UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

ELECTROMYOGRAPHIC COMPARISON OF A VARIETY OF ABDOMINAL EXERCISES TO THE TRADITIONAL CRUNCH

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science, Clinical Exercise Physiology

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ELECTROMYOGRAPHY COMPARISON OF A VARIETY OF ABDOMINAL EXERCISES TO THE TRADITIONAL CRUNCH

By Edward M. Stenger

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree Master of Science, Clinical Exercise Physiology.

The candidate has completed the oral defense of the thesis.

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ABSTRACT

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The purpose of this study was to compare a variety of abdominal exercises and abdominal exercise products to the traditional crunch to determine which exercises are most beneficial for activating the abdominal musculature. A secondary purpose was to compare upper versus lower rectus abdominis muscle activation between various exercise conditions. Fourteen subjects (6 males, 8 females) performed 5 repetitions for each exercise except for the isometric exercises where 5 second contractions were used for the abdominal exercises. The exercises that were tested were the Ab Coaster, Ab Straps, Ab Lounge, Ab Circle Pro, Ab Roller, Perfect Sit-up, Ab Rocket, Ab Wheel, stability ball crunch, bicycle crunch, yoga boat pose, side plank, front plank, decline bench curl-up, captain's chair crunch, and the traditional crunch. Surface electromyography (EMG) was recorded for the upper rectus abdominis (URA), lower rectus abdominis (LRA), external obliques (EO), and rectus femoris (RF). Electromyography between exercises was compared to the traditional crunch using a one-way ANOVA with repeated measures for each exercise. No exercises had significantly higher muscle activation than the traditional crunch for the URA and LRA. The Ab Wheel, side plank, Ab Circle Pro, and front plank had significantly lower URA and LRA muscle activation than the traditional crunch. A comparison of muscle activation between the URA and LRA found no significant difference for any of the 16 exercises with an overall EMG average of 69.6% of MVC for the URA and 67.1% of MVC for the LRA. Based upon these results it appears that the traditional crunch with the arms folded across the chest is an excellent exercise for activating the abdominal musculature. Also, the URA and LRA were shown to activate the same amount of muscle stimulation therefore it appears subject's recruit both the URA and LRA during abdominal exercises and cannot differentiate between the two.

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INTRODUCTION

Abdominal exercises are a key component of any exercise training program. The four predominant reasons why individuals perform abdominal exercises are to: 1) improve core strength and endurance, 2) reduce low-back pain, 3) enhance sports performance and 4) improve body image (Sternlicht et al., 2005; Youdas et al., 2008). This latter reason, to improve body image by having a well-defined “six-pack” has resulted in the marketing of a large number of exercise machines designed to target the abdominal muscles. New abdominal equipment and machines are created every year making this a multi-billion dollar industry (Sternlicht et al., 2005). The important question with any new piece of abdominal exercise equipment or abdominal exercise is simple: Is this new exercise more beneficial than the traditional crunch at activating the abdominal muscles?

The traditional crunch, where an individual lies supine with their feet flat on the floor, knees bent at a ninety degree angle, and the hands folded across the chest is considered to be the gold standard abdominal exercise. When performed correctly, a traditional crunch activates the rectus abdominis (RA) and the internal (IO) and external obliques (EO), while limiting activation of the sternocleidomastoid (SCM), erector spinae, (ES), rectus femoris (RF) and iliopsoas (IP) (Escamilla et al., 2010; Leung, 2005). The muscles of the nek, back, and hips are considered accessory muscles and should not be activated while performing an abdominal exercise. When these accessory muscles are activated during an abdominal exercise, they are assisting the true abdominal muscles

(RA, EO, and IO), which would result in it being less beneficial than a properly performed crunch.

Many people do not like to do crunches since they feel they are boring and also because they do not like getting down on the floor. Thus, manufacturers have designed many different exercises to assist people with abdominal exercises. In a study sponsored by the American Council of Exercise (ACE) (Francis and Davis, 2001), six different pieces of abdominal equipment and six different abdominal exercises were compared to the traditional crunch. Results from this study indicated that the bicycle crunch and the stability ball crunch were the more effective in targeting the abdominal muscles than the traditional crunch. Since the investigation by Francis and Davis (2001), more exercises and exercise machines have become popular for training the abdominal muscles. The main purpose of this study was to compare a variety of abdominal exercises and abdominal exercise products to the traditional crunch to determine which exercises are the most beneficial for activating the abdominal musculature. Muscle activation was recorded using electromyography (EMG). The exercise equipment that was tested included the Ab Circle Pro, Ab Roller, Ab Lounge, Perfect Sit-Up, Ab glider, Ab Rocket, Ab Wheel, and Ab Straps. Additional abdominal exercises that were tested were the yoga boat pose, stability ball crunch, decline bench curl-up, captains chair crunch, bicycle crunch, side plank, and the front plank. A secondary purpose of this study was to compare upper versus lower rectus abdominis muscle activation between the various exercise conditions.

METHODS

Subjects

Subjects were 16 apparently healthy volunteers (eight men and eight women) between the ages of 18 and 24 years. All subjects were free from any known cardiovascular and orthopedic problems. Subjects were required to have a body mass index (BMI) less than 25, in order to maximize EMG conduction. The study was approved by the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects prior to the start of any testing. Each subject provided written informed consent prior to undergoing any testing procedures. Subjects were not allowed to participate in the study if they had a history of acute or chronic back pain or if they could not complete the prescribed exercises.

Procedures

Each subject attended one practice session to become familiar with the study protocol and to practice all of the exercises to be completed in this study. On the second day, subjects first performed a maximum voluntary contraction (MVC), along with eight different abdominal exercises. On the third day, subjects again performed a MVC, along with nine abdominal exercises.

Day 2	Day 3
MVC	MVC
Traditional Crunch	Traditional Crunch
Stability Ball Crunch	Ab Lounge

Ab Coaster	Ab Circle Pro
Bicycle Crunch	Ab Wheel
Ab Straps	Ab Roller
Yoga Boat Pose	Side Plank
Perfect Sit-Up	Front Plank
Decline Bench Curl-Ups	Captain's Chair Crunch
	Ab Rocket

1. MVC: Subjects were on the decline bench, hands across their chest with a 90 degree angle at the torso and the hip; the tester then grasped onto the subject's shoulders and attempted to pull the subject downward on the bench while the subject resisted.

2. Traditional Crunch: The subject laid supine on the floor with their knees bent to 90 degrees and their hands folded across their chest; they then curled up until their head, neck, and shoulders were off the floor.

3. Stability Ball Crunch: The subject laid on a large stability ball, resting their shoulder blades on the ball with their knees bent to 90 degrees and their arms folded across their chest; they then curled up until their hips were bent to 90 degrees.

4. Yoga Boat Pose: The subject laid supine on the floor until prompted to start the yoga boat position. At this time the subject elevated their legs and extended their arms forward, parallel to the floor, with their body in a "V" shaped position for 5 seconds.

5. Bicycle Crunch: The subject laid supine on the floor with their legs straight and feet elevated six inches off the floor and with their hands locked behind their head; they then crunched by bringing their right knee towards their body, while simultaneously bringing their left elbow across to touch the right knee.

6. Decline Bench Curl-Up: Subjects started on the decline bench all the way down with their back resting on the pad with their hands across their chest; they then curled up to a 90 degree angle at the torso and the hip.

7. Perfect Sit-up: The subjects positioned themselves in the Perfect Sit-up; their feet were in the foot straps and their knees were bent to 90 degrees ; they held onto the head and neck cradle with their hands beside their head. They then curled up by bringing their upper body off the floor and simultaneously brought their knees to the chest until they heard an audible click.

7. Ab Straps: The subjects stood on a chair over a chin-up bar and positioned their arms in the Ab Straps; they then put their arms in the Ab Straps, resting their arms and gripping the handles of the chin-up bar at the same time. The test administrator then removed the chair and the subject raised their legs up to their chest as high as they could.

8. Ab Coaster: Subjects positioned themselves on the Ab Coaster with their hands on the handles and their knees resting on the pad supports; they then contracted their abdominal muscles bringing their knees up to the top of the rolling track.

9. Ab Lounge: Subjects positioned themselves in the Ab Lounge by extending their arms over their head and grabbing onto the handle and had their feet on the foot supports. Subjects then performed a “basic jackknife” by simultaneously bringing their upper body and feet towards one another until their body was in a “V” position.

10. Front Plank: Subjects laid flat in the prone position on the floor; they then elevated themselves off the floor, resting on their toes and forearms for five seconds.

11. Side Plank: Subjects laid flat on the floor on the right side of their body; they then elevated themselves and were on their right forearm and right foot for five seconds.

12. Ab Wheel: Subjects were on their knees leaning forward slightly to grab the Ab Wheel; subjects then rolled out as far as they possibly could.

13. Ab Rocket: Subjects positioned themselves on the Ab Rocket by sitting on the seat and placing their hands on the handle supports by their sides; they then leaned back until their back was one inch from the floor and then crunched forward.

14. Ab Circle Pro: Subjects positioned themselves on the Ab Circle Pro by placing their knees on the knee supports and then grabbing onto the support handles in front of them; they then swung their legs to the left side of the circle as high as they could go then rotated to the right side as high as they could go.

15. Captain's Chair Crunch: Subjects positioned themselves on the machine by resting their forearms on the pads, while holding onto the handles with their legs hanging down freely; they then crunched by raising both legs simultaneously as high at hey could.

16. Ab Roller: Subjects positioned themselves in the Ab Roller; their feet were flat on the floor and knees were bent to 90 degrees (similar to the traditional crunch); they positioned their neck on the pad and held onto the bar over their head, hands shoulder-width apart. They then curled up as high as possible.

On each day, the MVC and traditional crunches were performed first, followed by the other exercises which were performed in a random order. Prior to testing, subjects had electrodes placed on the upper and lower rectus abdominis (URA and LRA), external obliques (EO), and the rectus femoris (RF). The URA electrodes were placed 3 cm lateral to a vertical line midway between the xiphoid process and the umbilicus. The LRA electrodes were placed 3 cm lateral to a vertical line halfway between the umbilicus and pubic symphysis. The EO electrodes were placed on a vertical line two-thirds the distance between the iliac crest and the tenth rib. The RF electrodes were placed on a vertical line, halfway between the anterior superior iliac spine and the proximal edge of the patella (Escamilla et al., 2010; Willardson et al., 2010; Youdas et al., 2008). Before electrode placement, electrode sites were shaven, abraded, and cleansed with isopropyl alcohol to maximize the quality of the EMG recordings (Sternlicht et al., 2005).

Once prepped, subjects completed five repetitions of each exercise. A rest period of 2 minutes was given between each exercise (Hildenbrand et al., 2004; Youdas et al., 2008). No subjects felt fatigued between exercises or between days of testing.

EMG ANALYSIS

Electromyography activity of the URA, LRA, EO, and RF was recorded on a personal computer. The EMG signal was preamplified (gain 900x) using a differential amplifier (Delsys Trigno Wireless Systems, Boston, MA; bandwidth 20-450 Hz). Raw EMG signals were digitized at 400 Hz. All signal processing was performed using custom programs written with MATLab programming software (Version R2012b, MathWorks, Natick, MA). The EMG signals were digitally band-pass filtered (fourth-order Butterworth) at 20-500 Hz. The EMG amplitude (microvolts root mean square [μVrms]) values were calculated for each trial and represented as a percentage of the maximal EMG recorded during the MVC trial for that day. Subjects were prompted using a metronome set for 3 seconds per repetition (1.5 seconds for the eccentric phase and 1.5 seconds for the concentric phase) to complete each exercise. Five repetitions were recorded for each exercise. The middle three repetitions were used for analysis. For the isometric exercises, 9 seconds of data were recorded for analyzing.

STATISTICAL ANALYSIS

EMG between exercises was compared to the traditional crunch using a one-way ANOVA with repeated measures for each muscle. Pair wise comparisons were made using Fisher's LSD tests. Alpha was set at 0.05 to achieve statistical significance.

RESULTS

Fourteen apparently healthy men (6) and women (8) between 20-24 years of age completed the study. Data from two subjects were not used due to incomplete data. Descriptive characteristics of the subjects are presented in Table 1. Muscle activation for each exercise compared to the traditional crunch is presented in Figure 1 (URA), Figure 2 (LRA), Figure 3 (EO), and Figure 4 (RF), respectively. For the URA, the Ab Wheel, Ab Circle Pro, side plank, and front plank all had significantly lower muscle activation compared to the traditional crunch. For the LRA, the Ab Circle Pro, side plank, and front plank all had significantly lower muscle activation than the traditional crunch. For the EO, the decline bench curl-up, Ab Straps, Ab Coaster, Ab Lounge, Ab Wheel, and captain's chair crunch had significantly higher muscle activation compared to the traditional crunch. The side plank elicited significantly lower muscle activation compared to the traditional crunch for the EO. For the RF, the yoga boat pose, bicycle crunch, decline bench curl-up, Perfect Sit-up, Ab Straps, Ab Coaster, Ab Lounge, captain's chair crunch, and front plank all had significantly higher muscle activation compared to the traditional crunch.

A comparison of muscle activation between the URA and LRA found no significant difference for any of the 16 exercises. Overall, EMG average was 69.6% of MVC for the URA and 67.1% of MVC for the LRA.

Table 1. Descriptive characteristics of the subjects

	Female	Male
Age (years)	21.7 ± 1.16	21.8 ± 1.33
Height (in)	65.6 ± 3.37	71.3 ± 2.42
Weight (lbs.)	129 ± 11.98	164.3 ± 13.98
BMI	21.8± 1.16	22.7 ± 1.46

Values represent mean ± standard deviation.

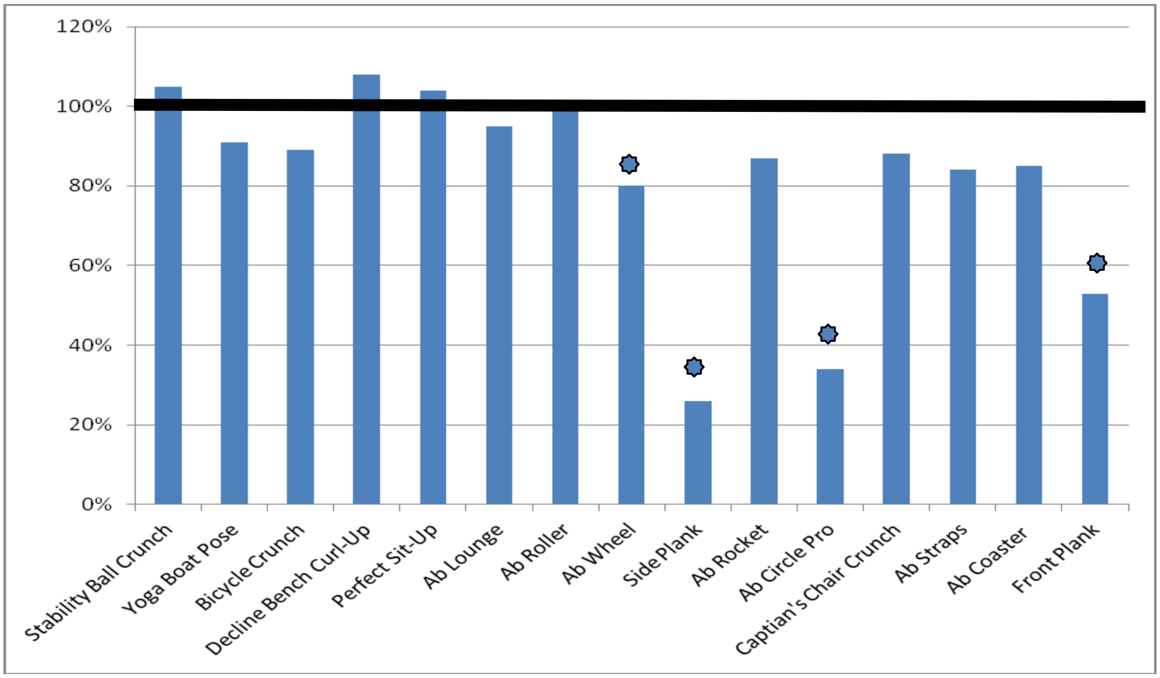

Figure 1. Comparison of the URA activation for the various exercises compared to the traditional crunch.

✹ Significant difference than the traditional crunch ($p<0.05$)

Line represents the traditional crunch.

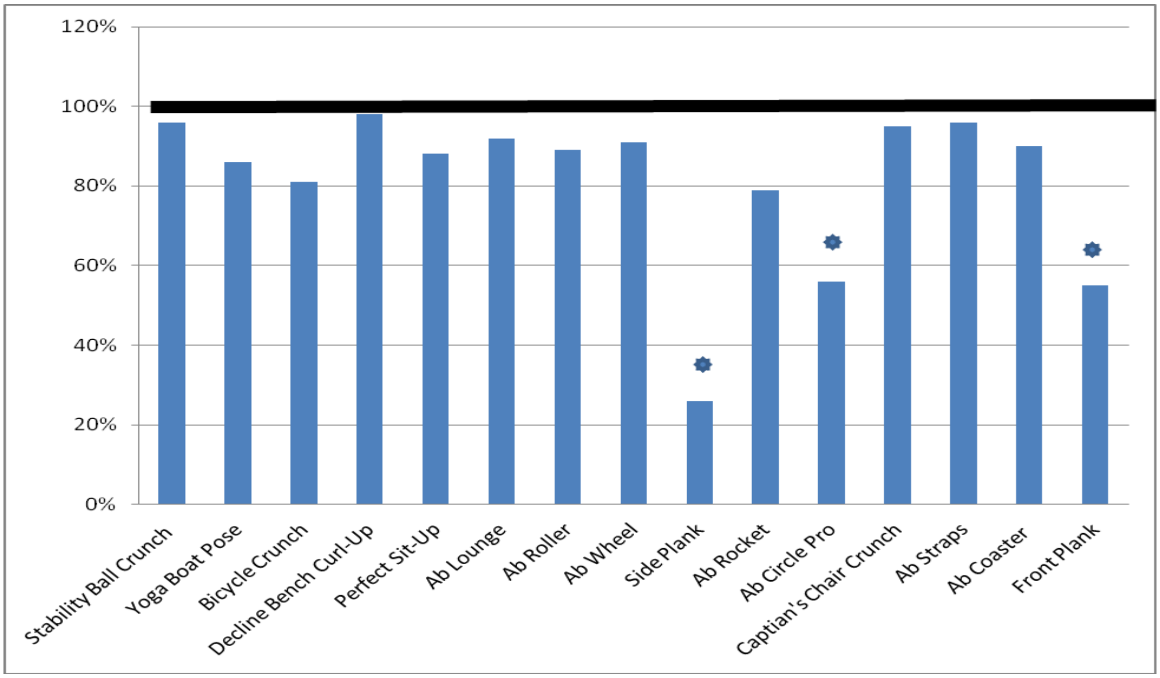

Figure 2. Comparison of LRA activation for the various exercises compared to the traditional crunch.

⭑ Significant difference than the traditional crunch ($p<0.05$)

Line represents the traditional crunch.

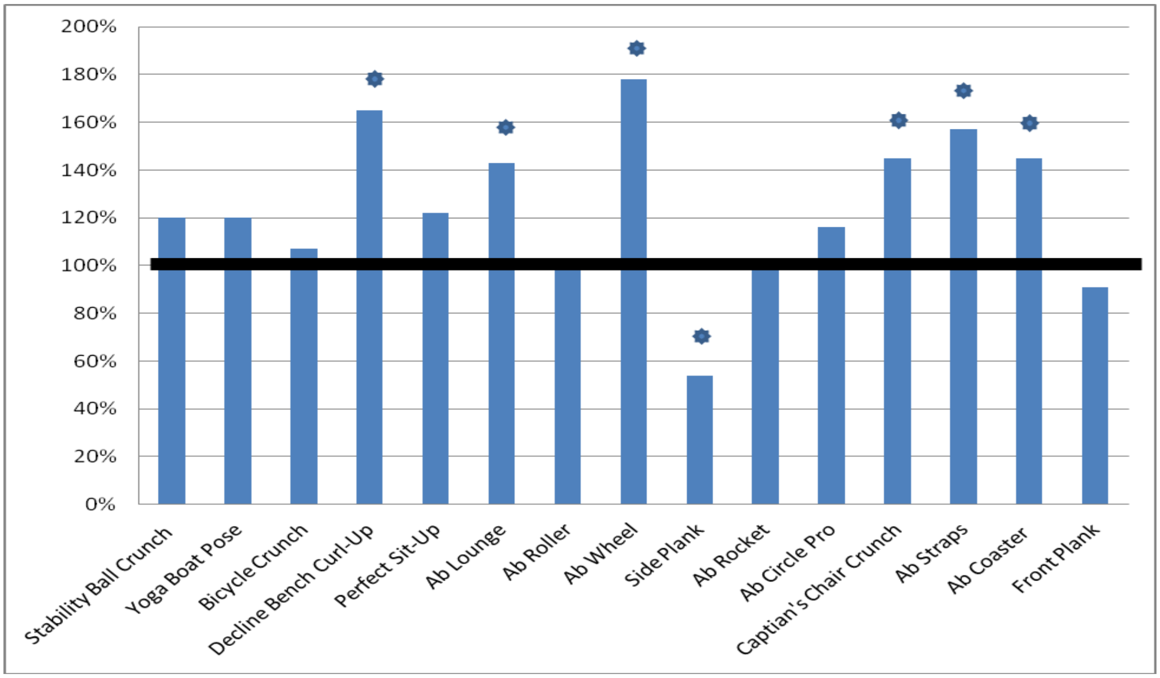

Figure 3. Comparison of EO activation for the various exercises compared to the traditional crunch.

✹ Significant difference than the traditional crunch ($p<0.05$)

Line represents the traditional crunch.

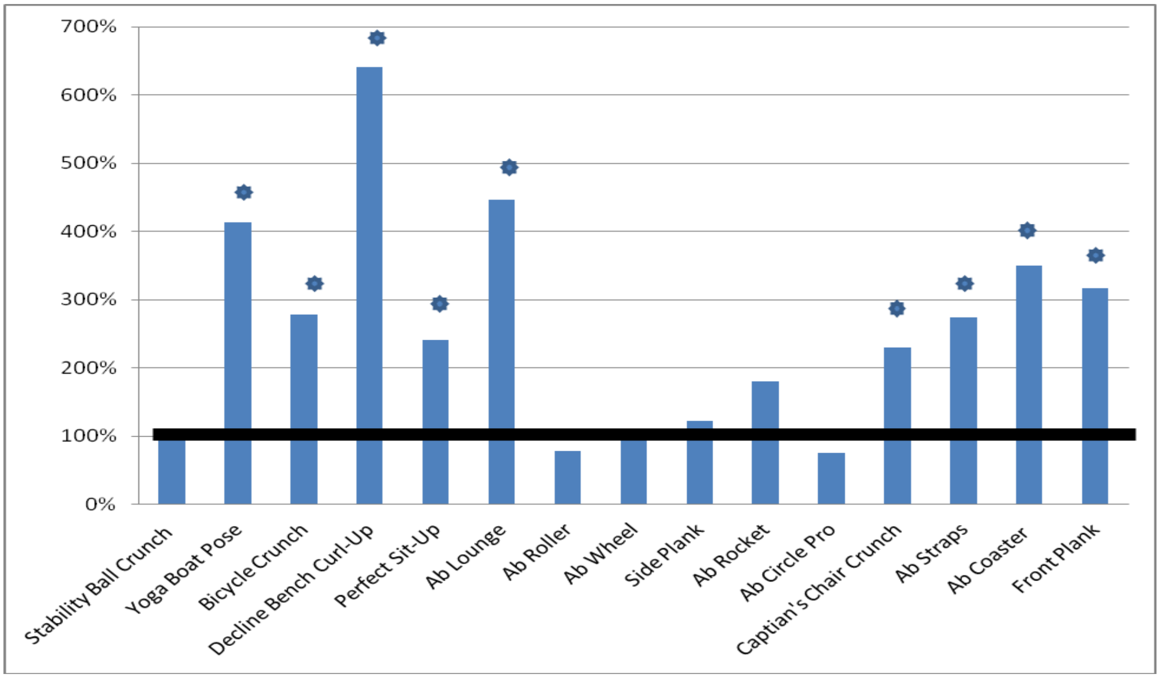

Figure 4. Comparison of RF activation for the various exercises compared to the traditional crunch.

✹ Significant difference than the traditional crunch ($p<0.05$)

Line represents the traditional crunch.

DISCUSSION

One of the main findings of this study was that none of the exercises elicited greater muscle activation of the URA or the LRA than the traditional crunch. This finding was similar to the results of several other published studies. Escamilla et al (2006) compared the Ab Roller, Ab Slide, and Torso Track to the traditional crunch. There was no significant difference in muscle activation for the URA or LRA between exercises. Delmont et al. (1999) compared the Ab Roller and the Ab-Flex to the traditional crunch and found no significant differences in the URA or LRA activation between the exercises. Schoffstall et al. (2010) found no significant difference between the traditional crunch supine v-up, prone v-up on ball, prone v-up on slide board, prone v-up on TRX, and prone v-up on power wheel and the traditional crunch (Schoffstall et al., 2010). In a study comparing the traditional crunch to the Ab Lounge, the traditional crunch actually elicited higher muscle activation for the URA and the LRA (Nelson et al., 2012).

Several studies have actually found that various abdominal exercises had significantly lower muscle activation in the URA and LRA than the traditional crunch, which agrees with our study. Escamilla et al. (2006) found that the Ab Twister, Ab Rocker, and Ab Doer all elicited significantly lower muscle activation in the URA and LRA than the traditional crunch. One study that found similar results to our study was conducted by Willardson et al. (2010). Their results found that the traditional crunch elicited higher muscle activation in the URA and LRA than the Ab Circle Pro and the side bridge. The results of this study (Willardson et al., 2010) led to a lawsuit whereby the manufacturers of the Ab Circle Pro were fined by the Federal Trade Commission for false advertising. The company had to pay the defendants between $15 million and $25 million (this value was dependant on how many refund claims were submitted) (Federal Trade Commission, 2012). The Ab Circle Pro had been advertised to help consumers lose up to 10 pounds in just 2 weeks. They have since modified their claims to not include specific weight loss claims.

In contrast to the findings of the present study, several studies found results that differed from ours. In a previous study supported by ACE it was found that 10 exercises elicited higher muscle activation of the URA and LRA than the traditional crunch. These exercises were the bicycle maneuver, captain's chair crunch, exercise ball, vertical leg crunch, Torso Track, long arm crunch, reverse crunch, crunch with heel push, Ab Roller, and Hover (Francis and Davis, 2001). Similarly, a study by Sternlicht et al. (2007) found that the stability ball crunch with the ball placed at the lumbar region elicited significantly higher muscle activation of the URA and LRA muscles when compared to the traditional crunch (Sternlicht et al., 2007).

One possible reason that our study did not find that any of our abdominal exercises elicited significantly higher muscle activation of the URA and LRA muscles was that we prompted our subjects to perform the traditional crunch deliberately and in time with the beat of the metronome. As a result, the mean EMG of the URA and LRA for the traditional crunch in our study was a combined 68.4% of MVC. Since everything else was compared to this, the room for a particular exercise to be better than this was smaller than if the traditional crunch were 40% of MVC, for instance. This makes a significant difference when analyzing the data. Since all of our abdominal exercises were compared to the traditional crunch, high EMG values for the URA and LRA make it difficult to be significantly better than that exercise.

A claim that is often seen with abdominal exercises is that one can get greater muscle activation of the URA compared to the LRA, or vice versa, with a certain exercise. There was no significant difference in muscle activation between the URA and LRA for any of the abdominal exercises. This finding is in agreement with the study conducted by Francis and Davis (2001) who stated, "the average exerciser appears unable to differentially recruit the upper and lower abdominal muscles." Hildebrand and Noble (2004) also found similar results in their study. There was no significant difference in URA and LRA activation between the Ab Roller, FitBall, trunk curl, and traditional crunch. One study, which exclusively compared URA and LRA muscle activation, showed there to be no significant difference between the URA and LRA EMG between the six abdominal exercises that were tested (Clark et al., 2003).

There were six abdominal exercises that had significantly higher muscle activation of the EO (decline bench curl-up, Ab Lounge, Ab Wheel, captain's chair crunch, Ab Straps,, Ab Coaster) compared to the traditional crunch. Several studies have found that a number of different exercises are more effective at activating the EO than the traditional crunch. Francis and Davis (2001) found that the captain's chair crunch and Ab Roller had significantly higher muscle activation than the traditional crunch. In a study conducted by Sternlicht et al., (2007) the stability ball crunch (placed at the lumber region) was found to elicit higher EMG activity compared to the traditional crunch. In another study, the Torso Track (high tension) and the Perfect Abs (seated high, floor medium, floor high) were found to elicit significantly higher EO muscle activation compared to the traditional crunch (Sternlicht and Rugg, 2003). A reason the EO could have shown higher activation for several of our exercises is because those machines were more free-moving and required the subject to maintain balance and control throughout the exercise. This would cause the subjects to contract the EO in order to maintain stabilization.

Lastly, the RF had significantly higher muscle activation compared to the traditional crunch in nine exercises which included the yoga boat pose, bicycle crunch, decline bench curl-up, Perfect Sit-up, Ab Lounge, captain's chair crunch, Ab Straps, Ab Coaster, and front plank. The front plank and yoga boat pose were both isometric exercises which required constant contraction of the RF to maintain balance. As for the other abdominal exercises that elicited significantly higher EMG activity than the traditional crunch, in all of these exercises the subjects had to pull their legs towards the body to complete the exercise or their feet were fixed. For instance, RF EMG activity for the decline bench curl-up was five times higher than the traditional crunch. This was because the feet were fixed and the body was in a decline position. As a result, the RF was firing constantly to maintain that position. This caused flexion at the hip and contraction of the RF. A study by Schoffstall et al., (2010) found that all five abdominal exercises they tested elicited significantly higher muscle activation than the traditional crunch. The common factor of all five of their exercises was that they were isometric exercises requiring constant contraction of the RF to maintain balance. Excessive muscle activation of the RF during abdominal exercises indicated that accessory muscles are being used to do the exercise. It is also felt that excessive activation of the hip flexors can cause compression and shear stress of the lower back which can lead to low back pain (Hildenbrand and Noble, 2004; Sternlicht and Rugg, 2003).

From this study it appears that the traditional crunch with the arms folded across the chest is an excellent exercise for the abdominal muscles. None of the other exercises tested had significantly higher muscle activation for the URA and LRA. However, a number of exercises had significantly higher muscle activation for the EO and RF. Activation of the EO would be beneficial for someone who is trying to condition their mid-section, whereas activation of the RF is generally contraindicated. As more products continue to be developed to target the abdominal region, research needs to be conducted on an on-going basis to evaluate their effectiveness.

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APPENDIX A

PRE-EXERCISE HEALTH SCREENING QUESTIONNAIRE

Electromyographic Comparison of a Variety of Abdominal Exercise Machines and Equipment Compared To a Traditional Crunch in Healthy Young Adults

Pre-Exercise Health Screening Questionnaire

Name: ____

Age__________ Height__________ Weight_________ BMI___________

1. **Have you done strenuous exercise within the past 24 hours (circle one)?**
   Yes No

2. Are you experiencing, or have previously experienced back pain which is made worse with exercise? Yes No

If yes, please explain____

____

Day #1 Exercise	**Day #2 Exercises**
1.____________________________	1.____________________________
2.____________________________	2.____________________________
3.____________________________	3.____________________________
4.____________________________	4.____________________________
5.____________________________	5.____________________________
6.____________________________	6.____________________________
7.____________________________	7.____________________________
8.____________________________	8.____________________________
9.____________________________	9.____________________________
	10.___________________________

APPENDIX B

INFORMED CONSENT

<u>INFORMED CONSENT</u>

Electromyographic Comparison of a Variety of Abdominal Exercises to the Traditional Crunch

I, ______________________________, volunteer to participate in a research study being conducted at the University of Wisconsin-La Crosse.

Purpose and Procedure

- The purpose of this study is to compare muscle activity (as measured by EMG analysis) during different abdominal exercises in men and women.
- My participation in this study will involve three testing sessions, lasting approximately 1 hour each.
- During the first session (practice session) I will perform all of the 16 different exercises to become accustomed to them. During the second session I will perform the traditional crunch, Ab Glider, stability ball crunch, bicycle crunch, Ab Straps, yoga boat pose, Perfect Sit-Up, and decline bench curl-ups. During the third session I will perform the traditional crunch, Ab Circle Pro, Ab Roller, side plank, front plank, captain's chair crunch, Ab Rocket, and the Ab Wheel.
- During all testing sessions, I will wear four adhesive electrodes over my abdominal muscles in order to record and measure muscle activity.
- Testing will take place in the Exercise Physiology lab located in Mitchell Hall on the University of Wisconsin-La Crosse campus.
- Research assistants will be conducting the research under the direction of Dr. John Porcari, a professor in the Department of Exercise and Sport Science.

Potential Risks

- Muscle fatigue and muscles soreness are possible risks associated with participating in this study.
- Skin irritation from placement of the EMG electrodes is possible.
- Individuals trained in CPR and Advanced Cardiac Life Support will be present for all testing sessions and the testing will be terminated if complications occur.
- The risk of serious or life-threatening complications, for healthy individuals, like myself, is <1:10,000 tests.

Benefits

- I may benefit by gaining knowledge about which is the most effective abdominal exercise.

Rights and Confidentiality

- My participation is voluntary.

- I can withdraw from the study at any time, for any reason, without penalty.
- The results of this study may be published in the scientific literature or presented at professional meetings using group data only.
- All information will be kept confidential through the use of number codes and my data will not be linked with personally identifiable information.

I have read the information provided on this consent form. I have been informed of the purpose of this test, the procedures, and expectations of myself as well as the testers, and of the potential risks and benefits that may be associated with volunteering for this study. I have asked any and all questions that concerned me and received clear answers so as to fully understand all aspects of this study.

If I have any other questions that arise I may feel free to contact the principal investigator: Edward Stenger (218) 234-0572, or his study advisor, Dr. John Porcari, 141 Mitchell Hall, (608) 785-8684. Questions regarding the protection of human subjects may be addressed to the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects at (608) 785-8124.

Participant: ________________________________ Date_____________

Investigator: ________________________________ Date_____________

APPENDIX C

REVIEW OF LITERATURE

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Abdominal exercises have become extremely popular over the years for rehabilitation, personal exercise routines, and in fitness classes. This increase in popularity has sparked the research world into determining which abdominal exercises and machines are most beneficial. First off to clear up a few myths: Everybody has abdominal muscles, however, most are not visible due to elevated amounts of abdominal fat. Secondly, abdominal exercises are not going to get rid of abdominal fat, cardiovascular exercise is needed to accomplish this. Finally, you should not perform abdominal exercises every day. Muscle activation is measured using electromyographic (EMG). EMG consists of connecting electrodes to subject's muscles in order to record muscle stimulation. Many EMG studies consist of focusing on different exercises and different machines which makes each study unique. The purpose of this paper is to review the literature concerning abdominal exercises with different techniques and machines while using EMG.

EMG Electrodes

The way one measures the EMG activity is with the use of electrodes. The earliest electrodes consisted of a small metal plate that was placed on the skin on top of a layer of electrolyte gel and then was anchored with a piece of tape to the skin (Kamen and Gabriel, (2012). Since these original electrodes were created, many new improvements have been made. Surface electrodes continue to be the most common; however, new electrodes such as indwelling electrodes have been created. The two most common types of surface electrodes are the passive electrodes and active electrodes. For the indwelling electrodes, the most common are needle electrodes and wire electrodes (Kamen and Gabriel, 2010).

Passive surface electrodes are most commonly used because they are of most convenience and very little training is needed to operate. Passive surface electrodes usually are simple silver disc electrodes (Basmajian and De Luca, 1985). With passive surface electrodes, the skin on which the electrode is placed must be removed by abrading it to decrease electrical impedance. Also, the use of an electrolyte gel or paste between the electrode and the skin will increase conductivity (Basmajian and De Luca, 1985).

Active surface electrodes are the newest form of surface electrodes when compared to the passive surface electrodes. Active surface electrodes are more popular than the passive surface electrodes because there is no need for preparation of the skin with these electrodes. There is no need to apply gel or to abrade the skin before applying active surface electrodes (Basmajian and De Luca, 1985). Active surface electrodes also include a preamplifier which causes the magnitude of the EMG signal to be increased by a factor of 10 or great (Kamen and Gabriel, 2010).

There are quite a few disadvantages with surface electrodes than can hinder EMG results. The main disadvantage with surface electrodes is that they can only be used on large superficial muscles. This can be problematic at times because one cannot segregate just one muscle out; instead the muscle must be viewed as a group. Because of this problem, there is a term known as “cross-talk” (Kamen and Gabriel, 2010). Cross-talk refers to action potentials from muscles neighboring the muscles of interest that the electrodes are placed on top of. An example of the phenomenon would be recording

EMG on the muscles of the forearm. It would be very difficult to differentiate the difference in muscle activity between the extensor carpi ulnaris muscle and the extensor digitorum muscle while using surface electrodes because the muscles are so closely associated to one another.

According to Merriam-Webster dictionary, the definition of indwelling means, “being an inner activating or guiding force.” The first indwelling electrode of interest was the needle electrode. Needle electrodes are usually 23-38 gauge needles with a smaller diameter wire attached to it (Kamen and Gabriel, 2010). The needles are barbed so when they are inserted directly into the muscle they get “hooked” on the muscle and stay in place (Basmajian and De Luca, 1985). An advantage of needle electrodes is the pin-point precision of them in the sense that they can identify an individual motor unit whether it is performing forceful muscle contractions or non-forceful muscle contractions. Another advantage of the needle electrode is the easy mobility of the electrode when new motor units want to be explored by the investigator (Basmajian, 1985).

The second type of indwelling electrodes is wire electrodes. Wire electrodes consist of a piece of stiff wire with insulation. First, a double-strand piece of wire is inserted into a hypodermic needle making a look with the wire. From this, the loop is then cut leaving the ends of the wire. The ends are then bent backwards to lie against the needle, making hooks out of the wires. Finally, the needle is inserted into the subject’s muscle and then removed while the wire stays within the subject’s muscle (Basmajian and De Luca, 1985). A great advantage to wire electrodes is the precision and accuracy of placement. Being able to direct the needle exactly where the investigator wants it allows for great accuracy (Kamen and Gabriel, 2010).

Along with the surface electrodes, indwelling electrodes also have disadvantages. A major disadvantage of indwelling electrodes is proper sterility is needed. Since the investigator is puncturing the subject's skin, they are being exposed to blood and other bodily fluids. Because of this, proper safety and technique is needed (Basmajian and De Luca, 1985; Kamen and Garbiel, 2010). Another disadvantage of the wire electrodes is the fact they cannot be moved or reinserted like the needle electrodes. If a new area is needed to be looked at, the investigator must create a whole new wire electrode and insert it in the new area (Basmajian and De Luca, 1985).

Electrode Placement

The placement of the surface electrodes is the most crucial part of any EMG study. Even the slightest error in placement sight can yield unwanted results. Surface electrodes must be aligned with the direction of the muscle fibers. If this is not done then EMG variability is greater (Merrletti et al., 2005). This also causes the conduction velocity to be either overestimated or underestimated depending on how the surface electrodes are placed. Along with correct placement of the surface electrodes, the correct environment should be selected as well. The environment in which an EMG study should take place is an electromagnetically quiet environment (Basmajian and De Luca, 1985). The skin of the subjects should be prepared carefully before the surface electrodes are applied. Preparation of the skin includes abrading the dead skin and oils from the electrode site (Willardson et al., 2010). Also, an electrolyte get should be applied to increase electrical conduction between the skin and the surface electrode (Kamen and Gabriel, 2010).

The surface electrodes should be placed between 5 and 20 millimeters apart from one another. This is dependent on the size of the muscle that is of interest (Kamen and Gabriel, 2010). The appropriate distance is necessary since one does not want the electrodes too far apart. This would lead to get low conduction. Conversely, if the electrodes are too close together the can cause a salt bridge between the two electrodes on the skin because of the electrolyte gel. A salt bridge is a connection between the electrolyte gel from the two electrodes coming into contact with one another (Kamen and Gabriel, 2010). This connection can cause a reduction in the recorded EMG activity (Kamen and Gabriel, 2010).

Most muscle of interest sites has three electrodes in that vicinity. Two of the surface electrodes (G1 and G2) will be placed directly over the muscle of interest whereas the third electrode (ground electrode) will be placed on an area near the muscle of interest (Kamen and Gabriel, 2010). A practical example for this would be placing two surface electrodes over the external obliques and placing the ground electrode over the anterior superior iliac spine. When a muscle is activated with these two surface electrodes on top op them, signals are sent from electrodes G1 and G2 to an amplifier which then inverts the activity of G2 (Kamen and Gabriel, 2010). Because surface electrodes pick up unwanted signals because of cross-talk, G1 and G2 are subtracted from one another by the amplifier which gets rid of the unwanted signals which is known as the signal-to-noise ratio (Kamen and Gabriel, 2010).

Muscles of Interest

The popularity for abdominal exercises has risen immensely over the past year which is why it is important to explore different abdominal exercises and also abdominal machines. Since the popularity and demand are so high for these types of exercises, the abdominal exercise industry has become a multi-billion dollar industry annually. The reasons why individuals perform abdominal exercises can be narrowed down to four reasons: 1) to improve come muscle strength and to build endurance, 2) to reduce effects of low back pain, 3) to enhance one's sports performance and lastly, 4) to improve one's body image.

It was stated by Escamilla et al. (2006) that in order to reduce the stress on the lower spine, an individual needs to increase abdominal strength and to have a stable trunk or core. Performing stability ball crunches for abdominal exercises have been shown to be one of the best ways to prevent low back pain and still obtain a productive abdominal workout (Chong et al., 2008).

The abdomen is composed of many muscles. The most superficial muscles are the external obliques. The external obliques originate on the external and inferior borders of ribs 5 through 12 and insert on the iliac crest. The next layer of muscle is the internal obliques. The internal obliques originate on the iliac crest as well as the lumbrodorsal fascia and insert on the inferior portion of ribs 9 through 12 and costal cartilages 8 through 10. The deepest abdominal muscle is the transverse abdominis which originates on the cartilage of ribs 6 through 12, the iliac crest and also the lumbrodorsal fascia, and inserts on the linea alba as well as the pubis. The last main abdominal muscle of interest is the rectus abdominis. The rectus abdominis originates on the superior surface of the pubic symphysis and inserts on the inferior surfaces of ribs 5 through 7 and the xiphoid process of the sternum (Martini et al., 2007). The rectus abdominis is usually divided into the upper rectus abdominis and lower rectus abdomins when conducting abdominal muscle research.

Other muscles of interest are considered when conducting research on the abdominal region. The secondary muscles consist of the muscles of the neck (sterncleidomastoid), back (erector spinae), and hip flexors (iliopsoas and rectus femoris) (Leung, 2005; Escamilla et al., 2010). The sternocleidomastoid (SCM) has two heads, one originating on the sterna end of the clavicle and the other head originating on the manubrium. These two heads merge together and insert on the mastoid prominence of the skull. The erector spinae (ES) is composed of many subdivisions, all originating on different areas of the cervical vertebrae all the way down to the iliac crest. The insertion of the ES starts at the mastoid process and extend all the way down to the inferior surfaces of ribs 6 through 12. The last two accessory muscles of interest are the iliopsoas and the rectus femoris. The iliopsoas is made up of the iliacus and the psoas major muscles. The iliacus originates on the iliac fossa and inserts on the distal portion of the lesser trachanter. The psoas major originates on the processes of thoracic vertebrae 12 to lumbar vertebrae 5 and inserts with the iliacus. The rectus femoris originates on the interior inferior iliac spine and forms the patellar tendon which attaches to the tibial tuberosity (Martini et al., 2007). The reason these accessory muscles are of interest during abdominal studies is because is an abdominal exercise is done incorrectly these muscles do a majority of the work rather than the true abdominal muscles (Leung, 2005).

Electrode Placement on Primary and Secondary Muscle Groups

As stated earlier, correct electrode placement is crucial when conducting EMG studies for numerous reasons. The precise area on which surface electrodes needs to be placed has been studied greatly. For starters, all of the electrodes should be placed on the right side of the participant to assure accuracy and consistency (Hildenbrand and Noble, 2004). All of the electrodes should have a 2 centimeter separation to avoid a salt bridge formation between the electrolyte gel from the 2 electrodes (Kamen and Gabriel, 2010). The electrode placement site for the rectus abdominis is between 2 and 3 centimeters lateral of the umbilicus (Willardson et al., 2010; Youdas et al., 2008). Surface electrode placement for the external obliques should be placed halfway between the costal margin and the anterior superior iliac spine (ASIS) of the iliac crest (Leung, 2005; Youdas et al., 2008). These electrodes should also be angled inward towards the pubic area since that is the direction muscle fibers run.

For secondary muscles of interest, the surface electrode placement for the rectus femoris is halfway down the anterior portion of the thigh which is usually consistent with the midway point of the ASIS and the superior portion of the patella (Youdas et al., 2008). The surface electrode placement site for the erector spinae should be at the same height as the iliac crest using the fifth lumbar vertebrae as a landmark; the electrode should be placed 3 centimeters laterally (Willardson et al., 2010). Finally, the surface electrode placement site of the sternocleidomastoid should be halfway between the origin of muscle, at the sternoclavicular joint and in insertion of the muscle at the mastoid process of the skull (Leung, 2005).

Related Studies

There have been numerous studies done comparing a traditional abdominal crunch to a few newer abdominal exercise machines. There has not been a study comparing more than 10 different abdominal exercises to the traditional crunch. No matter what the study is measuring, most of the procedures surrounding repetitions, rest, and other factors are relatively the same. The various studies have had the participants completing one set of 8 to 10 repetitions with 5 consecutive repetitions being recorded for the study (Sternlicht and Rugg, 2003; Sternlicht et al., 2005). To keep a consistent pace, a metronome was generally set at a pace of 2 seconds for each phase of the exercise (concentric and eccentric) (Sternlicht et al., 2005).

Some abdominal equipment have been studied on numerous occasions are the Ab Wheel, Ab Roller, stability ball crunch, side plank, bicycle crunch, and the captain's char crunch. Surprisingly, the front plank has not been studied that often compared to the side plank.

New abdominal equipment is being created every year making this a very popular subject. Some new equipment that has not been researched yet include the Ab Lounge, the Perfect Sit-up, Ab Rocket, Ab Straps, Ab Coaster, and Ab Circle. A new yoga pose that has also sparked interest in the abdominal exercise world is the boat-pose. These new machines and exercises need to be researched more to understand their full effects.

All abdominal machines and exercises are compared to the traditional crunch. The problem with the traditional crunch is there is no set standard for it. Most investigators have their own traditional crunch standards making it very hard to compared one abdominal study to another. Sternlicht and Rugg (2003) do the best job of defining a traditional crunch in their abdominal exercise study. The traditional crunch was defined as having the participants knees bent at a 90 degree angle with the feet flat on the floor. Participants were cued to grip their hands together behind their head. From this position participants were asked to flex their abdomen forward so their head and scapulas became elevated off the floor (Sternlicht and Rugg, 2003; Hildenbrand and Noble, 2004). Something that should be considered for the traditional crunch should be hand placement. Many people tend to flex or pull on their neck when performing the crunch, causing a great amount of stress on the cervical vertebrae. An Alternate to this would be to cross the arms over the chest and perform the traditional crunch as previously instructed.

Stability ball crunches have become a popular exercise for individuals who find it difficult to lie down on the floor. A study done by Sternlicht et al., (2007) compared the traditional crunch to a stability ball crunch, as well as where the best place to place the stability ball (lumbar region or scapular region). Participants performed the traditional crunch first on the floor and then tried to replicate the traditional crunch on the stability ball. The results from this study showed that placing the stability ball on the lumbar region of one's back yielded the highest muscle activation of the upper recuts abdominis, lower rectus abdominis, and external oblique muscles compared to the traditional crunch. EMG was 31%, 38%, and 24% higher, respectively, for the stability ball crunch, in comparison to the traditional floor crunch (Sternlichet et al., 2007). Petrofsky et al., (2007) confirmed what Sternlicht et al., (2007) found by conducting a similar study. The results of this study found that the traditional crunch had a peak muscle activation of 76% compared to the stability ball crunch, which has a peak muscle activation of 81%.

Side planks are another very common abdominal exercise. A side plank consists of the participant laying on the side of their body and raiding their hip off of the ground while supporting their body weight on their forearm and elbow (Willardson et al., 2010). One study concluded the side plank was more effective than the traditional crunch in activating the external oblique and erector spinae muscles (Willardson et al., 2010). This is problematic since the erector spinae are accessory muscles and should not be activated while performing abdominal exercises. In another side plank study, it was shown that the side plank was less beneficial compared to the traditional crunch in all muscles recorded (rectus abdominis, external oblique, internal oblique, and rectus femoris) (Youdas et al., 2008).

In a study conducted by Peter Francis and Jennifer Davis (2001), 12 abdominal machines and exercises were compared to the traditional crunch. The bicycle crunch and the captain's chair crunch were on the top of the list for muscle activation of the rectus abdominis yielding 148% and 112% higher muscle activation compared to the traditional crunch (Francis and Davis, 2001). Another piece of equipment that yielded higher results over the traditional crunch was the Ab Roller, which elicited a 5% higher muscle activation compared to the traditional crunch in the rectus abdominis (Francis and Davis, 2001).

Summary

Their have been numerous studies conducted over the years that have concentrated on abdominal exercises using EMG. This study will compare 17 different pieces of abdominal equipment and exercises and compare them to the traditional crunch. EMG studies are beneficial because the most effective exercises can be determined so that individuals may make wiser choices when it comes to deciding which exercises to incorporate into their exercise routines.

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