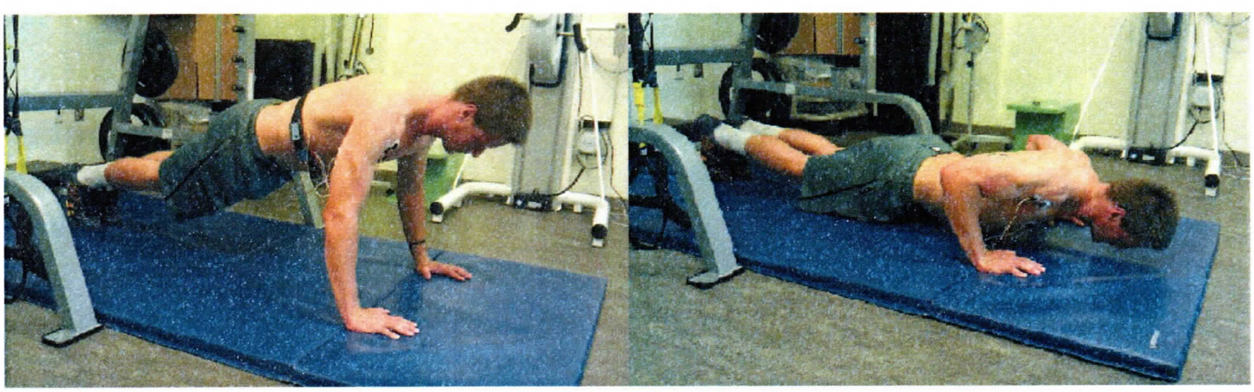
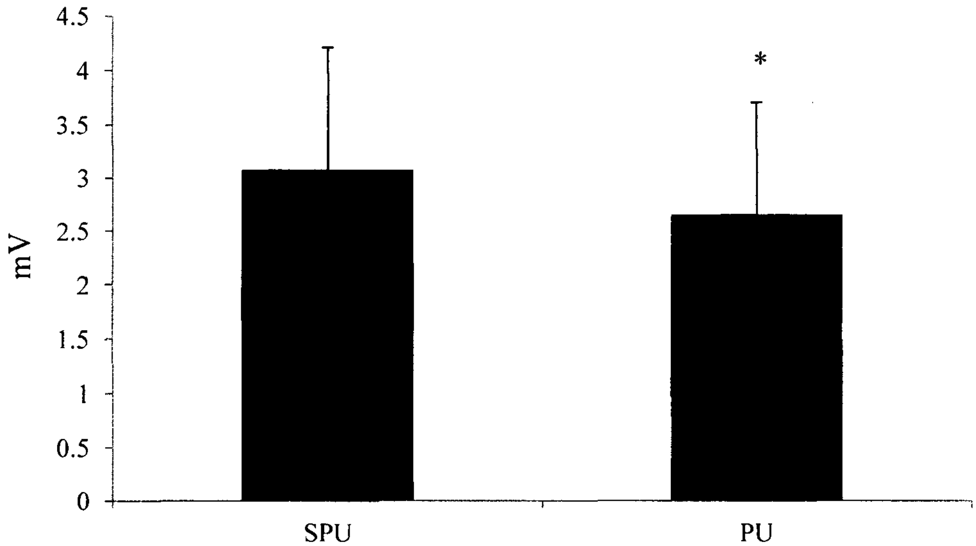
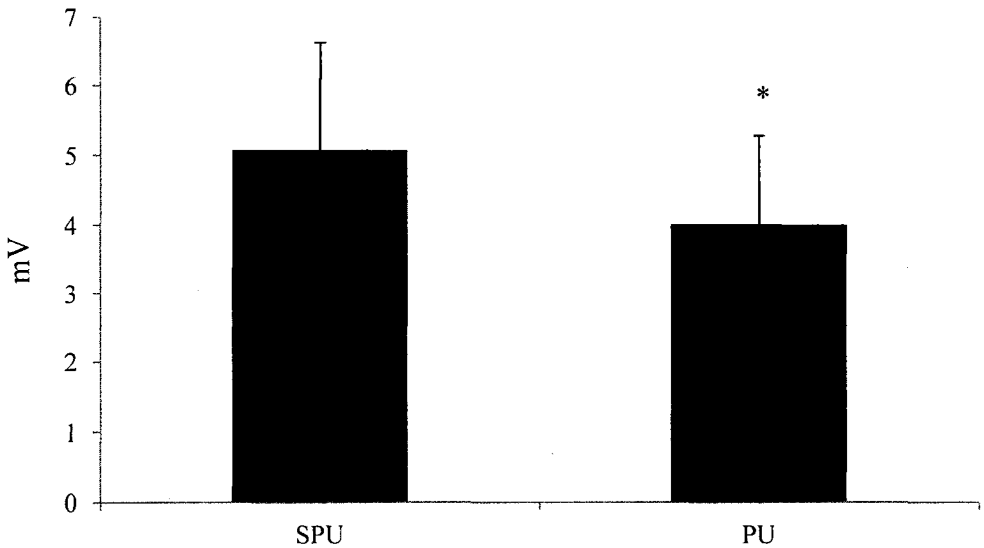


Figure 1. Comparison of Electromyographic Activity (mV) of the Pectoralis Major between Suspension Push-ups (SPU) and Traditional Push-ups (PU)



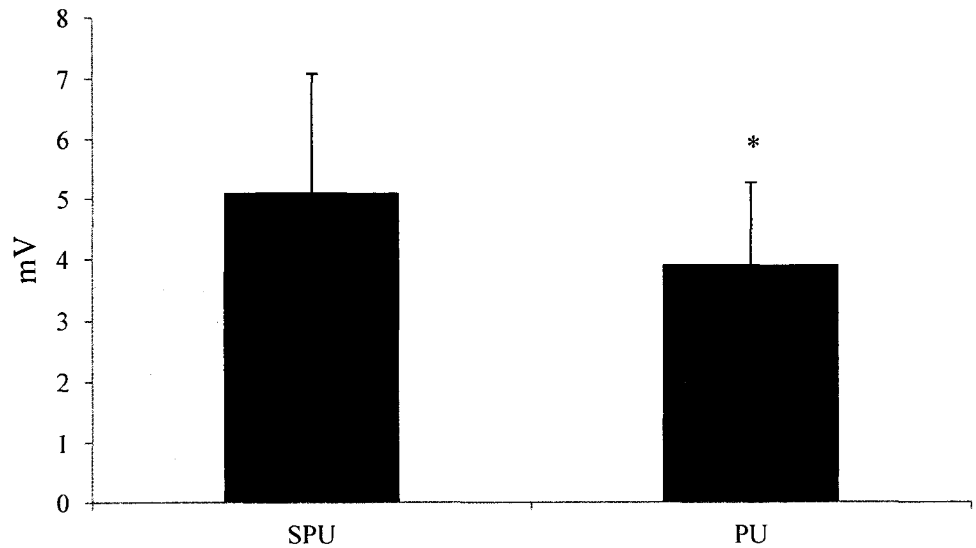
***PU was significantly lower than SPU ($p<0.05$)**

Figure 2. Comparison of Electromyographic Activity (mV) of the Anterior Deltoid between Suspension Push-ups (SPU) and Traditional Push-ups (PU)



**PU was significantly lower than SPU (p<0.05)*

Figure 3. Comparison of Electromyographic Activity (mV) of the Triceps Brachii between Suspension Push-ups (SPU) and Traditional Push-ups (PU)



**PU was significantly lower than SPU (p<0.05)*

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AUBURN
MONTGOMERY

Are you interested in participating in a **TRX SUSPENSION TRAINING** RESEARCH STUDY??

"Muscle Activation During TRX Suspension Training"

We are seeking male and female volunteers between the ages of 19 and 35 to participate in a study to examine the extent of core musculature activation during common TRX suspension training exercises. To participate, the following criteria must be met:

1. **Between the ages of 19 to 35 years**
2. **Free from cardiovascular, pulmonary, or metabolic disease**
3. **Not currently taking any prescription medications**

If you meet the criteria for the study, you will receive a body fat assessment performed by trained exercise professionals and information regarding suspension training.

If you are interested in participating in this study please contact:

Ron Snarr
Department of Physical Education and Exercise Science
Auburn University Montgomery
(334) 244-3472
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Dr. Michael Esco
Department of Physical Education and Exercise Science
Auburn University Montgomery
(334) 244-3161
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INFORMED CONSENT

Electromyographic activity of superficial core musculature during suspension training.

Auburn University Montgomery

<u>Department of Physical Education and Exercise Science</u>

You are invited to participate in a study that will examine the electromyographic activity of superficial musculature during common suspension training exercises. Mr. Ron Snarr is the principal investigator and Dr. Michael Esco is the co-investigator conducting this study. You were selected as a possible participant because you volunteered for the study and you fit the criteria of being between the ages of 19 and 35 years and are an apparently healthy individual free from cardiovascular, pulmonary and metabolic diseases.

If you decide to participate, you will be asked to report to the Human Performance Laboratory at Auburn University Montgomery between 7:00am and 11:00am on one day of the week (Monday through Friday) on one occasion. During this visit, you will complete a health history questionnaire and have the following variables measured: height; body weight; and body composition.

Body composition will be measured with the use of Dual Energy X-Ray Absorptiometry (DEXA). Human performance laboratories that undertake bone mineral density and body composition studies use DEXA as the standard technology due to its specificity, accuracy, and safety. There are usually no complications from this procedure. There is a small amount of radiation exposure, less that 1/10 the dose of a standard chest x-ray. Before conducting the DEXA scan, we will ask you to remove all metallic objects you have on your body and to lie motionless on the scanning bed of the machine. When in proper position, we will secure your legs with Velcro straps around the ankles to make sure they don't move during the assessment. You will be scanned from head to toe for a duration of 5 to 15 minutes.

All suspension training and traditional exercises will be evaluated at the Human Performance Lab at AUM. For each of the exercises, non-invasive BIOPAC surface electrodes will be placed on your abdominals, chest, shoulders, and arms to measure muscle activation. The sites that the electrodes will be placed will be properly prepared with small exfoliator pads and alcohol wipes to clean the surface of your skin. Your maximal voluntary contractions (MVC) will also be collected to allow normalizations of the EMG data. To obtain the MVC for the abdominal muscle, you will lay face-up with your knees bent at 90 degrees. Your arms will be placed across your chest. Next, you will attempt to perform a sit-up while the investigator provides a matched resistance to prevent motion. To obtain the MVC for your external obliques, you will be asked to lie on your left side while your knees are bent and arms placed across your chest. During this time, one investigator will hold your thighs in place to ensure your lower body doesn't move. From this point, you will rotate your upper body to the right until your chest and front shoulders face up. Next, you will be asked to rotate your upper body back toward the left side while the researcher provides a matched resistance. To obtain MVC of your hip flexor, you will lay down on your back, face-up with your legs fully extended and arms to the sides of your body. You will lift your right leg and bend your knee at a 90 degree angle with your foot held in the air. You will then attempt to bring your knee up and toward the stomach by flexing the [right] hip, while the researcher provides a matched resistance on your thigh.

After completion of the MVCs, you will be instructed on how to properly perform the exercises that will be evaluated. The nine exercises that you will be performing on the suspension device are as follows: plank, inverted row, pushup, side plank, prone V-up, knee tuck, rolling-like-a-ball, roll over, and teaser. Each exercise will be performed for approximately 6-10 repetitions. You will be allowed a one minute break between each exercise. The first exercise, suspension plank, is accomplished by adjusting the suspension training handles so that they are at the level of your mid-calf. Next, you will assume an all-four "quadruped" position directly in front of the suspension handles facing away from the attachment point. You will then proceed to place each foot into the suspension training foot cradle, located on each handle, and then assume a plank position (arms and legs fully extended; arms placed directly below your shoulders; ankles, knees, hips, shoulders and ears in a horizontal line). You will maintain this position for a minimum of 10 seconds. The second exercise, inverted row, will begin by adjusting the handles to your mid-torso level while standing. You will grasp the handles while facing towards the training device. Next, you will lean back with investigator support, until your arms are fully extended, while you hold the handles. Your feet will remain directly under the suspension attachment point. From this point, you will extend the shoulders and flex the elbows bringing your body up. You will stop when the handles have reached your chest. You will then slowly lower your body by fully extending your arms until reaching the starting position and then repeat. The third exercise, suspension push-up, is done by first adjusting the suspension training straps until they are at the level of your mid-calf. You will then assume a quadruped position facing the handles and floor. You will grasp each handle and assume a plank position by lifting your knees off the ground. The push-up will begin by you lowering your body towards the ground by flexing your arms and extending your shoulders and stopping when the suspension handles have reached the sides of your chest. You will then proceed to complete the repetition by pushing your body back up to starting position by fully extending your arms.

To complete the fourth exercise, side plank, the suspension training handles should be adjusted to the level of your mid-calf, after which you will sit on the ground placing each foot in the foot cradles, located on each suspension handle. You will then assume a side plank position (elbow on the ground, directly below your shoulder, and perpendicular to your body; entire body facing forward; shoulders and hips kept rigid and aligned with the anchor point; feet in a tandem position facing forward) and hold each repetition for no longer than 10 seconds. To perform the next exercise, suspended knee tuck, the handles should be placed at mid-calf level and you will assume the same starting position as that in the plank exercise. From the starting position, you will begin by flexing your hips and knees with control to 'tuck' your legs under your upper torso. You will then continue to 'tuck' your lower body until your knees reach your elbows and then extend your hips and knees to return to starting position. The next exercise, prone V-up, is also performed from the same starting position as the plank exercise. You will begin by bringing your hips overhead, by flexing your hips and keeping your knees extended, in order to create a pike, or inverted "V", position. In order to complete the repetition, you will then slowly lower your body by extending your hips to the original plank position and then repeating.

The Teaser is performed by laying supine and then simultaneously flexing the trunk and lifting the lower body away from the exercise mat to form a V-shape. Rolling Like a Ball begins by sitting on the exercise mat with the knees pulled into the chest, arms wrapped around the shins, and head tilted downward so that the body forms the shape of a ball. The exerciser then rolls backward along the spine and upward to the start position mimicking the rolling action of a ball. The Roll-Over is performed by lying on the back and lifting the lower body away from the exercise mat until the legs reach over the trunk and head. The lower body then begins to return to the start position but once the legs reach a 45-degree angle to the mat, the upper body is flexed away from the floor to form a V-shape.

The two traditional, non-suspension exercises will be the abdominal crunch and bicycle exercise. To perform the abdominal crunch, you will assume a standard sit-up position (lying on your back with knees bent to 90 degrees) with your arms crossed over your chest, and begin by flexing your trunk until your upper back is off of the mat while keeping your lower back in contact with the mat. You will then return to starting position. To begin the bicycle crunch you will once again assume the standard sit-up position, but with your hands behind your head. You will then rotate your right side toward the left, while simultaneously bringing your left knee towards your chest and then returning to starting position. You will then repeat the process on your opposite side. The traditional exercises will both be performed for approximately 6-10 repetitions.

Every effort will be made to minimize risks through preliminary screenings and observations during the test. Some discomforts and inconveniences are possible. Musculoskeletal injury (strain or sprains) could occur. There is a possibility of nausea, dizziness, fainting, and/or fatigue as a result of exercise. Should injury occur as a result of the experimental protocol it would be your responsibility to seek medical attention. Muscle soreness in the lower body could also occur 24 to 48 hours after the test.

Personnel in charge will attempt to minimize all risks. For instance, the exercises will be terminated if you experience any of the following: chest pain, fatigue, shortness of breath, wheezing, leg cramps, claudication, dizziness, syncope, cyanosis or pallor. You will be screened to determine if you have any health problems that would prevent you from performing these exercises. All personnel have been trained in CPR. Emergency procedures are posted in the Human Performance Laboratory. You are free to withdraw from the study at any time.

You will become familiar with suspension training and common exercises performed on the device. You will also obtain information regarding your core musculature and upper body activation during selected exercises when performed on a suspension training device. This information will be useful in establishing an exercise program in the future that contains suspension training.

Any information obtained in connection with this study that can be identified with you will remain confidential and will be disclosed only with your permission. If you give me your permission by signing this document, I plan to disclose your information to Dr. Michael R. Esco, Dr. Michelle Olson, and Mr. Brett Nickerson only for the purpose of assisting with statistical analysis. Only group data will be analyzed and used. No individuals will be identified in any final reports.

Your decision whether to participate will not prejudice your future relations with Auburn University Montgomery. If you decide to participate, you are free to withdraw your consent and to discontinue participation at any time without penalty. If you decide later to withdraw from the study, you may also withdraw any information that has been collected about you.

If you have questions concerning this study please feel free to ask Ronald Snarr directly or via phone at (334) 244-3472. If you have questions concerning your rights as a human subject please call Debra Tomblin at (334) 244-3250.

YOU ARE MAKING A DECISION WHETHER TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TOPARTICIPATE, HAVING READ THE INFORMATION PROVIDED ABOVE.

________________________ ______________________

Subject's Signature Date

________________________ ______________________

Investigator's Signature Date