A COMPARISON OF THE PLANK AND PERFECT PLANK USING ELECTROMYOGRAPHY

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ABSTRACT

**Purpose:** The purpose of this study is to determine whether there is a difference in muscle activation and blood lactate and force production analysis among the two plank variations, the prone plank and the plank done in the perfect plank machine. It was hypothesized that (1) post exercise blood lactate will be higher after the perfect plank exercise due to greater instability if the exercise, (2) EMG will show greater activity qualitatively and quantitatively in the abdominal muscles and less in the lower back on the perfect plank machine when compared to the prone plank due to the upright posture, and (3) EMG activation will be greater in females for both plank exercises. Decreased muscular strength in females will require more oxygen to the abdominal muscles which equates to the muscles working harder. **Methods:** Subjects included 15 males and 15 females. All subjects completed 2 variations of the plank exercise for 15 seconds on separate days; the prone plank and perfect plank. In order to analyze the two exercises, wireless electromyography sensors were placed on the anterior deltoids, external obliques, rectus abdominis, and erector spinae on the left and right sides of the body. Pre and post blood lactate concentration was also extracted to monitor anaerobic work. Repeated measures was used to analyze the prone plank and perfect plank to determine if one plank was more effective than the other. **Results:** The left and right rectus abdominis (0.07955 ± 0.089843, 0.12595 ± 0.182388) showed trends of more stimulation on average from
the perfect plank as compared to the prone plank (.04575 ± .029244, .06513 ± .100986). The left and right erector spinae also saw trends of more activation from the perfect plank (.09343 ± .188366, .10750 ± .180212) when compared to the prone plank (.03606 ± .092540, .06124 ± .146232). The left and right obliques saw similar stimulation in the perfect plank (.05012 ± .069828, .05073 ± .045048) when compared to the prone plank (.04686 ± .027402, .05543 ± .029668). The left and right deltoid saw a trend of increased activation in the prone plank (.10924 ± .082333, .08911 ± .050784) when compared to the perfect plank (.06294 ± .102281, .05478 ± .085322). The results from the blood lactate proved to be significant between the two exercises (p=.024) with perfect plank seeing a greater increase when compared to the prone plank. **Conclusion:** Based on the results, the rectus abdominis and erector spinae trended toward being stimulated more, on average, with the use of the perfect plank. The obliques showed no trends in muscle activity. Both exercises were equally as effective in oblique stimulation. The deltoids were activated more in the shoulders in the prone plank. Changes in lactate point towards the perfect plank being a more difficult, anaerobic exercise.
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CHAPTER 1

INTRODUCTION

The prone plank is a popular exercise for stimulating the core muscles and has been advocated for both clinical and physical conditioning.\textsuperscript{11} Benefits of the prone plank include improved core stability, or the ability to lumbopelvic region to maintain appropriate trunk hip posture, balance and control.\textsuperscript{4} One of the main problems with the traditional prone plank is compromising the low back when we become fatigued. The proposed perfect plank machine is designed to contract the core muscles but reduce the risk for lower back discomfort and reduce injury risk. There is no clear cut cause, but Low back pain is one of the most frequently occurring musculoskeletal disorders with a lifetime prevalence of 84%.\textsuperscript{7} Electromyography (EMG) is one way that we can monitor muscle stimulation throughout an exercise. Studies show that stimulation of the core and low back muscles occur during a plank exercise.\textsuperscript{7} More specifically, studies that have implemented different plank variations have stated that the activation of the core musculature is greater in the variations when compared to a prone plank exercise.\textsuperscript{11} Currently, there is no research on upright planking devices looking at muscle activation of the core and lower back. With this study, we want to gather data from a new plank
variation to see if there are similarities or differences when compared to the planking strategies done in previous research.

**Purpose of the study**

The purpose of this study is to determine whether there is a difference in EMG and blood lactate and force production analysis among the two plank variations, the prone plank and the plank done in the perfect plank machine.

**Hypotheses**

- It is hypothesized that post exercise blood lactate will be higher after the perfect plank exercise due to greater instability if the exercise
- It is hypothesized that the EMG will show greater activity qualitatively and quantitatively in the abdominal muscles and less in the lower back on the perfect plank machine when compared to the prone plank due to the upright posture
- The differences between male and females will show greater EMG activation in females for both plank exercises.

**Impact**

The data in this study has the potential to show that plank variations, more specifically an upright plank method, has the ability to stimulate the targeted muscles that we would expect in the prone plank. The results could confirm that another plank variation is more effective in stimulating the core muscles.
CHAPTER II

LITERATURE REVIEW

Previous studies have shown that the plank exercise is effective in stimulating the core muscles. Moreover, variations of the plank exercise have been proven to be more effective and stimulate more muscle when compared to a prone plank. The methodology of adding plank variations and comparing them to the prone plank are in line with this research and show the benefits of each of the variations have.

Plank and Electromyography

Schoenfeld et al.\textsuperscript{16} examined the core muscle activation of the prone plank with modified versions that added posterior tilt and a long lever together and separately. Electromyography was used to measure each plank variation among the 19 participants. The four plank variations were the traditional prone plank, Plank with posterior tilt, plank with a long lever where the angle of elbows in relation to the body is greater than 90 degrees, and a plank with posterior tilt and a long lever. The protocol measured each planking position for 30 seconds with a 5 minute rest interval between the 4 variations. Muscles measured during the testing were the upper rectus abdominis (URO), lower abdominal stabilizers (LAS), external oblique (EO), and erector spinae (ES). The results
showed that, compared to the traditional plank, the long-lever posterior-tilt plank displayed a significantly increased activation in the URO, LAS, and EO.\textsuperscript{16} The long-lever plank also showed some increase in activation when compared to the traditional plank in the URO and LAS. The posterior tilt plank only saw minor increases in activity of the EO when compared to the prone plank. The results trend towards the long-lever component contributing more to the observed differences in muscle activation. The positioning of the arms lends towards the core musculature activating more muscle when compared to the other variations.\textsuperscript{16}

Lee, Kang, and Shin\textsuperscript{11} studied the possibility of developing a spine stability assessment method using surface EMG of the low back and abdominal muscles in activities including the traditional plank.\textsuperscript{11} “Low back pain is one of the most frequent musculoskeletal disorder with a lifetime prevalence of 84%.”\textsuperscript{11} There is no clear cause but this study looked at the muscle activation of the Plank through EMG. Prior to completing the protocol, 20 asymptomatic participants (10 male and 10 female) completed the walking, planking and isometric back extensions before and after holding a 10 minute static upper body deep flexion.\textsuperscript{11} The measurement sites were the Erector Spinae (ES), External oblique (EO), and Rectus Abdominis (RA). Results showed that that amplitude of the antagonist ES muscles during the plank decreased significantly after the 10 minute period of deep flexion.\textsuperscript{11} This result shows that deep flexion prior to the plank exercise can reduce the activation of the lower back and potentially reduce the amount of lower back problems due to the plank exercise.

Snarr and Esco\textsuperscript{17} investigated the EMG activity of the Rectus Abdominis (RA), External Oblique (EO), and Erector Spinae (EA), while performing planks with and
without the assistance of instability devices. The study consisted of 12 individuals, 6 men 
(23.92 ± 3.64) and 6 women (22.57 ± 1.87 years). The average age of the male 
participants was 23.92 ± 3.64 and women was years. Each participant completed 2 
isometric contractions of 5 different plank variations where an instability device was used 
for some of the exercises. Mean peak, and normalized EMG of the RA, EO, and ES 
were compared amongst each of the 5 exercises. The 5 exercises used were the regular 
plank, plank with elbows on a swiss ball, plank with feet on a swiss ball, plank with 
elbows in a TRX, and a plank with the feet in a TRX. The TRX is a suspensions training 
system with a mounting attachment. Results showed that planks performed with 
instability devices increased EMG activity in the superficial musculature when compared 
to the traditional plank. This result shows that the use of an instability device may be 
beneficial when the intensity of the exercise needs to be increased but it is worth noting 
that if there is a history of weakness in the lumbar region, the instability devices do add 
increased activation of the ES during these exercises. Each of the instability plank 
variations saw an increase in muscle activation in the RA, EO, and ES.

Tong, Wu, & Nie tested the validity and reliability of a sports-specific 
endurance plank test for the evaluation of core muscle function. 36 athletes (28 male 
and 8 female) participated in the study. The group of athletes consisted of long distance 
runners, swimmers, and various team sports. During the test, surface EMG of the Rectus 
Abdominis (RA), external oblique (EO), and erector spinae (ES) on the right side of the 
body were collected. The testing procedures consisted of a pre-fatigue core workout 
prior to the completion of the plank exercise. Each participant completed 4 exercises in 
circuit fashion. The seated upper torso rotation with a 4 kg medicine ball, static prone
torso extension with a 4 kg medicine ball, supine lower rotations with a 4 kg medicine ball, sit-ups with a 10 lb dumbbell, lateral side bend with a 10 lb dumbbell and rotating lumbar extension with a 10 lb dumbbell. The sport specific plank test required 9 stages. The first stage was a plank hold for 60 seconds. Subsequent parameters were to lift the right arm off the ground for 15 seconds, return it to the ground and do the same with the left arm. Immediately following the lifting and lowering of each arm for 15 seconds the right and left legs were held static as well. The final 15 second interval consisted of lifting the opposite arm with the opposite leg and switching to do the same for the other arm and leg for 15 seconds as well. The subjects returned to the plank position for 30 seconds to complete the test. Due to the pre fatigue workout, subjects saw nearly a 50% increase activation during the plank test. The results show that the sport-specific endurance plank test is a valid and reliable method for assessing core muscular endurance in athletes.  

Kim et al studied the effects of additional isometric hip adduction during the plank exercise on abdominal muscles. 20 healthy young men participated in the study. Surface Electromyography (sEMG) was used to monitor the activity of the bilateral rectus abdominis (RA), internal oblique (IO) and the external oblique (EO). Each participant completed three types of plank exercises. They were the plank with bilateral isometric hip adduction, the plank with unilateral isometric hip adduction and the traditional plank exercise. A Thera-band was used to create the unilateral and bilateral adduction. Each subject had 3, 5 second intervals of lateral and bilateral isometric contractions during the trials. There was a 30 second rest period between trials and a 3 minute period between exercises. The results showed that the application of the bilateral
and unilateral adduction significantly increased the activation of the RA, IO, and EO muscles. The unilateral adduction increased stimulation even more than bilateral adduction. These findings suggest that additional isometric hip adduction during a plank could increase the overall muscle activation, and in particular, the unilateral adduction might be even more effective.

Kang et. al investigated the effect of isometric hip adduction and abduction on trunk muscle activity during plank exercises. Nineteen healthy male subjects were recruited for this study. All subjects performed the traditional prone plank exercise (TP), a plank with isometric hip adduction (PHAD) and a plank with isometric hip abduction (PHAB) by using an elastic band. There were 2 muscles targeted by electromyography and they were the internal obliques (IO) and external obliques (EO). Each plank exercise was performed for 5 seconds and was repeated 3 times. There was a one minute rest period in place between trials. Results showed significant differences among the different exercises. There was significantly greater IO muscle activity in the PHAB and PHAD plank variations when compared to the TP. There was also significantly greater muscle activity in the EO when the PHAB and PHAD were compared to the TP. There was no significant difference when the PHAB and PHAD were compared to one another in the EO and IO.

Roth, Donath, Zahner, and Faude evaluated male and female soccer players and the characteristics of trunk muscle activation and performance during strength-endurance related trunk field tests. Thirty-nine subjects were included in the test. There were 18 females and 21 males. The prone plank, side plank, and dorsal positions were all tested. In order to normalize all results of the field test, isometric force was measured in trunk
extension and flexion, rotation, and lateral flexion. The protocol for the exercises included an inclinometer which allows for standardization of movements and restricts movement to the exercise being measured. The prone plank was used and subjects lifted their feet alternately at a pace of once second per foot. For the side plank, the trochanter had to maintain contact with top bar of the inclinometer at a rate of 2 seconds on and 2 seconds down on the floor repeatedly. For the dorsal testing procedure, a modified Sorensen test was used. For this test, athletes were prone on an elevated vaulting box with the iliac crest on the border and the feet in a fixed position. The inclinometer was set at level positioning and 30 degrees of flexion capability. With the same frequency of 2 seconds up and 2 seconds down from the inclinometer, the athlete performed the test. To ensure the accuracy, all testing was performed with a metronome set to the cadence of each exercise. Termination criteria was limited to the athletes’ ability to maintain the pace of the metronome. Results showed that performance, as time to failure, did not differ between male and female players.\textsuperscript{15} In the prone plank position, muscle activation showed an increase over time. EMG of the Rectus Abdominis was significantly higher in females than males.\textsuperscript{15} There were also differences observed among males and females in the Rectus Abdominis and Erector Spinae.\textsuperscript{15}

Atkins et. al studied the neuromuscular activation of global core stabilizers when using suspension training techniques, compared with more traditional forms of isometric exercise.\textsuperscript{1} Eighteen elite, male youth swimmers participated in this study. Surface electromyography (sEMG) was used to determine the rate of muscle contraction in musculature associated with core strength and stability. The rectus abdominus (RA), external obliques (EO), erector spinae (ES). A maximal voluntary contraction test was
used to determine peak amplitude for all muscles. Static contraction of the core was achieved using a modified plank position, with a Swiss ball and without one. A plank variation was then held using suspension straps. Both of the plank variations were held for 30 seconds. Analysis of sEMG showed that suspension planking produced higher peak amplitude in the RA than using a prone or Swiss ball plank. There was no difference in either the EO or ES musculature between plank variations. The conclusion of the study shows that suspension training noticeably improves engagement of anterior core musculature when compared with both lateral and posterior muscles.¹

Learman, Pintar, & Ellis studied the effects of muscular endurance and resisted strengthening protocols on abdominal strength and endurance in a sample of young subjects. Seventy-nine subjects (45 males and 34 females) were included in the study. The test was a pre-posttest design where each individual participated in the 12 week program. The three groups in the test were the strength group, endurance group, and control group. Abdominal strength and endurance were evaluated using an isokinetic dynamometer (IKD) and four floor tests including the timed front plank (FP), angle sit (AS), sit-up (SU), and handheld dynamometer (HD).¹⁰ Among the three groups there was no significant difference between the exercises in the post test. There was, however, a positive trend of improvement in the amount of time that the strength, and endurance group could hold the plank position at the end of the 12 week trial.

Parkhouse and Ball¹⁴ studied the effects of a 6 week unstable static versus unstable dynamic core training program, on field based fitness tests. The study included 12 subjects (6 male: 21.2±3.3 years; 174.5±6.3 cm; 78.7±3.7 kg, 6 female: 20.6±1.7 years; 172.6±4.7 cm; 67.7±2.3 kg) who were split into two even groups and randomized
into the static or dynamic core training groups. The study took place over a 6 week period, and participants were tested once per week. The testing was a pretest-posttest design where the subjects performed two 45 min sessions per week for six weeks. Seven performance tests, consisting of three core exercises (plank; double leg lowering; back extensions), one static (standing stork), and 3 dynamic (overhead medicine ball throw, vertical jump, and 20 meter sprint). The standing stork was done with hands on the hips, and lifting 1 leg and placing the sole of the foot on the inner thigh of the other leg. Participants then raised the heel of the straight leg to stand on the toes and held the position for as long as possible. Each group had 6 separate exercises to complete within their designated group. The static core group completed the following exercises: Side plank, shoulder bridge, full plank, birddog, diagonal crunch, and reverse hyperextension. The birddog exercise involves a prone positioning where the individual is on hands and knees while alternating between raising the opposite arm with the opposite foot. The dynamic core group completed the following exercises: jack knife, russian twist, reverse hyperextension, lateral roll, hip crossover, reverse crunch. The jack knife exercise was completed by suspending the feet in the air and touching ones toes while maintaining the same positioning of the feet. At the end of the program, each individual was tested on the initial tests listed above. In relation to the plank exercise, after completing the program, the static and dynamic exercise group saw increases in overall time for which they could hold the prone plank. The dynamic group saw a 23.3% increase in plank time while the static group saw an 8.5% increase in time. Both of the increases were significant improvements among the two groups.
Sumiaki et al. completed a study that aimed to quantify muscular activity levels during abdominal bracing with respect to muscle- and exercise-related differences. Ten young men, considered to be healthy, participated in the study. The testing battery consisted of 5 static core exercises: abdominal bracing, abdominal hollowing, prone, side, and supine plank. Abdominal bracing was in a standing posture with the feet shoulder width apart. Participants were instructed to activate the abdominals with maximum force without hollowing the abdomen. Abdominal hollowing was in the same position and subjects were instructed to retract the navel with maximum force towards the spine. Five dynamic exercises were included and they were: V-sits, curlups, sit-ups, back extensions on the floor and on the bench. Surface EMG (sEMG) recorded muscle activation of the rectus abdominis (RA), external oblique (EO), internal oblique (IO), and erector spinae (ES). Percent EMGmax was used to normalize the values obtained during maximal voluntary contraction of each muscle. Results showed that the % EMGmax value during abdominal bracing was significantly higher in IO (60%) than in the other muscles (RA: 18%, EO: 27%, ES: 19%).

Cortell-Tormo et al evaluated the influence of scapular position on the core muscles during a prone plank. Research shows that pelvic tilt plays an important role on the electromyographical (EMG) activation of core musculature. 15 subjects participated in this study with 10 males and 5 females respectively. Surface electromyography of the rectus abdominis (RA), external oblique (EO), internal oblique (IO) and erector spinae (ES) was assessed in each subject. In order to assess the scapula in relation to the plank, four variations of the prone plank were evaluated: scapular abduction with anterior (ABANT) and posterior (ABRET) pelvic tilt; and scapular adduction with anterior
(ADANT) and posterior (ADRET) pelvic tilt. Individual muscle EMG and overall EMG for the four plank exercises were analyzed in each individual. Results showed that the ADRET resulted in higher overall EMG activity across all muscle groups when compared to the ABANT and ADANT. The testing also showed that ADRET resulted in greater EMG activity compared to ADANT, ABANT, and ABRET for EO, IO, and ES. For the RA, ADRET was significantly higher compared to ADANT and ABANT.

Swain and Redding studied differences in trunk muscle endurance in a sample of tertiary level dance students with and without low back pain. Low back pain (LBP) is a common condition in all levels of dance. The study consisted of 17 dance students. The students were divided into two groups. The first group (n=11) was the LBP group and the second group (n=6) was the non LBP group. The protocol had each subject perform the right and left side plank, two-legged leg raise and the Sorensen test which is a trunk extension examination. A significant difference between groups was observed for the right and left side plank and students with LBP displayed lower levels of endurance compared to those without the LBP. The results of this study shows that reduced trunk muscle endurance is present among dancers with LBP.

Byrne et. al examined the effects of suspension training on muscle activation during performance of variations of the plank exercise. Twenty-one individuals participated in the study. All individuals completed 2 repetitions each of 4 different plank exercises that consisted of a floor based prone plank, a planks with arms suspended, feet suspended, or feet and arms suspended using a TRX Suspension System. Muscle activation was recorded from rectus abdominis, external oblique, rectus femoris, and serratus anterior (SA) muscles using electromyography and each plank exercise was held
for a duration of 3 seconds.\textsuperscript{2} A significant effect of plank type was found for all muscles. It was found that all abdominal muscle activation was higher in all suspended plank exercise when compared to the prone plank. The highest level of abdominal muscle activation occurred when the hands and feet were suspended in the TRX during the plank. The results display that increasing the suspension of hands and feet increase the stimulation of the core musculature.

**Summary of Electromyography**

The use of plank variations to study changes in muscle activation shows that there are ways to implement instability devices, positioning, and variations of the plank exercise to elicit changes within the core musculature. The foundation of this study is to look at an upright plank variation that is not a variation found in previous research to see if there are differences between the standard plank and the perfect plank.

**Blood Lactate**

Navalta & Hrncir\textsuperscript{13} studied the lactate response from core stabilization exercises following a bout of high intensity anaerobic exercise. The study consisted of 12 individuals. The study was set up so that the resting lactate was obtained 5 minutes after resting upon arrival. Following a 30 second wingate interval subjects either rested or performed core stability exercises. Part of core stabilization included the prone plank. A result of performing the plank and other core stabilization exercises saw lactate numbers decrease more when compared to the values that were obtained in those who rested instead of the core stabilization.\textsuperscript{13}
Summary of research

There is little research about the effects of core exercises and blood lactate levels. There will be results from this study that will show what effect core exercise has on blood lactate. The research of core exercise, more specifically the plank exercise, has proven that plank variations can be more effective than the prone plank. However, to date there has been no research regarding upright planking devices and the impact that they could have. The results of this research will show whether or not the perfect plank is an adequate variation to the plank exercise.
CHAPTER III

METHODS

Research Design

An experimental design was used to compare the lactates and root mean square of the EMG activity in the two plank exercises to see if one of the exercises influenced each variable more than the other. The independent variables were the plank type; perfect plank or prone plank. The dependent variables were EMG production, and blood lactate. Subjects were randomized between the prone plank and perfect plank to avoid order effect.

Subjects

Thirty subjects (15 males and 15 females) ages 18–40 participated in this study. Subjects were obtained through a convenience sample in proximity to Cleveland State University. Participants were recruited through word of mouth and advertisements via flyers (Appendix A). Each subject completed a pre-screening questionnaire (Appendix B). They were excluded if they did not meet the age range or if they had musculoskeletal pain, and were not low risk. Only those who were low risk were included. All eligible participants completed the informed consent (appendix C) on the day of the test.
Procedures

Participants who qualified for the study were given an informed consent form (Appendix C)

The consent form was approved by the Institutional Review Board at Cleveland State University. All testing was conducted in the Human Performance Lab at Cleveland State University. Upon arrival for testing, each subject was instructed of the protocol. The perfect plank machine was used (appendix D, figure 1) and compared to the traditional prone plank (appendix D, figure 2). The prone plank was done lying down with the subject resting the forearms on a mat with the feet on the other end of the mat in this plank variation. Prior to examination, skinfold analysis with the 4-site method for males and females was used to calculate body fat percentage (Jackson & Pollack 4 site method). The four sites were the abdomen, suprailiac, triceps, and thigh. Each site was assessed using skinfold calipers. Each individual was prepped and monitored with the Delsys wireless EMG monitoring system (Delsys inc. Natick, Ma) in the following locations: The front deltoid, rectus abdominis, external oblique, and erector spinae (see appendix C, figure 3 for electrode positioning). Each EMG site was prepped using an alcohol pad. The stratum corneum was cleaned of oils and keratinized cells to increase electrode conduction. Analysis of EMG amplitude was done by calculating the root mean square envelope of each muscle group EMG signal. The root mean square envelope was calculated by using a moving window that squaring all of the amplitude values, averaged those squared values, and taking the square root of that value. This measure is calculated along the full duration of the trial. To account for acclimation to the exercise, an overall average of the RMS signal amplitude measurements was taken from the 4 second marker
to the 14 second marker ensuring that the data was consistent without artifact. The RMS amplitudes were taken within the Delsys software and data was transferred to MATLAB for analysis of the 10 second timeframe. The groups began testing by being randomized into starting on the perfect plank machine or in the traditional prone plank exercise. Each subject will perform a trial set for 15 seconds of the plank variation they completed on each day. After the practice trial, the plank was recorded for 15 seconds. The same protocol was used for the subsequent session no less than 24 hours from the time of the previous plank variation. A blood lactate was taken from each individual after 2-3 minutes of rest before and immediately after completing the plank exercise series. The blood lactate will be gathered from a blood sample using a finger stick. The finger will be cleaned and dried. A lancet will prick the finger and a drop of blood will be drawn into the micro cuvette for analysis using the nova biomedical Lactate Plus (Nova biomedical, Waltham, MA). The data gathered via EMG (peak force and average EMG), blood lactate, and pressure changes from the sensor mat will be compared between the plank variations.

inferior margin of olecranon process with a vertical fold. The suprailiac measure will be gathered just above the iliac crest at the midaxillary line using a diagonal fold (Appendix E, figure 2) which represents the natural angle of the iliac crest at the anterior axillary line which is superior to the iliac crest. The thigh will be assessed midway between the inguinal crease and the proximal border of patella with a vertical fold. Each individual will be prepped and be monitored with the Delsys wireless EMG monitoring system (Delsys inc. Natick, Ma) in the following locations: The front deltoid, rectus abdominis, external oblique, and erector spinae (see appendix C, figure 3 for electrode positioning).
Each EMG site will be prepped using an alcohol pad. The stratum corneum will be cleaned of oils and keratinized cells to increase electrode conduction. Analysis of EMG will be done using the root mean square. The groups will begin the testing by being randomized into starting on the perfect plank machine or in the traditional prone plank exercise. Each subject will perform a trial set for 15 seconds of the plank and perfect plank. After the practice trial, 1 set of each exercise will be performed for 15 seconds with a 15 minute rest period between the prone plank and the perfect plank. A blood lactate will be taken from each individual after 2-3 minutes of rest before and immediately after completing the plank exercise series. The blood lactate will be gathered from a blood sample using a finger stick. The finger will be cleaned and dried. A lancet will prick the finger and a drop of blood will be drawn into the micro cuvette for analysis using the nova biomedical Lactate Plus (Nova biomedical, Waltham, MA). The data gathered via EMG (peak force and average EMG), blood lactate, and pressure changes from the sensor mat will be compared between the plank variations.

**Delimitations**

- Subjects aged 18-40
- No history of Low back pain or previous procedures
- Body composition:
  - Males below 18% body fat
  - Females Below 28% body fat
Data Analysis

Repeated measures was be used for the statistical analysis to measure the mean and standard deviation of the EMG measures, blood lactate measures pre and post exercise, and gender differences. SPSS (version 22) will be used for all analyses with .05 used as the level of significance.
CHAPTER IV

RESULTS & DISCUSSION

Results

All 30 subjects completed the two plank exercises to determine if there was a difference in muscle activation and pre/post blood lactates. All subjects were within the gender specific body fat ranges and age group. Subject characteristics by gender are shown in table 1.

Table 1. Characteristics by gender.

<table>
<thead>
<tr>
<th></th>
<th>Males (N=15)</th>
<th>Females (N=15)</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td>Gender</td>
</tr>
<tr>
<td>Age (years)</td>
<td>23.2 ± 2.1</td>
<td>23.6 ± 1.64</td>
<td>.567</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>14.25 ± 4.26</td>
<td>22.1 ± 3.70</td>
<td>.000*</td>
</tr>
</tbody>
</table>

*Significant difference (p ≤ .05)

There was no significant difference in age among males and females (p=.567). However, there was a significant difference in body composition, as males had a significantly lower body fat percentage when compared to females (p=.000).
Electromyography of the prone plank vs. the Perfect Plank

The mean, standard deviation, and significance of the electromyography of the Rectus abdominis, external obliques, anterior deltoids, and erector spinae are shown in table 2.

**Table 2.** Electromyography.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>N</th>
<th>Perfect Plank (RMS)</th>
<th>Standard deviation</th>
<th>Prone Plank (RMS)</th>
<th>Standard deviation</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Rectus Abdominis</td>
<td>30</td>
<td>0.07955</td>
<td>0.089843</td>
<td>0.04575</td>
<td>0.029244</td>
<td>0.056</td>
</tr>
<tr>
<td>Right Rectus Abdominis</td>
<td>30</td>
<td>0.12595</td>
<td>0.182388</td>
<td>0.06513</td>
<td>0.100986</td>
<td>0.123</td>
</tr>
<tr>
<td>Left external oblique</td>
<td>30</td>
<td>0.05012</td>
<td>0.069828</td>
<td>0.04686</td>
<td>0.069828</td>
<td>0.051</td>
</tr>
<tr>
<td>Right external oblique</td>
<td>30</td>
<td>0.05073</td>
<td>0.045048</td>
<td>0.05543</td>
<td>0.045048</td>
<td>0.059</td>
</tr>
<tr>
<td>Left anterior deltoid</td>
<td>30</td>
<td>0.062</td>
<td>0.102281</td>
<td>0.10924</td>
<td>0.082333</td>
<td>0.815</td>
</tr>
<tr>
<td>Right anterior deltoid</td>
<td>30</td>
<td>0.05478</td>
<td>0.085322</td>
<td>0.08911</td>
<td>0.050784</td>
<td>0.603</td>
</tr>
<tr>
<td>Left erector spinae</td>
<td>30</td>
<td>0.09343</td>
<td>0.188366</td>
<td>0.03606</td>
<td>0.09254</td>
<td>0.157</td>
</tr>
<tr>
<td>Right erector spinae</td>
<td>30</td>
<td>0.1075</td>
<td>0.180212</td>
<td>0.06124</td>
<td>0.146232</td>
<td>0.304</td>
</tr>
<tr>
<td>----------------------</td>
<td>----</td>
<td>--------</td>
<td>-----------</td>
<td>---------</td>
<td>---------</td>
<td>-------</td>
</tr>
</tbody>
</table>

*Significant difference (p ≤ .05)

**Blood Lactate**

The mean, standard deviation, and significance level of the blood lactates after completing the perfect and prone planks are shown in table 3.

**Table 3. Blood Lactate.**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Perfect</th>
<th>Standard deviation</th>
<th>Prone</th>
<th>Standard deviation</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>30</td>
<td>1.67</td>
<td>0.79565</td>
<td>1.73</td>
<td>0.78058</td>
<td>0.752</td>
</tr>
<tr>
<td>Post</td>
<td>30</td>
<td>3.013</td>
<td>1.56221</td>
<td>2.33</td>
<td>1.09339</td>
<td>0.024*</td>
</tr>
</tbody>
</table>

*Significant difference (p ≤ .05)

There was a significant (p=.024) blood lactate interaction as illustrated in Figure 1.

**Gender differences**

**Electromyography**

Differences among genders in electromyography are shown in table 4.
<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Sig. (2 tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Rectus abdominis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(perfect) male</td>
<td>15</td>
<td>.07022</td>
<td>.063936</td>
<td>.579</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.08888</td>
<td>.111560</td>
<td></td>
</tr>
<tr>
<td>Right rectus abdominis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(perfect) male</td>
<td>15</td>
<td>.12720</td>
<td>.142168</td>
<td>.971</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.12471</td>
<td>.220663</td>
<td></td>
</tr>
<tr>
<td>Left deltoid (perfect)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>male</td>
<td>15</td>
<td>.03173</td>
<td>.028694</td>
<td>.095</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.09415</td>
<td>.136964</td>
<td></td>
</tr>
<tr>
<td>Right deltoid (perfect)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>male</td>
<td>15</td>
<td>.02952</td>
<td>.021931</td>
<td>.106</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.08003</td>
<td>.115031</td>
<td></td>
</tr>
<tr>
<td>Left external oblique</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(perfect) male</td>
<td>15</td>
<td>.03675</td>
<td>.023014</td>
<td>.302</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.06349</td>
<td>.095852</td>
<td></td>
</tr>
<tr>
<td>Right external oblique</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(perfect) male</td>
<td>15</td>
<td>.04090</td>
<td>.029830</td>
<td>.295</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.05872</td>
<td>.057334</td>
<td></td>
</tr>
<tr>
<td>Left erector spinae</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(perfect) male</td>
<td>15</td>
<td>.14011</td>
<td>.258271</td>
<td>.179</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.04674</td>
<td>.046081</td>
<td></td>
</tr>
<tr>
<td>Right erector spinae</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(perfect) male</td>
<td>15</td>
<td>.12787</td>
<td>.238729</td>
<td>.545</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.08712</td>
<td>.096908</td>
<td></td>
</tr>
<tr>
<td>Left rectus abdominis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Prone) male</td>
<td>15</td>
<td>.03813</td>
<td>.017634</td>
<td>.074</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.10563</td>
<td>.062730</td>
<td></td>
</tr>
<tr>
<td>Right rectus abdominis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(prone) male</td>
<td>15</td>
<td>.03669</td>
<td>.016734</td>
<td>.125</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.09356</td>
<td>.138246</td>
<td></td>
</tr>
<tr>
<td>Left deltoid (prone)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>male</td>
<td>15</td>
<td>.07259</td>
<td>.028675</td>
<td>.074</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.10563</td>
<td>.062730</td>
<td></td>
</tr>
<tr>
<td>Right deltoid (prone)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>male</td>
<td>15</td>
<td>.11146</td>
<td>.105592</td>
<td>.885</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.10702</td>
<td>.053679</td>
<td></td>
</tr>
<tr>
<td>Left external oblique</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(prone) male</td>
<td>15</td>
<td>.04044</td>
<td>.016546</td>
<td>.204</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.05329</td>
<td>.034541</td>
<td></td>
</tr>
<tr>
<td>Right external oblique</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(prone) male</td>
<td>15</td>
<td>.05078</td>
<td>.029215</td>
<td>.400</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.06008</td>
<td>.030387</td>
<td></td>
</tr>
<tr>
<td>Left erector spinae</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(prone) male</td>
<td>15</td>
<td>.01948</td>
<td>.023372</td>
<td>.335</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.05263</td>
<td>.128856</td>
<td></td>
</tr>
<tr>
<td>Right erector Spinae</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(prone) male</td>
<td>15</td>
<td>.04613</td>
<td>.057883</td>
<td>.580</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>.07636</td>
<td>.201134</td>
<td></td>
</tr>
</tbody>
</table>

*Significant difference (p ≤ .05)
Blood Lactate

The pre and post blood lactate values by gender are shown in table 5.

**Table 5.** gender differences pre and post lactate.

<table>
<thead>
<tr>
<th></th>
<th>Male (mmol)</th>
<th>Standard deviation</th>
<th>Female (mmol)</th>
<th>Standard deviation</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Perfect</td>
<td>1.4667</td>
<td>0.66404</td>
<td>1.88</td>
<td>0.88253</td>
<td>0.158</td>
</tr>
<tr>
<td>Post Perfect</td>
<td>2.6267</td>
<td>1.03955</td>
<td>3.4</td>
<td>1.91162</td>
<td>0.18</td>
</tr>
<tr>
<td>Pre Prone</td>
<td>1.9867</td>
<td>0.92108</td>
<td>1.4867</td>
<td>0.52897</td>
<td>0.079</td>
</tr>
<tr>
<td>Post Prone</td>
<td>2.1667</td>
<td>0.91078</td>
<td>2.5067</td>
<td>1.25895</td>
<td>0.404</td>
</tr>
</tbody>
</table>

*Significant difference (p ≤ .05)*

Discussion

Electromyography

The results showed that the Perfect plank, on average, stimulated the Rectus abdominis and erector spinae more than the prone plank. On average, the mean root mean square (RMS) of the abdominals on the perfect plank shows trends of being greater than that of the prone plank. The results of Atkins et al. showed that modified versions of the plank exercise using suspension straps were better in stimulating the anterior core muscles (i.e. rectus abdominis). The result collected in the erector spinae muscles in males are contrary to the hypothesis that activation would be less. Cugliari and Boccia (2017) found that a modified version of the prone plank with the feet placed in TRX
bands stimulated far less activation than seen in this study with the perfect plank machine. The assumption was that less activation meant a more beneficial exercise for the low back. However, with an upright posture, as in the perfect plank, the back is in a neutral position. Jacobs et al. (2016) found that a merely standing in an upright posture with dorsiflexion of the feet recruited the Erector Spinae muscles and followed with Rectus abdominis activation which may help to explain why those muscle groups were activated more in the perfect plank than the prone plank.

Anterior deltoid activation in the perfect plank was, on average, less when compared to the prone plank. This suggests that the body weight placed on the shoulder joint could be indicative of activation. The perfect plank may be an alternative isometric core exercise for those who have anterior deltoid injuries but are looking to stimulate the rectus abdominis muscles without involving stress on the shoulder.

The average activation of the external obliques for both exercises shows that both are similar in their ability to activate this muscle group. When compared to other abdominal exercises, Atkins et. al (2015) found that prone plank variations with a swiss ball and the TRX suspension system did not change the recruitment of the external obliques.

**Blood Lactate**

Gratas-Delamarche et al. (1993) found that male and female cyclists who performed 30 seconds of anaerobic work via the wingate test saw similar increases in blood lactate after the conclusion of the 30 second period. These values were greater than the increases in lactate for the plank exercises, but would be expected because of the
work done over 30 seconds as opposed to 15 seconds. The significant increase in blood lactate in the perfect plank in relation to the prone plank shows that more anaerobic work is required for the perfect plank. In relation to electromyography, Chwalbińska et al. (1998) found that electromyography and lactate accumulation increase in tandem with one another. The rectus abdominis and erector spinae saw more activation on average, when compared to the prone plank. The only muscle group with less activation trending toward the prone plank were the anterior deltoids. Even though there were no significant differences, the larger muscles groups (i.e. rectus abdominis and erector spinae) being more activated could point towards those higher post exercise lactates after the perfect plank exercise.

Gender differences

There were some differences in electromyography between male and female subjects across the two exercises. None of the trends proved to be significant but the perfect plank seems to have a slightly better effect on females for activation when compared to males. Although not significant, females saw a trend of increased activation in the deltoids, rectus abdominis, and obliques for both plank variations.

Blood lactate was another parameter between the genders that differed slightly. The average post lactate values were higher and a greater percentage of change in the females for both exercises. McCracken, Ainsworth, and Hackney (1994) found that periods in the menstrual cycle do effect post lactate values in women. There was no stipulation for monitoring menses during this experiment so the elevated values that were obtained could have been due to the physiological differences between men and women in this aspect. Gratas-Delamarche et al. (1993) found contrasting differences in lactate
accumulation after wingate testing. Results showed a greater increase in males compared to females. When you factor in that women had a trend of more EMG activation in both exercises, the results make sense in the lactates being higher because that would indicate that the anaerobic work was harder for females when compared to males.
CHAPTER V

SUMMARY & CONCLUSION

Summary

Previous research has shown that variations of the plank exercise are effective in stimulating the core muscles as much, if not more than the traditional prone plank exercise. There isn’t much to show that one gender is superior to the other, however. The trends of muscle stimulation and lactate values show that the perfect plank is a good alternative exercise when targeting the core muscles.

Conclusion

Based on the results, the rectus abdominis and erector spinae trended toward being stimulated more, on average, with the use of the perfect plank. The obliques showed no difference but were adequate to the prone plank in stimulation. The deltoids were activated more in the shoulders in the prone plank. This result is intriguing for those who may have had shoulder injuries in the past or are looking for a plank variation that takes some stress off of the shoulder joint. The primary hypothesis was partially supported. The EMG activation was more, on average, and shows trends in the perfect plank for the rectus abdominis. The erector spinae muscles were more activated in the
perfect plank when compared to the prone plank for males when compared to females. The secondary hypothesis was supported, in that, the perfect plank did stimulate a greater change in the blood lactate which equates to more anaerobic work being done when you factor in all the muscles. However, the muscles contributing to this change are unknown. The original hypothesis was that more activation meant that the low back was unstable. However, the perfect plank was designed to keep the back upright as the core contracts. Thus, more activation doesn’t mean that the exercise is harmful. It could potentially be a way to strengthen the back muscles without compromising form. The final hypothesis was also supported. Females did achieve more activation when compared to males. This result is intriguing given that the average body fat for women was significantly different when compared to the males. It is possible that the difficulty of the exercise was less for males when compared to females due to body composition. The submaximal nature of the exercise could have been more challenging thus stimulating more activity in the females, in some muscle groups, when compared to males.

**Limitations**

Potential limitations of this study include the unfamiliarity with the upright perfect plank device. Had there been an introductory period to the perfect plank, there may have been more familiarity when performing the exercise. There was also no monitoring of the prone plank position. Perhaps having users all have spread feet or feet together would have standardized the prone plank. There were questions prior to using the perfect plank from many of the subjects. Specific cues on contracting the core and having a straight alignment of the body could have been beneficial in making sure everyone was as close as can be to having the same form throughout each exercise.
Another factor to consider is the duration of the plank. Perhaps 30 seconds as opposed to 15 seconds would have stimulated even more changes in lactate and electromyography. The lactate values were significant between the two exercises but still near resting norms.

Future research recommendations

Future research will be necessary to look into differences between the prone plank and perfect plank. Trials with longer exercise duration and a different design may be helpful in furthering the case of the perfect plank being a significantly better exercise for the core muscles.

Application

This study has shown that, in agreement with previous literature, alternative plank exercise variations could be more effective exercise than the traditional prone plank. The perfect plank device has the potential to benefit coaches and athletes as well as the general fitness individual that is looking for a different exercise that is effective in stimulating the core muscles.
REFERENCES


DEVICES. Journal Of Strength & Conditioning Research (Lippincott Williams & Wilkins), 28(11), 3298-3305. doi:10.1519/JSC.0000000000000521


Appendices
Appendix A:

Volunteers needed for a comparison study of the prone plank and perfect plank

Volunteers, between the ages of 18-40, are needed to participate in a study comparing the prone plank and perfect plank exercise. The research will take place in one session at the Cleveland State University Human Performance Laboratory in the Physical Education building (PE60). In your session, you will be asked to fill out an activity questionnaire that provides us with age, gender, and activity level as well as a health screening to approve participation. Subjects will complete two exercises: The prone plank and a plank in the perfect plank machine on top of a sensor mat. We will gather a blood lactate will be measured prior to and following exercise. Electromyography (EMG) will be analyzed on the following four muscle groups: Upper Abdominals, external oblique’s, anterior deltoids, and the erector spine.

Risks: It is not anticipated that this study will present any risks outside of discomfort that is associated with exercise and body compositions analysis from skinfold measurements. The session will take approximately 30 minutes from start to finish. You may end your participation at any time with no penalty.

Benefits: The goal of this study is to determine which plank exercise is more effective. It is hoped that the data in this study will help determine how effective alternate plank exercises, such as the perfect plank machine, are compared to the prone plank.

This research is being conducted by Masters thesis student Matt Ivers, Kenneth Sparks, Ph.D., Douglas Wadja, Ph.D., and Emily Kullman, Ph.D.

If you would like to volunteer, Please contact:

Matt Ivers, Graduate Assistant
m.ivers18@vikes.csuohio.edu
Appendix B:

AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

Assess your health status by marking all true statements

History
You have had:
___ a heart attack
___ heart surgery
___ cardiac catheterization
___ coronary angioplasty (PTCA)
___ pacemaker/implantable cardiac
defibrillator/rhythm disturbance
___ heart valve disease
___ heart failure
___ heart transplantation
___ pacemaker/implantable cardiac
defibrillator/rhythm disturbance
___ heart valve disease
___ congenital heart disease

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Symptoms
___ You experience chest discomfort with exertion.
___ You experience unreasonable breathlessness.
___ You experience dizziness, fainting, or blackouts.
___ You take heart medications.

Other health issues
___ You have diabetes.
___ You have asthma or other lung disease.
___ You have burning or cramping sensation in your lower legs when walking short distances.
___ You have musculoskeletal problems that limit your physical activity.
___ You have concerns about the safety of exercise.
___ You take prescription medication(s).
___ You are pregnant.

Cardiovascular risk factors
___ You are a man older than 45 years.
___ You are a woman older than 55 years, have had a hysterectomy, or are postmenopausal.
___ You smoke, or quit smoking within the previous 6 months.
___ Your blood pressure is &gt;140/90 mm Hg.
___ You do not know your blood pressure.

If you marked two or more of the statements in this section you should consult your physician or other appropriate health care
___ You take blood pressure medication.  
### provider before engaging in exercise. You

___ Your blood cholesterol level is > 200 mg/dL.  
### might benefit from using a facility with a

___ You do not know your cholesterol level.  
### professionally qualified exercise staff to

___ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister).

___ You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week).

___ You are > 20 pounds overweight.

___ None of the above

You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-guided program or almost any facility that meets your exercise program needs.
Appendix C:

INFORMED CONSENT

TO PARTICIPATE IN THE ELECTROMYOGRAPHY, BLOOD LACTATE, AND SENSOR MAT ANALYSIS COMPARISON OF THE PLANK AND PERFECT PLANK STUDY

Introduction

We are inviting you to participate in a research study that is being conducted by student and faculty researchers from Cleveland State University’s Human Performance Laboratory. The research will be conducted by an Exercise Science Graduate Student, Matt Ivers, Dr. Kenneth Sparks, Dr. Doug Wajda, and Dr. Emily Kullman in the Department of Health and Human Performance.

Before you decide whether or not you would like to participate in this study, you need to understand the purpose, benefits, and possible risks. The informed consent is very important so please read carefully and understand the testing protocol. Please ask any questions regarding the study that you may have. The study will consist of 20 subjects.

The purpose of this study is to compare the effects of the traditional plank versus the perfect plank in regards to Electromyography (EMG) measurements and blood lactate measures before and after the testing period. The tests will take place at Cleveland State University’s Health and Human Performance Laboratory.

Testing Procedures

You will be asked to fill out a questionnaire about your risk factors. Prior to each plank exercise, we will gather skinfold measurements and resting blood lactate. We will also prep the Rectus Abdominis, Internal oblique’s, External oblique’s and the Erector Spinae with Electromyography (EMG) sensors. You will be asked to hold the plank position on the ground and in the incline plank simulator for 15 seconds in a pre-trial period and the same for the plank set during the testing period. After each exercise we will measure blood lactate and allow 15 minutes of recovery before moving on to the second plank variation.

Possible Risks and Discomforts

The blood lactate measure will require samples of blood. Two prior to exercise and two immediately after the exercise is concluded. There also may be some discomfort during the exercise testing or during the skinfold measurements.

The laboratory is also equipped with an AED and emergency procedures are listed which include calling EMS (x911) and stating to the dispatcher, “We have a medical emergency.
in the HUMAN PERFORMANCE LABORATORY, PE BUILDING-ROOM B60”. CPR and First Aid will be administered until the EMS arrives.

In the event you are injured as a result of participation in this research, please notify the research team and seek medical attention by your primary care physician. The costs of such medical care will be billed to you or your insurance company. There are no plans to provide compensation for research related injury.

Benefits

There are no direct benefits to you from this investigation. However, the results from these tests may help us determine if there is increased stimulation of the core and a difference in lower back support between the two exercises as well as blood lactate and pressure points of both exercises.

Privacy and Confidentiality

I understand that the data and information obtained from this study will be confidential and will not be disclosed to anyone without my consent. With my consent, I grant that the information and data collected may be used for research purposes, however, I will not be identified. My results may be used in group data for statistical or scientific purposes which may benefit future research of core exercises. Individual responses will not be associated with data and your identity will be kept confidential.

All research documents will be secured in a locked file cabinet for 3 years in the Health and Human Performance Laboratory at Cleveland State University. After 3 years the documents will be destroyed.

Participation

I understand that participation in this project is voluntary and I have the right to withdraw at any time without consequences. I understand that if I have any questions about my rights as a participant, I can contact Cleveland State University’s Institutional Review Board at (216) 687-3630.

If I have any questions about the procedures I can contact Dr. Kenneth Sparks at 216-687-4831 or Graduate Student Matt Ivers at (614) 915-4040.

I attest that I have no other known health problems that could prevent me from successfully participating in the procedures.

Acknowledgement

The purpose, procedures, known discomforts and risks, and possible benefits to me and to others regarding the study have been explained to me. I have read the consent form or it has been read to me, and I understand it.

I agree to participate in this study and have been given a copy of this consent form.
Signature: _____________________ Date: ________________

Witness: _____________________ Date: ________________
Appendix D: Testing Pictures

Figure 1: The perfect plank machine on the sensor mat
Figure 2: Prone Plank and Sensor mat
Figure 3: Electrode placement

The picture above shows the placement of electrodes for the Rectus abdominis, external oblique, and anterior deltoids.
Figure 4: The erector spinae EMG placement, show above.
APPENDIX E

Figure 1: The picture above is the technique used for a vertical fold

Figure 2: The picture above is the technique for a diagonal fold