EFFECT OF FOOT POSITION ON ISOMETRIC BENCH PRESS PERFORMANCE

A Thesis
by
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Abstract

EFFECT OF FOOT POSITION ON ISOMETRIC BENCH PRESS PERFORMANCE

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The bench press is a multi-joint exercise commonly used to improve upper body strength. Previous investigations have analyzed kinetic and kinematic variables during different bench press variations. However, no known studies have examined the effect of foot position on force output and muscle activity. The purpose of this investigation was to examine the effects of 3 different foot placements on isometric bench press force and muscle activity. Twenty-one recreationally trained males (age: 22.57 ± 1.36 years; height: 176.95 ± 6.80 cm; body mass: 85.15 ± 12.54 kg) participated in this investigation. Self-reported one-repetition maximum (1RM) of at least body mass was used as inclusion criteria (self-reported absolute 1RM: 119.37 ± 26.44 kg; relative 1RM: 1.40 ± 0.22). Subjects performed the isometric bench press with a normal foot placement with both feet down on the ground (FD), both feet up on the edge of the bench (FU), and both feet resting on an adjacent bench parallel to the ground (FO) in a randomized order. After 2 familiarization trials with FD placement, subjects performed 3 maximum voluntary isometric contractions for approximately 3 s each. Peak force (PF) and average integrated electromyography (avgIEMG) values were recorded for the pectoralis major (PM), anterior deltoid (AD), triceps brachii (TB), vastus lateralis (VL), biceps femoris (BF), and gastrocnemius (G) muscles. PF output for FD, FU, and FO was 1134 ± 295 N, 1182 ± 247 N, and 1161 ± 249 N, respectively. The avgIEMG for the PM with the feet down, up, and out was 1.25 ± 0.50 mV, 1.19 ± 0.46 mV, and 1.20 ± 0.47 mV respectively. The avgIEMG for AD for feet down, up, and out was 3.20 ± 1.18 mV, 3.18 ± 1.23 mV, and 3.12 ± 1.18 mV, respectively. The avgIEMG for TB for feet down, up, and out was 2.26 ± 0.97 mV, 2.17 ± 0.93 mV, and 2.18 ± 0.89 mV, respectively. The avgIEMG for VL for feet up, down, and out was 0.26 ± 0.30 mV, 0.11 ± 0.01 mV, and 0.24 ± 0.25 mV, respectively. The avgIEMG for BF for feet down, up, and out was 0.21 ± 0.22 mV, 0.12 ± 0.05 mV, and 0.16 ± 0.10 mV, respectively. The avgIEMG for G for feet down, up, and out was 0.25 ± 0.14 mV, 0.23 ± 0.11 mV, and 0.20 ± 0.06 mV, respectively. A repeated measures general linear model returned no significant differences between conditions for force or muscle activity. Additionally, a Pearson correlation coefficient of 0.54 (sig. = 0.01) indicates a strong relationship between self-reported 1RM and isometric bench press in the foot down position. Different foot positions do not have a significant effect on peak force or muscle activity of upper and lower body muscles during the isometric bench press. In this investigation, the bar was attached to a rack which did not permit lateral, anterior, or posterior motion of the bar. In a free weight bench press where these types of motion are possible, the results may be different. Although force output and muscle activity were not different between isometric conditions, stability may be increased with both feet on the ground during a dynamic movement.

Keywords: bench press, force output, electromyography

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Table of Contents

List of Figures

Introduction

The bench press (or chest press) is often performed with some degree of instability with the intent to increase muscle activity of the prime movers or trunk musculature. Literature has compared electromyography (EMG) and kinetic measures such as peak force (PF), power, and one-repetition maximum (1RM) between variations of the bench press (Cotterman, Darby, & Skelly, 2005; Goodman, Pearce, Nicholes, Gatt, & Fairweather, 2008; Koshida, Urabe, Miyashita, Iwai, & Kagimori, 2008; Marshall & Murphy, 2006; McCaw & Friday, 1994; Norwood, Anderson, Gaetz, & Twist, 2007; Saeterbakken & Fimland, 2013; Saeterbakken, Van Den Tillaar, & Fimland, 2011; Santana, Vera-Garcia, & McGill, 2007; Schick et al., 2010; Snarr & Esco, 2013; Uribe et al., 2010; Zemková et al., 2014). Previous investigations comparing the standard bench press to a Smith machine bench press have revealed increasing EMG activity of the antagonist muscle group, as well as trunk musculature, suggesting that additional muscles are recruited to increase stability (Saeterbakken et al., 2011). The chest press is also sometimes performed with the person's back on a Swiss ball. However, research indicates that there is a significant decrease in PF output when performing the isometric chest press on a Swiss ball compared to a stable condition (Anderson & Behm, 2004). Therefore, it is unlikely that sufficient loading (≥80% 1RM) can occur to induce strength gains (Earle, 2008). It appears that a certain degree of instability can enhance force output via increased musculature (barbell vs. dumbbell bench press), although too much instability (Swiss ball) drastically decreases force output. The bench press is also occasionally performed with the feet in the air or on the end of the bench, creating a smaller area of support. The National Strength and Conditioning Associations's (NSCA) Essentials of Strength Training and Conditioning suggests establishing and maintaining a five-point contact system helps to improve spinal stability and safety (Earle, 2008). However, other sources suggest placing one's feet on the edge of the bench if a lifter's feet do not lay flat on the ground or to reduce compressive forces on the lumbar spine (Algra, 1982; Alvar, 2013). To date, there is no record of known studies that have investigated the effect of foot placement on isometric bench press force output and EMG activity. The purpose of this study was to determine the effect of different foot placements during the isometric bench press on peak force output and muscle activity of upper-body prime movers and lower-body stabilizing musculature. It was hypothesized that PF and EMG would be significantly higher in the foot down condition, indicating that the feet play a role in body stabilization and thus force production in the bench press.

Force production and 1RM values during bench press variations have been investigated by several studies (Anderson & Behm, 2004; Cotterman et al., 2005; Koshida et al., 2008; Saeterbakken & Fimland, 2013; Saeterbakken et al., 2011; Santana et al., 2007; Stock, Beck, Defreitas, & Dillon, 2010; Zemková et al., 2014). Anderson and Behm (2004) reported a 59.6% decrease in force output of isometric bench press when performed on a Swiss ball. Koshida et al. (2008) found similar results that indicated peak force, velocity, and power significantly decreased when performing a dynamic barbell bench press on a Swiss ball with 50% 1RM. Although 50% 1RM is not sufficient to improve strength, research has suggested highest muscular power occurs at 40% to 50% of 1RM in the bench press (Mayhew, Ware, Johns, & Bemben, 1997). Research has also indicated that peak power was significantly higher during the concentric phase on a stable bench at higher loads (60 kg to 90 kg), although there was no difference in peak power at lighter loads (20 kg to 60 kg) (Zemková et al., 2014). Another study has revealed that the Smith machine bench press 1RM and dumbbell bench press are 3% and 17% less, respectively, than the barbell bench press (Saeterbakken et al., 2011). These findings suggest that increased muscle recruitment may account for controlling the path of free weights versus the Smith machine. However, using dumbbells requires more stabilization via co-contraction of the upper-arm and thus force output needed to stabilize the shoulder joint instead of producing force in the desired direction. Further research supports this notion, indicating that subjects' 6RM strength when performing the movement with their back on a balance cushion placed on a stable bench was 93% of the stable condition 6RM (Saeterbakken & Fimland, 2013). However, 6RM strength was even lower (92%) when performing the movement with the shoulders on a Swiss ball. This further supports the notion that optimal loading occurs when increased muscle recruitment is used to produce force for the intended motion with minimized instability. No known studies have measured the effect of different lower body positions on isometric force output.

In addition to kinetic variables, much of the previous research has examined EMG activity with varying stability requirements of upper body presses (Goodman et al., 2008; Marshall & Murphy, 2006; McCaw & Friday, 1994; Norwood et al., 2007; Saeterbakken & Fimland, 2013; Saeterbakken et al., 2011; Santana et al., 2007; Schick et al., 2010; Snarr &

Esco, 2013; Stock et al., 2010; Uribe et al., 2010). Although EMG is typically increased with instability, reduced force output suggests this higher activity is due to joint stabilization. Snarr and Esco (2013) reported significantly higher EMG values for the agonist muscle group (pectoralis major, triceps brachii, and anterior deltoid) while performing push-ups on a TRX® Suspension Trainer® versus a standard push-up. However, this study failed to measure force output, and therefore, has no practical application in terms of training effects. Recent research by Calatayud et al. (2014) found conflicting data indicating greater muscle activity in the pectoralis major and the anterior deltoid, two of the three prime movers, during the stable condition (standard push-up). In addition, the triceps brachii, upper trapezius, rectus femoris, and erector lumbar spinae EMG activity was greater in each of four different suspension system push-ups when compared to the stable condition (Calatayud et al., 2014). These findings suggest increased musculature is recruited to help stabilize torso and shoulder joints during an unstable condition. However, less contact points or a smaller area of support (feet in the air or on bench) may deny lower body musculature the ability to stabilize the body, creating a less stable version of the bench press. Thus, net force output would decrease since antagonist co-contraction is necessary to stabilize the joints (Anderson & Behm, 2004). Perhaps the activation of lower body musculature can allow for greater stability and more force to be produced in the intended direction (the upward phase of the bench press). An investigation by Marshall and Murphy (2006) indicated greater muscle activity of the rectus abdominis (RA), transverse abdominis/internal (TA/IO), and anterior deltoid when performing a dumbbell chest press on a Swiss ball. Also of note, the rating of perceived exertion was significantly greater on the Swiss ball for the same absolute load. Norwood et al. (2007) investigated muscle activity of six muscles during four conditions of varying instability: stable (standard barbell bench press), lower-body instability (shoulders on stable bench, feet on BOSU ball), upper-body instability (shoulders on Swiss ball, feet on stable surface), and dual instability (shoulders on Swiss ball, feet on BOSU ball). The EMG activity suggests increasing muscle activity with increasing instability of both upper and lower body. Saeterbakken and Fimland (2013) reported greater EMG activity of pectoralis major and triceps brachii on a stable surface compared to a Swiss ball. However, this was one of few studies using the same relative load as opposed to the same absolute load. Conflicting research suggests that increasing instability of a press movement will recruit more muscle (according to EMG) but produce less force output or 1RM, perhaps due to muscle activity stabilizing the shoulder instead of producing the desired movement.

Although findings comparing kinetic values are fairly consistent among the literature, much of the research to date has found conflicting data regarding muscle activation during the bench press with varying degrees of instability. In addition, scarce research has investigated the activity of lower body musculature and its effect on force output, as well as muscle activity of the prime movers. The bench press exercise is performed with the feet on a bench (reducing the area of support) may require more stabilization than with the feet placed on the floor, therefore requiring more force to stabilize joints and less net force.

Thus, the purpose of this investigation was to determine kinetic and EMG activity differences between isometric bench press performed with both feet on the ground, both feet on the edge of the bench, and both feet resting on an adjacent bench, keeping the whole body parallel to the ground.

Methods

Participants

College-aged male subjects were familiar (perform at least once per week) and proficient (1RM ≥ bodyweight) in the barbell bench press (age: 22.57 ± 1.36 years; height: 176.95 ± 6.80 cm; body mass: 85.15 ± 12.54 kg; self-reported bench press 1RM: 119.37 ± 26.44 kg). The subjects did not have any existing medical conditions or contraindications that would exclude them from the study. The subjects were notified of the risks involved and signed informed consent before beginning testing. This study was approved by the Institutional Review Board (IRB) at Appalachian State University.

Study Design

The subjects completed a single testing session. During the test session, each subject performed the isometric bench press with both feet flat (right foot directly on a force plate), legs bent with feet placed on the edge of the bench (near buttocks), and legs supported horizontally, parallel to the ground. Subjects were allowed two warm-up trials at 50% and 75% of perceived maximal effort with the foot down placement before collecting data for each condition. The subjects performed the three conditions in a randomized order. All three trials were completed for each condition before switching to the next foot placement.

EMG was recorded from the pectoralis major (PM), anterior deltoid (AD), triceps brachii (TB), vastus medialis (VM), biceps femoris (BF), and gastrocnemius (G) on the right side of the body. Subjects then completed three trials of 3 s of maximal isometric contraction for each condition. Verbal encouragement was given during all trials. Sufficient rest was allowed (1-3 min) between trials of same condition (Weir, Wagner, & Housh, 1994). Sufficient rest was also allowed (1-3 min) between each condition.

Isometric Bench Press.

The isometric bench press was performed with the subject lying supine on a bench placed on a force plate (AMTI, BP6001200, Watertown, Massachusetts, USA) and performing a maximal voluntary isometric contraction (MVIC) for approximately three seconds. An isometric contraction was chosen to increase the fidelity of the muscle activity measurements. The normal foot placement condition was performed while lying supine on a bench with feet placed flat in location of subject's choice. The feet up condition was performed while lying supine on a bench with heels of feet placed on the edge of the bench, near the buttocks. The feet out condition was performed with the subject's feet straight out and placed on an adjacent bench, so that the subject's whole body was parallel to the ground. The grip width was determined by placing forearms perpendicular to ground with elbows bent to 90°. Head placement, grip width, and foot placements were marked for each subject to keep body position consistent.

A vertical force-time curve was recorded using a shielded BNC adapter chassis (BNC-2090; National Instruments, Austin, TX) and an analog-to-digital card (National

Instruments, NI PCI-6014; Austin, Texas, USA) at 1000 Hz. LabVIEW (version 7.1; National Instruments) was used for recording and analyzing the data. Peak force of the 3 s contraction was calculated.

Electromyography.

The EMG activity of the PM, AD, TB, VM, BF, and G muscles was measured at 1,000 Hz using a telemetry transmitter (8-channel, 12-bit analog-to-digital converter; Noraxon USA Inc., Scottsdale, AZ). Skin was shaved, abraded, then wiped with an alcohol swab to enhance adhesiveness of electrodes and clarity of signal. A surface electrode (Delsys Trigno Wireless System, Natlick, Massachusetts, USA) was placed on the skin of the muscle belly of each muscle parallel to the direction of the muscle fibers. The amplified signal recorded during each of the trials was detected by the receiver-amplifier (Telemyo 900, gain = 2,000, differential input impedence = 10 MΩ, bandwidth frequency 10-500 Hz, common mode rejection ratio = 85 dB; Noraxon USA) and then sent to an A/D card (KPCMCIA-12AI-C; Keithley, Cleveland, OH) and analyzed using MyoResearch software (version 4.0; Noraxon USA). The signal was full-wave rectified and filtered (six pole Butterworth, notch filter 60 Hz, band pass filter 10-200 Hz). The integrated value (μ V·s) was calculated and averaged over the 3 s isometric contraction.

Statistical Analysis.

A repeated measures general linear model was used to determine within-group differences for peak force and muscle activity. A Pearson correlation was also used to determine the relationship between self-reported 1RM values and PF of each condition. The statistical analysis was performed using SPSS version 12.0 (SPSS Inc., Chicago, IL).

Results

There were no significant differences in PF or avgIEMG between the three foot placement conditions. PF and avgIEMG values are shown in Figures 1 and 2. PF output for FD, FU, and FO was 1134 ± 295 N, 1183 ± 247 N, and 1162 ± 249 N, respectively. The avgIEMG for PM for feet down, up, and out was 1.25 ± 0.50 mV, 1.19 ± 0.46 mV, and 1.20 ± 0.47 mV, respectively. The avgIEMG for AD for feet down, up, and out was 3.20 ± 1.18 mV, 3.18 ± 1.23 mV, and 3.12 ± 1.18 mV, respectively. The avgIEMG for TB for feet down, up, and out was 2.26 ± 0.97 mV, 2.17 ± 0.93 mV, and 2.18 ± 0.89 mV, respectively. The avgIEMG for VL for feet down, up, and out was 0.26 ± 0.30 mV, 0.11 ± 0.01 mV, and 0.23 ± 0.25 mV, respectively. The avgIEMG for BF for feet down, up, and out was 0.21 ± 0.22 mV, 0.12 ± 0.05 mV, and 0.16 ± 0.10 mV, respectively. The avgIEMG for G for feet down, up, and out was 0.25 ± 0.14 mV, 0.23 ± 0.11 mV, and 0.20 ± 0.06 mV, respectively. Pearson correlation coefficient of $r = 0.54$ (sig. = 0.01) was found between self-reported 1RM and PF in the FD condition.

Discussion

The primary finding from this investigation is that there are no significant differences in PF or EMG activity between the three different foot positions. Additionally, the isometric bench press is a valid indicator of dynamic bench press performance. The PF values found in the present study were similar to those found in a previous isometric bench press investigation (Kilduff et al., 2002). Although PF and EMG did not differ between foot positions in the isometric bench press in the current study, the dynamic bench press may require more stabilization which could affect PF and EMG activity, as well as bar path. Other factors such as coaching or motivation may also have a role in PF and EMG activity.

Differences in force and power output and 1RM have been observed with different variations of the bench press. Barbell bench press 1RM was higher than Smith machine 1RM in a previous investigation by Cotterman et al. (2005) with $n = 32$, suggesting that increased muscluture recruited for the less stable condition (barbell) enhanced 1RM. However, the bench press bar path does not follow a vertically linear path like most Smith machines and therefore warrants hesitation when comparing the two (McLaughlin & Madsen, 1984). In the present study, there were no differences in force output between the stable and less stable conditions. In a different study, barbell load was 3% and 17% greater than Smith machine and dumbbell bench, respectively (Saeterbakken et al., 2011). Though the Smith machine follows a fixed path, dumbbell 1RM was lower than the barbell 1RM which supports the idea that less stable versions of the bench press result in loss of strength and power. Still, the current study does not support this result in the isometric bench press. Force, power, and velocity were significantly lower during a Swiss ball bench when compared to the standard bench press as well as mean power during the concentric phase of the Swiss ball bench press and squat performed on BOSU ball (Zemková et al., 2014). Research has also indicated a significantly higher 6RM load in a standard bench press compared to a dynamic movement on a Swiss ball or balance cushion placed on bench

(Saeterbakken & Fimland, 2013). Since force and power outputs are greater in stable conditions, whole-body stabilization and equilibrium may present the major limitation in force generation in less stable conditions (Santana et al., 2007). Although the results from the current study suggest foot position does not contribute directly to force production, the lower body may provide a greater stabilizing role in a dynamic movement. In addition, the lumbar and thoracic spinal positions are altered as the spine is extended in the foot down position, resulting in a decreased distance the bar must travel in a dynamic movement. Although this arched position may not reflect increased force output, it reduces the amount of work needed to complete a repetition. Therefore, differences in PF may not be noticable in the isometric bench press when the bar is not traveling vertically.

Norwood et al. (2007) reported greater EMG activity of stabilizing musculature during four different bench press varitaions: standard bench press, single instability of the lower body (shoulders on stable bench, feet on BOSU ball), single instability of the upper body (shoulders on circular balance cushion placed on bench, feet on ground), and dual instability (shoulders on balance cushion placed on bench, feet on BOSU ball). Linear effects suggest that root mean square (RMS) values for muscle activity of latissimus dorsi (LD), internal oblique (IO), erector spinae (ES), BI, and soleus (S) increased with increasing instability. However, the absolute load was fairly light and held constant between conditions (9.1 kg) although it has been shown that rating of perceived exertion is significantly higher when performing the bench press on an unstable surface (Marshall & Murphy, 2006; Norwood et al., 2007). Though these findings indicate increased musculature is recruited as stability decreases at the same absolute load, it remains unclear whether relative loading would produce similar results provided that a greater absolute load can be achieved in a stable condition. Work by Norwood et al. (2007) does confirm the role of lower body muscles providing stability in the bench press. Previous research has indicated EMG activity is significantly greater at 90% 1RM compared to 70% 1RM during the Smith machine and barbell bench press (Schick et al., 2010). Therefore, it is important to note that EMG activity should not be compared using the same absolute load between stable and unstable conditions. A 1RM or MVIC should be found in both stable and unstable conditions before comparing EMG using relative loads. Higher EMG activity may be obtained using the same absolute load on a less stable surface. However, this increased muscule activity does not contribute to force production in the desired direction and thus strength, power, or hypertrophy gain.

Other factors may also play a role in general bench press performance. Verbal instruction has been shown to selectivly increase muscle activity of prime movers in trained athletes (Snyder & Fry, 2012). In addition, simply “psyching-up” may increase force production in trained athletes (Tod, Iredale, McGuigan, Strange, & Gill, 2005). Although all the subjects used in the current study were proficient at the bench press, more experienced subjects may have a better mental approach to maximal contractions. Additionally, the height or leg length of the subjects may have affected the comfort of the feet up position. Taller subjects may have had a difficult time fitting their heels on the bench since the bench and bar were in a fixed position.

Although PF and EMG activity were not significantly different in the current study, the less stable dynamic bench press may elicit significant differences in PF or muscle activity. Previous research has indicated that force output or 1RM decreases with increasing stability. Additionally, EMG activity may be increased under unstable conditions. However, the loss in force production may negate the enhanced muscle activity used to stabilize the joints during less stable conditions. In addition, although the lower body does not directly contribute to force production in the present study, it may play a role in creating stabilization in a dynamic movement.

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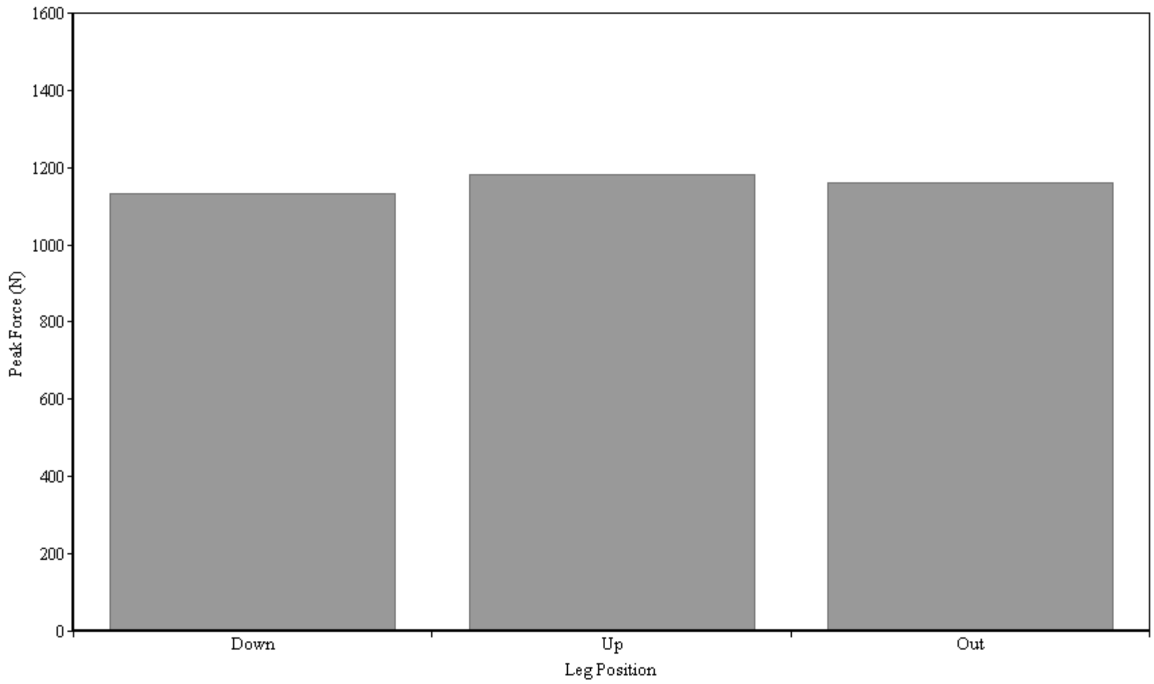

Figure 1. This figure shows the average peak force of all subjects with each foot position. There were no significant differences found between the three foot positions.

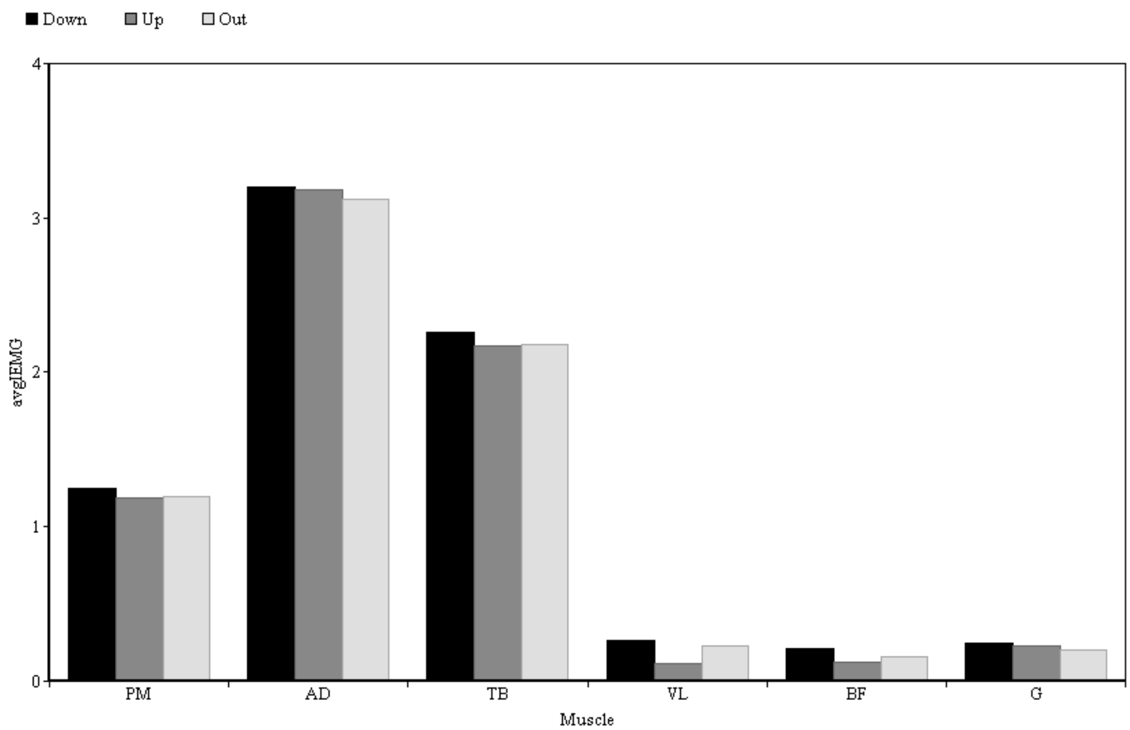

Figure 2. This figure shows the average EMG value of all subjects for each muscle from each foot position. There were no significant differences found between the three conditions for any of the muscles measured.

Vita

Andrew Warren Pichardo was born in Fort Worth, Texas. After graduating from Brewer High School, he attended Midwestern State University and graduated with a Bachelor of Science in Exercise Physiology. After graduating, he went on to pursue his Master of Science in Exercise Science from Appalachian State University. At Appalachian State University, he took a teaching assistantship under Dr. Jeffrey McBride. Andrew graduated with his Masters of Science in May 2015. Andrew's parents are Alexis and Peggy Pichardo who reside in Orlando, Florida.